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# Team-Teaching Experiences of a Mathematician and a Mathematics Teacher Educator: An Interpretative Phenomenological Case Study

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Team-Teaching Experiences of a Mathematician and a Mathematics Teacher Educator:

An Interpretative Phenomenological Case Study

by

Sarah K. Bleiler

A dissertation submitted in partial fulfillment  
of the requirements for the degree of  
Doctor of Philosophy  
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College of Education  
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## **Dedication**

This dissertation is dedicated to my parents, Thomas and Diane.

Mom and Dad, you have always believed in me, supported me, and loved me unconditionally. It is because of you that I was able to find the strength to endure this journey and achieve my goals. Thank you for guiding me through these 28 years of life. You have taught me all of the most important things I know. I love you so much.

And as Pa always says, "Math is Power."

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## **Abstract**

In recent years, experts and organizations involved in mathematics education have emphasized the importance of collaboration between mathematicians and mathematics teacher educators as a means of improving the professional preparation of mathematics teachers. While several such collaborative endeavors have been documented in the extant literature, most research reports have focused on the products, rather than the process, of collaboration. The purpose of this interpretative phenomenological case study is to gain an understanding of the lived experiences of a mathematician and a mathematics teacher educator as they engaged in a team-teaching collaboration within the context of prospective secondary mathematics teacher preparation. Participants in this study are a mathematician (Dejan) and a mathematics teacher educator (Angela) who worked together to plan, implement, and assess prospective secondary mathematics teachers enrolled in a mathematics content course (Geometry) and a mathematics methods course (Teaching Senior High School Mathematics).

I employed interpretative phenomenological analysis (Smith, Flowers, & Larkin, 2009) as the methodological framework. Consequently, I attempted to make sense of Dejan and Angela's experiences as they engaged in active reflection on those experiences. I also utilized the situated learning perspective (Lave and Wenger, 1991; Wenger, 1998) as a theoretical lens to guide the design and interpretation of this study. I assumed that learning, meaning, and understanding are situated in communities of practice, and therefore, to understand the meaning-making of Dejan and Angela during

their team-teaching experiences, I paid particular attention to their understandings and identities as members of their respective communities of practice in mathematics and mathematics education.

The themes that emerged from my analysis illustrate (a) how crossing community boundaries led to Dejan and Angela's increased awareness of their practice, (b) the roles of coach and student taken on by Angela and Dejan throughout the collaboration in an effort to increase Dejan's awareness of the needs of PSMTs, and (c) the influence of mutuality as a driving force in the instructors' collaborative experiences. In using the situated learning perspective as an interpretive lens to describe and explain Dejan and Angela's meaning-making throughout their collaboration, I demonstrate (a) the importance of the dual processes of participation and reification to facilitate learning and meaning between instructors, (b) the ways in which a lack of shared history can hinder communication between collaborators, (c) the influence of a community's "regime of mutual accountability" on collaborators' decision making and interactions, and (d) the value and complexities of brokering and crossing boundaries.

## **Chapter 1: Introduction**

### **Statement of the Problem**

The mathematical performance of America's students has recently been described as "mediocre" and well below the level expected of an international leader (National Mathematics Advisory Panel [NMAP], 2008, p. xii). However, mathematical proficiency is crucial not only to remain internationally competitive, but also to ensure the "eminence, safety, and well-being" (NMAP, 2008, p. xi) of our nation. To ensure a citizenry equipped with the knowledge and tools needed to become mathematically proficient, the nation is in dire need of well-prepared and effective mathematics teachers (Conference Board of the Mathematical Sciences [CBMS], 2001; National Council of Teachers of Mathematics [NCTM], 2007; NMAP, 2008).

One crucial aspect of teachers' knowledge that contributes to effectiveness in the classroom is their ability to make connections between content and pedagogy (Ball & Bass, 2000; CBMS, 2001; Hill, Rowan, & Ball, 2005). Unfortunately, experts in mathematics education have suggested the current context of mathematics teacher education is not optimal for helping prospective teachers make such connections (Adler & Davis, 2006; CBMS, 2001; Ferrini-Mundy & Findell, 2001; Kahan, Cooper, & Bethea, 2003; Williams, 2005). Many prospective secondary mathematics teachers (PSMTs) take mathematics content courses in one department and mathematics methods/pedagogy courses in a different department, and therefore may miss out on making important connections between the two if the instructors teaching these courses do not actively

work toward this goal (Adler, 2005; CBMS, 2001). Therefore, researchers and practitioners in the field have called for collaboration between mathematicians and mathematics teacher educators, the two main groups responsible for educating and preparing PSMTs (Bass, 2005; CBMS, 2001, 2012; Ferrini-Mundy & Findell, 2001; McCallum, 2003; Millman, Iannone, & Johnston-Wilder, 2009; Wu, 2006).

For the purposes of this research, I use the term mathematician to refer to an individual who holds a terminal degree in the subject matter of mathematics and has little formal training in pedagogy or teacher preparation. I use the term mathematics teacher educator (MTE) to refer to an individual who holds a terminal degree in mathematics or education, and who has extensive training in pedagogy and/or teacher preparation within the discipline of mathematics. In general, the distinction between these two groups is not always clear, and individuals may refer to themselves under both titles (Even, 2008; Millman et al., 2009). The focus of this study is on mathematicians and MTEs who work in institutions of higher education and are involved in the preparation of prospective mathematics teachers.

In some institutions, mathematicians and MTEs work in separate departments, mathematicians within a college of arts and sciences and MTEs within a college of education. In other institutions, these two groups of individuals work in the same department, typically the mathematics department within a college of arts and sciences. Despite the respective department, collaboration between these two groups has been, historically, infrequent (Dörfler, 2003; Ferrini-Mundy & Findell, 2001; Wu, 2006). In fact, some suggest a considerable amount of distrust pervades relationships between mathematicians and MTEs (CBMS, 2001; Ferrini-Mundy & Findell, 2001; Heaton &

Lewis, 2011; Wu, 2006). Ferrini-Mundy and Findell (2001) provided an anecdotal account of the context of mathematics teacher preparation,

Lack of mutual respect and cooperation between faculty in colleges of arts and sciences and faculty in education is a long-standing obstacle to the effective education of teachers. Unfortunately, it is quite common for undergraduate students to hear faculty in mathematics criticize faculty in education for lacking high standards, for not understanding mathematics, or for teaching material that has no substance. And, conversely, students hear their education professors complain about poor teaching in the mathematics department or lack of attention by mathematics faculty to current issues such as the role of technology. (p. 38)

Many of the accounts in the literature paint a similar picture of the relationship between mathematicians and MTEs within the context of mathematics teacher education (CBMS, 2001; Dörfler, 2003; Heaton & Lewis, 2011; Wu, 2006). The majority of these accounts rely largely on anecdotal evidence and personal experience. For example, Dörfler (2003) illustrated the “gulf between the two scientific communities” (p. 147) by highlighting what he perceived as key cultural, linguistic, and epistemological differences between the two communities, drawing upon his years of experience as a member of both communities. Dörfler acknowledged the limitations of his anecdotal account, explaining that his purpose was to “mark basic trends in the relationships between the two fields” (p. 164). He called for researchers to engage in systematic inquiries to investigate his anecdotal descriptions of the relationships between the two communities.

Despite what appear to be significant differences between mathematics and mathematics education, leaders from both communities have proposed collaboration

between mathematicians and MTEs as a primary means to enrich mathematics teacher preparation (e.g., CBMS, 2001; Cheng, 2006; Ferrini-Mundy & Findell, 2001; Millman et al., 2009; Wu, 2006). Over the past decade, organizations such as the National Science Foundation, Texas Instruments, and the United States Department of Education have issued grants to support such collaboration. Researchers who have written about these grant-funded projects have focused primarily on the products of collaborative efforts, such as curricular materials or collaboratively developed courses (e.g., Eaton & Carbone, 2008; Kehle, Maki, Norton, & Nowlin, 2005). Little research has examined the actual dynamics of collaboration, or the meanings those involved attribute to the collaborative process. An in-depth look into the lived experiences of a mathematician and a MTE as they collaborate within the context of prospective secondary mathematics teacher preparation could provide a basis for thinking about some of the particularities of collaboration between members of these two communities. I believe it is only through such an investigation that we will be able to understand the unique affordances and challenges of collaboration between mathematicians and MTEs.

### **Rationale for the Study**

If calls for collaboration between mathematicians and MTEs are to be taken seriously, and if such collaborations are to be successful, a better understanding of the experience of collaboration as lived by mathematicians and MTEs is essential. In order to move past the “us versus them” mentality that persists in many mathematics and education departments in institutions of higher education (Ralston, 2004), it is important to examine the process of collaboration and the meanings mathematicians and MTEs attribute to collaborative work. Only then can researchers and practitioners learn from

and build on those experiences. Unfortunately however, most of the prior research and literature related to collaborative endeavors among mathematicians and MTEs has focused on the products, not the process, of collaboration.

For example, several groups of mathematicians and MTEs have convened in round-table discussions at the national level in an attempt to come to a consensus on critical issues in mathematics education (Ball, Ferrini-Mundy, Kilpatrick, Milgram, Schmid, & Schaar, 2005; Common Ground Conference Report, 2006). The importance of these meetings cannot be underestimated; they have led to numerous areas of agreement about the preparation of teachers and the most important issues in school mathematics. However, the authors of these reports have provided little or no information about (a) how mathematicians and MTEs engaged in collaborative discussion, (b) the issues found to be irreconcilable, (c) the ways in which participants came to consensus during discussions, or (d) the meaning meeting participants attributed to their collaborative work.

Similarly, several smaller-scale collaborations between mathematicians and MTEs have been discussed in the literature in relation to the resulting products of collaboration. These products include the curriculum for an innovative master's degree program (Eaton & Carbone, 2008; Williams, 2005), a performance assessment task and rubric (Koirala, Davis, & Johnson, 2008), and "linked" courses intended to help PSMTs make connections between university-level mathematics and the content of the secondary mathematics curriculum (Kehle et al., 2005). Again, although these research studies have examined the products resulting from collaborative efforts between mathematicians and MTEs, they have provided little insight into the process of collaboration itself. This is

particularly problematic because the reported collaborations resulted in the successful development of products for use in teacher preparation. Analysis of the lived experiences of individuals involved in such collaborations could have led to valuable insights about how to nurture and sustain relationships between these two communities.

In several research studies, MTEs, serving in the role of educational researchers, have interviewed mathematicians to better understand their perspectives on teaching and learning (Burton, 1999, 2002, 2004; Nardi, 2008; Nardi, Jaworski, & Hegedus, 2005). In final written accounts, these researchers compared the perspectives of the interviewed mathematicians with the perspectives of the education community more broadly (accounted for through both personal experience of the MTE/researcher and references to the theoretical literature base in mathematics education). Although these studies focused to a greater extent on the process of collaboration than the studies I mentioned in the previous two paragraphs, their main purpose has been to gain a deeper understanding of mathematicians' perspectives on teaching and learning, and not on the collaborative process. Moreover, because the MTEs in these studies served as the researchers, rather than the unit of analysis, there is a lack of information about MTEs' perspectives on teaching and learning as attained through systematic analysis.

In summary, although evidence from the past decade suggests mathematicians and MTEs have begun to heed the call for collaboration, most research has focused on the products of collaborative efforts. Researchers have paid little attention to the dynamics of the process inherent in such collaborations. Smith, Flowers, & Larkin (2009), in their text *Interpretative Phenomenological Analysis: Theory, Method, and Research*, explained that interpretative phenomenological analysis (IPA) is particularly well suited to study

questions that “reflect process rather than outcomes” (p. 47), and that have as their major focus meaning, rather than “concrete causes or consequences, of events” (p. 47).

Adhering to Smith et al.’s suggestions, I conducted an interpretative phenomenological case study of a team-teaching collaboration between a mathematician and a MTE as a means to shed light on the nature and process of collaboration between these two communities.

### **Purpose of the Study**

The purpose of this interpretative phenomenological case study is to gain an understanding of the lived experiences of a mathematician and a MTE as they engaged in a team-teaching collaboration within the context of PSMT preparation. Participants in the team-teaching collaboration in this study were a mathematician (Dejan) and a MTE (Angela) who worked together to plan, implement, and assess PSMTs enrolled in a mathematics content course (Geometry) and a mathematics methods course (Teaching Senior High School Mathematics) during the Fall 2010 and Spring 2011 semesters, respectively.<sup>1</sup> This specific collaboration is one of four team-teaching partnerships funded through the Knowledge for Teaching Secondary School (KnoTSS) NSF DR K-12 grant (#0821996), a project developed to examine the nature and process of team-teaching collaborations between mathematicians and MTEs at several sites across the United States.

### **Research Questions**

The following research question served to guide the inquiry:

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<sup>1</sup> The names “Dejan” and “Angela” are pseudonyms.

- In what ways do a mathematician (Dejan) and a MTE (Angela) make sense of their experiences engaging in a team-teaching collaboration within a mathematics content course (Geometry) and a mathematics methods course (Teaching Senior High School Mathematics) for PSMTs?

The following sub-questions highlight specific aspects of Dejan and Angela's team-teaching experiences, and provide insight into the overarching question stated above:

1. In what ways do Dejan and Angela make sense of their similarities or differences in relation to their perceptions of teaching and learning?
2. In what ways do Dejan and Angela make sense of their roles within the team teaching collaboration?
3. What do Dejan and Angela perceive as the affordances, if any, of their experiences in the team-teaching collaboration?
4. What do Dejan and Angela perceive as the constraints, if any, of their experiences in the team-teaching collaboration?

### **Definition of Terms**

For the purposes of this study, I define the key terms as follows:

1. Team-teaching: a teaching collaboration between two or more instructors in which each member of the team shares equal responsibility in planning, teaching, and assessing the course (modified from Nevin, Thousand, and Villa, 2009).

2. Mathematician: an individual who holds a terminal degree in the subject matter of mathematics and has little formal training in pedagogy or teacher preparation.
3. Mathematics teacher educator (MTE): an individual who holds a terminal degree in mathematics or education, and who has extensive training in pedagogy and/or teacher preparation within the discipline of mathematics.
4. Prospective secondary mathematics teacher (PSMT): an undergraduate student enrolled in a university teacher preparation program with the goal of becoming certified as a mathematics teacher at the secondary level (grades 6-12).

### **Significance of the Study**

The current study illuminates ways a mathematician and a MTE make sense of their experiences working together to teach a mathematics content and a mathematics methods course for PSMTs. Through my examination and depiction of Dejan and Angela's perceptions related to (a) their similarities or differences with regards to perspectives on teaching and learning, (b) their roles within the collaboration, and (c) the affordances and/or constraints of their team-teaching experiences, I hope readers of my study will be able to relate to, reflect on, and learn from the particularities of this case. I expect this study will provoke readers, particularly mathematicians and MTEs, to think deeply about their own educational experiences, their assumptions about the teaching and learning of mathematics that stem from those experiences, and how those assumptions might help or hinder progress in the education of PSMTs at their own institutions. In giving equal voice to the mathematician and the MTE in this study, my goal is to make it

possible for members of both communities to relate to and empathize with both Dejan and Angela.

Stake (1995) emphasized the importance of naturalistic generalization (i.e., generalizations made by the reader of the case study in relation to his or her prior knowledge and understanding of issues in the case) within case study research. Similarly, Smith et al. (2009) suggested that rather than attempt “empirical generalizability,” interpretative phenomenological research is better suited for “theoretical transferability” (p. 51). In this sense, through a detailed examination of a particular case, readers should be able to gauge the transferability of the major themes that result from the case analysis to their own (potentially similar) contexts. To aid in this process, I employed situated learning theory (Lave & Wenger, 1991; Wenger, 1998) as the interpretive lens for my analysis of Dejan and Angela’s experiences. Consistent with IPA methodology, employment of such a theoretical lens can help readers make connections between their own contexts/experiences and those of Dejan and Angela.

Flyvbjerg (2006) explained the need for in-depth contextual knowledge of a certain phenomenon in order to move one’s understanding from beginner to expert. It is my hope that through this in-depth portrayal of the meanings Dejan and Angela attributed to their experiences in a team-teaching collaboration, readers will be able to add to and deepen their understanding of the dynamics and inner-workings of such collaborations, and use that deeper understanding to inform their own collaborative research or practice. As suggested by Barritt (1986), “By heightening awareness and creating dialogue, it is hoped research can lead to better understanding of the way things appear to someone else and through that insight lead to improvements in practice” (p. 20).

In addition to improving the understanding of the readers of this research, this study also has “practical consequences” of importance (Lester, 2010). Prior research has shown university faculty members’ involvement in educational research leads to a greater degree of self-reflection on and understanding of one’s practice (Lester & Evans, 2009; Nardi et al., 2005). Through Dejan and Angela’s participation in this collaborative team-teaching experience, and consequently their participation in this research study, they have developed in their own learning and understanding of (a) the disciplines of mathematics and mathematics education, (b) the affordances and constraints of the collaborative process, and (c) the ways in which their background experiences influence their meaning-making when interacting within their partner’s community of practice. Moreover, after participating in this team-teaching experience, Dejan and Angela have continued to engage in collaborative discussions and projects that bridge the communities of mathematics and mathematics education at their institution.

Additionally, through an in-depth description of Dejan and Angela’s collaboration, I aim to add to the extant literature related to the characterization of the academic communities of mathematicians and MTEs. As discovered by Nevin et al. (2009) in their review of team-teaching research within the broader teacher education spectrum, “Descriptive studies of university professors who have established collaborative teaching relationships indicate that the process of collaboration does lead to insights and distinctions about their respective disciplines” (p. 571). Through the insights I gleaned from this study, I offer suggestions for other mathematicians and MTEs in terms of potential starting points for collaborative efforts and areas that might need more fragile care when attempting collaboration.

Finally, because I have studied only one case of a team-teaching collaboration between a mathematician and a MTE, I will not be able to provide “grand generalizations” (Stake, 1995, p. 20) outside of the current case. However, I will provide a detailed description and interpretation of Dejan and Angela’s experiences in the team-teaching collaboration in the hope that the thoroughness of my written account lends insight into the larger phenomenon of collaboration between mathematicians and MTEs. As Stake (1995) suggested, we are interested in cases “for both their uniqueness and commonality” (p. 1). Furthermore, it is my hope this single case study will provide one of many cases that can be used as a data source for a future study that employs analytic induction (Smith et al., 2009) to develop theoretical accounts that depict the experiences of mathematicians and MTEs across various collaborative contexts.

### **Research Background and Interest in the Study: Situating Myself in the Inquiry**

My academic background includes a Bachelor’s and Master’s degree in mathematics and current study toward a Ph.D. in mathematics education. I earned my Master’s degree, and am working toward my doctoral degree within the same university, but in different departments. In this section, I share a brief autobiographical account of the experiences that have led me to my current role as a doctoral student in mathematics education and my interest in the topic of this dissertation study.

From a very young age, I wanted to become a mathematics professor. I even told my parents about my desire to write a mathematics textbook. There were always two things about which I was passionate: mathematics and teaching. Therefore, I never wavered from my goal to become a mathematics professor. As a first generation college student, I knew little about the academic world and its various institutional arrangements.

In order to fulfill my dream of becoming a mathematics professor, I planned to follow what I believed to be the primary route to the profession, by earning a Ph.D. in mathematics.

I was successfully on track toward achieving this goal as I progressed through my undergraduate degree and began graduate school. As a Master's student studying mathematics, I had several interactions with graduate students who were studying "mathematics education," at my institution. I had a relatively naïve understanding of the field of education, but it piqued my interest as I reflected on the influence mathematics educators could have on the teaching profession at all levels (K-16) by means of their education of future teachers. As I continued to learn more about the professional possibilities in mathematics education, I made the decision to transfer from the mathematics department (in the College of Arts and Sciences) to the mathematics education department (in the College of Education) after earning my Master's degree in mathematics. My transition from the world of mathematics to the world of education sparked my interest in the topics under consideration in this proposed study.

When I transferred from the mathematics department to the education department, I experienced a "culture shock," one which others have similarly described (e.g., Goldin, 2003). I attribute this "shock" primarily to the vast differences in teaching philosophies and research epistemologies held by my instructors in both departments, differences so great that at times it seemed mathematicians and MTEs were talking about two distinct subjects. In my mathematics classes, professors would generally take a teacher-centered, lecture-style approach to instruction. Professors mainly approached teaching as a way to "transfer" knowledge to students. There was rarely content-based discussion among

students during my mathematics classes, and I often saw the courses as individual entities with little connection to other disciplines or even to other courses in mathematics.

Conversely, in my education classes, professors took a student-centered, inquiry-based approach to instruction. Professors did not approach teaching as a way to transfer knowledge, but instead they considered the classroom as a space for learners and instructors to share their experiences and prior knowledge in order to construct new knowledge. Although some education professors lectured more than others, I continuously saw connections between the topics of my courses. Almost all of my classes included discussion among students and instructors as a key component of the learning process.

In terms of research, and their philosophies of science, many of the mathematics faculty seemed to hold a postpositivistic view of science, in which there exists a “reality” that can be uncovered, albeit imperfectly, through rigorous deductive methods that aim at determining cause/effect relationships (Paul, 2005). Conversely, the majority of the education faculty held a constructivist, interpretive view of science, in which “reality” is constructed and reconstructed both individually and collectively through interaction with other people and the world (Paul, 2005). I related to Goldin (2003) as he discussed his experience transitioning between the mathematics and mathematics education communities:

I became aware in the different academic communities of powerful, tacitly held assumptions, beliefs, and expectations, conflicting deeply with each other.... My scientific understandings left me profoundly skeptical of the sweeping claims and changing fashions that seemed to characterize educational research, while it

became equally clear to me that relatively few mathematical scientists appreciated the challenges and complexities of K-12 education. The conflicting values of the communities to which I belonged, but did not ‘really’ belong, posed difficult career obstacles- much that was valued by one culture was overtly derogated by the other. (p. 175)

I began to wonder how the seemingly incompatible cultures established within the mathematics and mathematics education departments affected prospective secondary mathematics teachers, a population of students required to study concurrently within each department. These students often voiced concerns about the paucity of pedagogical connections made in their mathematics classes, the excessive focus on cooperative learning strategies in their education classes, and the overall lack of connections to the content of high school mathematics within courses in both departments. From my experiences “living” in both worlds, and from observations and discussions with prospective teachers frustrated with the disjoint nature of their program of study, I became particularly interested in collaboration between mathematicians and MTEs within the context of preservice teacher education.

I was fortunate to be able to take on the role of a participant observer in another team-teaching partnership between a mathematician and a MTE in the year before I conducted this dissertation study. My role during that first team-teaching endeavor included: (1) course development/planning for content and methods courses, (2) conducting focus groups with students in the courses, (3) producing a scholarly article in which the two team-teachers and the two participant observers (another MTE and me) reflected on their collaborative experiences (Thompson, Beneteau, Kersaint, & Bleiler, in

press), and (4) participating in a national meeting focused on the topic of team-teaching collaborations between these two groups. I believe my experiences as a participant observer within this first team-teaching collaboration equipped me with the background knowledge and research skills needed to effectively carry out this dissertation case study.

## **Conclusion**

The purpose of this interpretative phenomenological case study is to gain an understanding of the lived experiences of a mathematician and a MTE as they engaged in a team-teaching collaboration within the context of prospective secondary mathematics teacher preparation. Examining a single case using IPA, I explored the ways Dejan and Angela made sense of their similarities or differences in relation to their perceptions of teaching and learning, the ways they made sense of their roles within the team teaching collaboration, and the affordances and constraints they perceived as a result of their experiences.

This study provides an in-depth look into the key issues that arose within a naturalistic context wherein a mathematician and a MTE worked together to teach courses for prospective secondary mathematics teachers. I take the reflective utterances of Dejan and Angela not as representative of the communities of mathematicians and MTEs, but instead, as representative of their personal understanding of “being” in their respective communities (Hemmi, 2006). Through analysis of these reflective utterances, I aim to provide insight into how Dejan and Angela’s identity as members of the mathematics and mathematics education communities influenced their meaning-making during their team-teaching collaboration. This analysis shines light on several important implications for future collaborative work between members of these two communities.

## **Chapter 2: Review of the Literature**

The literature guiding the current study resides in the following three major topic areas: (1) the professional preparation of secondary mathematics teachers, (2) collaboration between mathematicians and MTEs, and (3) team-teaching. In this chapter, I review the relevant literature on each topic, and conclude with a conceptual framework that relates the findings from my literature review to the theoretical tenets guiding the inquiry.

### **The Professional Preparation of Secondary Mathematics Teachers**

Historically, teachers have presented school mathematics as if it were simply a set of isolated facts and procedures students were expected to know, usually through repetitious practice problems and memorization (National Research Council [NRC], 2001; NMAP, 2008). In 1989, NCTM published *Curriculum and Evaluation Standards*, a document whose authors seriously challenged this interpretation of school mathematics. Within that document, NCTM called for less focus on computation and basic skills, and greater focus on problem solving, communication, and reasoning. In 2000, NCTM published *Principles and Standards for School Mathematics*, an updated version of the 1989 standards. In that document, NCTM further expressed the need for students to communicate mathematically, become competent in reasoning and proof, make connections across mathematical domains and representations, and become proficient problem solvers.

Given NCTM's (1989, 2000) recommendations for the ways in which school mathematics should be viewed in order to elicit the greatest student learning of the subject, many researchers focused their attention on the knowledge and preparation teachers need in order to be successful teaching in this manner (Adler & Davis, 2006; Ball, 2003; Ball, Lubienski, & Mewborn, 2001; Ball, Thames, & Phelps, 2008; Kahan et al., 2003; Ma, 1999). In the following sections, I investigate the traditional structure and assumptions of secondary mathematics teacher preparation, review the types of knowledge researchers have identified as essential for teaching mathematics, and explore the potential of collaboration between mathematicians and MTEs as a solution to some of the obstacles identified in the first two subsections.

#### **Structure and assumptions of secondary mathematics teacher preparation.**

The structure of university-based teacher preparation for secondary content area teachers in the United States has traditionally consisted of four main components: (a) coursework in the liberal arts and sciences, (b) course work in the content area (e.g., university-level mathematics), (c) coursework in general and content-specific pedagogy, and (d) practicum experiences (Darling-Hammond & Bransford, 2005). For the population of secondary mathematics teachers, the trend throughout the 20<sup>th</sup> century was a continued focus on mathematical content knowledge within teacher preparation programs. This is evidenced by reports such as *Tomorrow's Teachers*, written by the Holmes Group (1986) and several reports written by the Mathematical Association of America's (MAA) Committee on the Undergraduate Program in Mathematics (CUPM) in the 1970s and 1980s. Each of these reports suggested an increased content preparation for secondary mathematics teachers in the United States. Some suggested five- or six-

year programs in which teachers would earn the equivalent of a Masters degree in the content area (Holmes Group, 1986).

**Content knowledge is necessary but not sufficient.**

Although mathematics teachers' development of content knowledge is a necessary precursor to effective teaching within the discipline, researchers have shown content knowledge alone is not sufficient. For example, Begle (1972) conducted a study with 308 high school algebra teachers in which the teachers' content knowledge of algebra was assessed using a standardized measure. Begle compared teachers' knowledge of algebra content to the achievement of their students on standardized measures of algebra proficiency. He found there was no significant correlation between teachers' content knowledge and student achievement in these algebra classrooms.

In another study, Monk (1994) used data from the Longitudinal Survey of American Youth to determine if mathematics teacher factors such as number of undergraduate mathematics content courses taken, number of undergraduate mathematics methods courses taken, major/non-major in mathematics, or advanced degree, correlated with 10<sup>th</sup> and 11<sup>th</sup> grade student achievement on an exam built from National Assessment of Educational Progress (NAEP) items. His findings indicated that although the number of undergraduate mathematics courses taken by a teacher was positively correlated with student achievement, there was no significant increase in student achievement after teachers reached a threshold of five university-level mathematics courses. That is, teachers' completion of up to five content courses was significantly associated with increased student achievement, but teachers' completion of more than five content courses did not result in a significant increase in student achievement.

Monk (1994) also found (a) the number of mathematics methods courses taken by a teacher had a greater positive impact on student achievement than the number of mathematics content courses taken, (b) teachers with a major in mathematics were not significantly correlated with increased student achievement, and (c) teachers' advanced degree completion was not significantly correlated with student achievement, and in fact, advanced degree completion and student achievement were negatively related. These findings indicate that although content knowledge is necessary, teachers' increased content preparation as it is traditionally structured (in the form of a mathematics major and traditional upper level university mathematics courses) does not necessarily contribute to increased student achievement in high school mathematics.

### **What knowledge do teachers need?**

Many researchers, recognizing the limitations of teachers' sole preparation in generic content knowledge, have focused their attention on identifying some other aspects of professional knowledge needed by mathematics teachers. In a seminal piece related to this research agenda in the broader teacher education literature, Shulman (1986) considered the various ways teachers use content knowledge within the context of teaching. From his research on novice teachers, Shulman developed a theoretical framework that represented the various categories of content knowledge necessary for work as a teacher: (1) subject matter knowledge, (2) curricular knowledge, and (3) pedagogical content knowledge.

The first category, subject matter knowledge, represents a teacher's understanding of the organization of basic principles of the subject together with an understanding of the ways knowledge claims are verified within the discipline. The second category,

curricular knowledge, represents a teacher's understanding of alternative curricular materials, the content covered in other subject areas, and the content covered in earlier or later grade levels. The third category, pedagogical content knowledge, was defined by Shulman as "the particular form of content knowledge that embodies the aspects of content most germane to its teachability" (Shulman, 1986, p. 9). Under the category of pedagogical content knowledge, Shulman included teachers' understanding of the representations that make subject matter intelligible to students, familiarity with the most common preconceptions held by students about certain subject matter, and knowledge of the best strategies for helping students overcome misconceptions. Although education researchers (e.g., Dewey, 1904) recognized the importance of teachers' pedagogical content knowledge years prior to Shulman's research, by giving a name to the concept, his research sparked a widespread study of the topic throughout many subject areas, not least of which was mathematics.

Mathematics education researchers have since spent many years studying pedagogical content knowledge for mathematics teachers. Some researchers, through direct observation of teaching practices, have focused on identifying ways teachers use their knowledge of content within the classroom (Ball & Bass, 2000); others have used interviews with teachers to determine the various ways content knowledge can come to play within the context of teaching (Even, 1993; Marks, 1990); and still others have demonstrated a direct correlation between teachers' achievement on tests created to assess pedagogical content knowledge and their students' achievement in mathematics (Hill et al., 2005).

Researchers have developed several additional terms such as *mathematical knowledge for teaching* (Ball, 2003), *specialized content knowledge* (Ball et al., 2008), and *mathematical content knowledge for teaching* (Kahan et al., 2003) to represent more specific aspects of pedagogical content knowledge employed by teachers of mathematics, such as being able to explain the meaning behind mathematical principles and procedures, judge the accuracy and value of mathematics curricular materials, and use multiple representations to help students better understand mathematical concepts. The results of all these studies lead to one firm conclusion, the importance of teachers' deep understanding of content and pedagogy and their ability to integrate the two within the classroom. As suggested by CBMS (2001),

Teachers need explicit disciplinary focus, but few positive results can be expected by merely requiring teachers to major in an academic subject. Studying subject matter in relation to subject matter pedagogy helps teachers be more effective. Teacher education programs that emphasize the underlying nature of the subject matter...more often result in knowledgeable, dynamic teachers with transformed dispositions and understandings of subject matter and pedagogy. (p. 121)

### **Limitations of the current structure of teacher preparation.**

Although the development of secondary teachers' generic mathematical content knowledge has traditionally been the main focus of teacher preparation (Ferrini-Mundy & Findell, 2001; Sowder, 2007), the studies discussed in the above section have demonstrated that there is a much deeper mathematical knowledge teachers need in order to teach effectively. Ball and Bass (2003) argued that teachers need to develop a

“decompressed” knowledge of mathematics rather than the “compressed” knowledge that is typically valued in upper-level university mathematics courses. They explained,

A powerful characteristic of mathematics is its capacity to *compress* information into abstract and highly usable forms. When ideas are represented in compressed symbolic form, their structure becomes evident, and new ideas and actions are possible because of the simplification afforded by the compression and abstraction. Mathematicians rely on this compression in their work. However, teachers work with mathematics as it is being learned, which requires a kind of decompression, or “unpacking”, of ideas. (Ball & Bass, 2003, p. 11)

To illustrate the distinction between compressed and decompressed mathematical knowledge, consider the tasks in Figures 1-3 (modified from Adler & Davis, 2006). Task 1 requires that PSMTs solve a linear equation. Although PSMTs may have a conceptual understanding for how and why their solution strategy works, they are not expected to decompress or unpack that understanding for the purposes of this task. Conversely, Task 2 requires PSMTs to reflect on the procedure used for solving linear equations. The second part of the task requires PSMTs to consider the specific cases when familiar heuristics for solving such equations (e.g., dividing both sides of the equation by  $a$ ) may result in a meaningless operation (e.g., if  $a$  equals 0). Task 2, unlike Task 1, requires PSMTs to unpack their mathematical understanding of the procedure for solving linear equations; however, it does not require pedagogical knowledge for successful completion.

Finally, Task 3 requires both an unpacking of mathematical knowledge and pedagogical insight. In order to successfully complete this task, PSMTs need to unpack

their mathematical content knowledge related to solving quadratic equations to determine when the mathematical strategy a student uses may be incorrect even though the overall solution is correct (e.g., although  $x = 1$  is the correct solution when solving the quadratic equation  $x^2 - 2x = -1$ , Solution #1 is limited by the fact that the student based his or her solution on the visual depiction of a graph that is restricted by its upper and lower bounds on the coordinate grid). In addition, Task 3 requires PSMTs to think about how they could communicate the strengths and weaknesses of each of the student solutions, a skill they will need to employ as they become teachers.

Task 1:

$$\text{Solve for } x: 3x - 15 = -2x + 18$$

*Figure 1.* Compressed mathematical task, modified from Adler & Davis (2006)

Task 2:

In solving the equation  $ax + b = cx + d$ , we typically do things to both sides of the equation that can be “undone” (if we want).

- (a) Make a list of things we might do to solve the equation above, and explain how each of those things could be undone.
- (b) Are there any values of the variables  $a, b, c$ , and  $d$  in the equation above that could cause potential problems given the steps you outlined in part (a) of this task? Explain.

*Figure 2.* Decompressed mathematical task, modified from Adler & Davis (2006)

Task 3:

Here are two solutions to the equation  $x^2 - 2x = -1$  presented by students in an Algebra II course:

Solution 1:  $x = 1$ . I drew the graphs  $y = -1$  and  $y = x^2 - 2x$ . They intersect in only one place, at  $x = 1$ .

Solution 2:  $x = 1$  because if  $x^2 - 2x = -1$ , then  $x^2 - 2x + 1 = 0$  and this factorizes to get  $(x - 1)(x - 1) = 0$ ; so  $x = 1$ .

- (a) Explain clearly which of these solutions is correct/incorrect and why.
- (b) Explain how you would communicate the strengths, limitations, or errors in each of these solutions to the students.

*Figure 3.* Decompressed mathematical task connected to pedagogy, modified from Adler & Davis (2006)

Unfortunately within many of the courses and instructional sequences used with prospective mathematics teachers, compression of mathematical ideas remains the norm (Adler & Davis, 2006; Ball & Bass, 2003). In a study conducted in South Africa, Adler and Davis (2006) analyzed the formal evaluative tasks within four different university teacher preparation programs for secondary mathematics teachers. They found that within the mathematics courses (designed specifically for teacher preparation) the overwhelming majority of tasks asked for teachers to reproduce mathematical knowledge without any explicit reasoning involved (i.e., compressed, rather than unpacked, mathematics).

Similarly, Kahan et al. (2003) explained that the mathematical content PSMTs learn in their teacher preparation programs is usually “forward-looking,” meaning the reason for learning the content is to succeed and progress in future mathematics classes. They argued that instead, teachers need to learn mathematics in a “backward-looking”

format, meaning that the reason for learning the content is to understand the secondary curriculum more deeply.

Hodge, Gerberry, Moss, & Staples (2010) interviewed seven mathematicians who taught university content courses (such as real analysis, abstract algebra, and differential equations) in which PSMTs were enrolled. These mathematicians found it difficult to articulate the ways in which the content of university mathematics courses was connected to the content teachers would teach at the high school level. Some of this difficulty came from mathematicians' lack of familiarity with the context and curriculum of secondary mathematics, and thus suggested a need for mathematicians to engage in discussions related to the secondary school context so that they (and the PSMTs in their courses) can better understand the connections between the university and school mathematics curriculum.

Despite the multitude of research demonstrating the importance of pedagogical content knowledge and specialized content knowledge in mathematics, the development of such knowledge in the United States prospective teacher population has a great amount of variability depending on the teacher preparation program (Schmidt, Cogan, and Houang, 2011), and has largely been neglected in the practice of teacher preparation (CBMS, 2001; Ferrini-Mundy & Findell, 2001; Williams, 2005). CBMS (2001) explained the result of such neglect as follows:

There is evidence of a vicious cycle in which too many prospective teachers enter college with insufficient understanding of school mathematics, have little college instruction focused on the mathematics they will teach, and then enter their

classrooms inadequately prepared to teach mathematics to the following generations of students (p. 5)

A final critique of traditional secondary mathematics teacher preparation is related to inconsistencies in pedagogical practices and ideologies of university instructors responsible for teaching courses in teacher preparation programs. PSMTs typically learn mathematics from instructors using a teacher-centered, transmission-style approach within their university mathematics content courses but at the same time are encouraged to teach using a student-centered, inquiry-based model in their mathematics methods courses (Ferrini-Mundy & Findell, 2001). Because teachers tend to teach in the ways they themselves have been taught (Lortie, 1975; Sowder, 2007), this creates a challenge because PSMTs experience learning mathematics in one way, but are expected to teach in another.

### **The potential of collaboration as a catalyst for reform in teacher preparation.**

In the previous section, I described some of the limitations of the traditional structure of secondary mathematics teacher preparation. One of the most commonly suggested “answers” to many of the problems that exist in secondary mathematics teacher preparation programs is collaboration between mathematicians and MTEs, the two groups of university faculty most immediately responsible for the development and implementation of the mathematics teacher preparation curriculum (CBMS, 2001, 2012; Cheng, 2006; Ferrini-Mundy & Findell, 2001; Heaton & Lewis, 2011; Holton, 2001; Millman et al., 2009; Nardi et al., 2005; Wu, 2006). If prospective teachers need to engage in tasks that help them decompress mathematics and integrate pedagogy (Ball & Bass, 2003), it makes sense that experts in mathematics and education might come

together to develop such tasks. If prospective teachers need to learn mathematics in ways that help them connect to the mathematical content they will teach at the secondary level (Hodge et al., 2010; Kahan et al., 2003; NMAP, 2008), MTEs could serve as a great resource for mathematicians to learn about the secondary curriculum. Finally, if prospective teachers have trouble reconciling differences between the pedagogical techniques used by their mathematics instructors and those espoused by their MTE instructors (Ferrini-Mundy & Findell, 2001), it could be valuable for mathematicians and MTEs to engage in dialogue about research on effective pedagogical practices and the expectations for teachers in the field.

Although mathematicians often serve as instructors in content-based courses for PSMTs, MTEs have historically taken the lead role in the consideration and development of teacher preparation programs (Sowder, 2007). However, the authors of CBMS (2001, 2012) asserted that mathematicians need to reconsider the important role they play in the preparation of future teachers,<sup>2</sup> and that mathematicians and MTEs should work together closely in an effort to design and implement preparation programs that meet the specific needs of PSMTs. In the following section, I review the literature related to collaborations between mathematicians and MTEs in greater detail in an effort to understand the

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<sup>2</sup> There is preliminary evidence that these calls for mathematicians to become more highly invested in the preparation and development of mathematics teachers have led to increases in mathematicians' involvement in the design and implementation of mathematics courses specific to the needs of future mathematics teachers at the elementary level (CBMS, 2011; McCrory & Cannata, 2010). Much less is known about such initiatives at the secondary level.

potential for collaborations to serve as a catalyst for reform in secondary mathematics teacher education.

### **Collaboration between Mathematicians and MTEs**

Collaboration is a term that pervades educational literature. Calls for and implementation of collaborative initiatives in education are seemingly endless, particularly with respect to reform in teacher education (Darling-Hammond, Pacheco, Michelli, LePage, Hammerness, with Youngs, 2005). Typically, colleges of education and their faculty hold primary responsibility for the professional preparation of future teachers (Darling-Hammond et al., 2005; Sowder, 2007). Faculty members in arts and science departments, who are responsible for teaching a large proportion of courses taken by prospective teachers, have little professional training in teacher education or pedagogy (Darling-Hammond et al., 2005). Moreover, the reward structures in university arts and science departments have traditionally favored faculty involvement in scholarship over involvement in teaching or service (Sowder, 2007). Therefore, arts and science faculty have seldom felt responsible for preparing teachers in ways beyond the development of generic content knowledge (Darling-Hammond et al., 2005). In the discipline of mathematics, this phenomenon is described by Nardi et al. (2005),

Teachers of university mathematics courses, on the whole, have not been trained in pedagogy and do not often consider pedagogical issues beyond the determination of the syllabus; few have been provided with incentives or encouragement to seek out the findings of research in mathematics education. In days gone by, it was assumed that the faculty's responsibilities were primarily to present material clearly, and that "good" students would pass and "poor" ones

fail. Of course, given the current climate of accountability, this is no longer the case. (p. 285)

Although cultural norms such as faculty training and departmental reward systems have limited the involvement of mathematicians in the professional preparation of teachers, it is now well-known that teachers need to develop an integrated knowledge of both content and pedagogy (as described in the previous section of my literature review). In addition to the responsibility of mathematics departments to ensure the adequate preparation of PSMTs, these departments are now facing external accountability pressures from federal and/or state legislatures and accrediting bodies to ensure that all mathematics majors demonstrate learning within the undergraduate mathematics program of study (Madison, 2006; National Research Council, 2003; Steen, 2006). Correspondingly, these issues necessitate a greater involvement of mathematicians in discussions about pedagogy in general, and teacher education in particular (Darling-Hammond et al., 2005).

In mathematics teacher education, organizations such as CBMS (2001) and NCTM (2000) have placed great emphasis on the need for mathematicians and MTEs to work together in an effort to create a cohesive education for prospective mathematics teachers and to help teachers integrate content and pedagogy within their own classrooms. As discussed in the previous section of my literature review, teachers (a) need to learn the content they will be expected to teach at a deeper level as well as have an understanding of the connections between the content they will teach and the content at earlier and later grade levels (Hodge et al., 2010; Kahan et al., 2003; NMAP, 2008), (b) should experience learning mathematics in ways similar to how they will be expected to

teach the subject (Ferrini-Mundy & Findell, 2001; Sowder, 2007), and (c) need support in unpacking mathematical concepts (Adler & Davis, 2006; Ball & Bass, 2003), all of which are more likely to be adequately addressed through the joint expertise of mathematicians and MTEs.

In the following sub-sections, I look more closely at the literature related to collaborations between mathematicians and MTEs. I begin by describing the history of relationships that have traditionally existed between the two communities. Then, I review literature that has focused on (a) the end-products of collaborative efforts between mathematicians and MTEs, (b) the outcomes of national meetings between mathematicians and MTEs, and (c) interview studies conducted by MTEs (serving as researchers) in order to determine mathematicians' perspectives on teaching and learning.

### **The history of relationships between mathematicians and MTEs.**

Although calls for collaboration between mathematicians and MTEs are widespread, the realization and implementation of such collaborations are not. Relationships between members of these two communities have often been “strained” (Nardi et al., 2005, p. 285) and characterized by a lack of trust and respect (CBMS, 2001; Ferrini-Mundy & Findell, 2001; Heaton & Lewis, 2011; Wu, 2006). Ferrini-Mundy and Findell (2001) explained,

Lack of mutual respect and cooperation between faculty in colleges of arts and sciences and faculty in education is a long-standing obstacle to the effective education of teachers. Unfortunately, it is quite common for undergraduate students to hear faculty in mathematics criticize faculty in education for lacking high standards, for not understanding mathematics, or for teaching material that

has no substance. And, conversely, students hear their education professors complain about poor teaching in the mathematics department or lack of attention by mathematics faculty to current issues such as the role of technology. (p. 38)

The prevalence of thorny relationships between university mathematicians and those involved in K-12 education is not a new phenomenon in the context of higher education. When the community of research mathematicians first began to develop in the United States during the first half of the twentieth century, apart from the already established research communities in Europe, prominent mathematicians such as E. H. Moore called for the mathematics community to become involved with school mathematics at the pre-college level (Parshall, 2003). Moore's philosophy on teaching was based on a "learn by doing" approach that parallels many of the recommendations set forth by the mathematics education community today (e.g., NCTM, 2000). He believed mathematicians should play a key role in school mathematics in order to help develop future scholars of mathematics in the United States. However, few mathematicians heeded that call. They had worked hard to establish their programs and departments that finally gave them standing as mathematicians instead of as mathematics teachers, the latter being a role many mathematicians viewed as less prestigious (Parshall, 2003).

In fact, many faculty members in higher education (an almost entirely male population) viewed teaching as a woman's job, and therefore did not wish to concern themselves with pedagogical matters (Lagemann, 2000). Therefore, although most research mathematicians were also responsible for instruction at the university level, they did not view school mathematics within their domain of responsibility. It was not until

the post-World War II era that mathematicians began to seriously think about their role in the context of school mathematics (Parshall, 2003).

The launching of Sputnik (the first satellite to orbit the Earth) by the Soviet Union in 1957 sparked a crisis in the United States over the mathematical and scientific progress of students. This crisis influenced many mathematicians and mathematics educators to lead reform initiatives to change the face of mathematics education in the country throughout the next few decades. An unfortunate result of these efforts was an erupting conflict between the two groups during the 1990s over the curricular goals and content to be addressed in school mathematics, a conflict that came to be known as “the math wars” (Schoenfeld, 2004). As a result of the math wars, the two communities grew apart and a great disdain between them seemed to emerge (Mervis, 2006).

In an article written for the *Bulletin of the American Mathematical Society*, Bass (2005), a prominent mathematician who has become actively involved in mathematics education research, outlined two of the common beliefs held by mathematicians and mathematics educators about members of the other group. He explained, “it is a common belief among *mathematicians* that attention to education is a kind of pasturage for mathematicians in scientific decline,” and that “many *educators have questioned* the relevance of contributions made by research mathematicians, whose experience and knowledge is so remote from the concerns and realities of school mathematics education” (p. 418). However, as Bass (2005) advocated, it is necessary to dispel these “common myths” (p. 418) and for the two groups to work together in close collaboration in order to prepare future teachers.

Needless to say, based on the rocky history between these two groups, attempts at collaboration between mathematicians and MTEs could present difficulties. Nevertheless, the need for collaboration is great, and several attempts at such collaboration have ensued in recent years. In the following sections, I review the findings from research in which mathematicians and MTEs have worked together in some capacity to improve teacher education.

### **Research focused on the end-products of collaboration.**

Prior research on collaboration between mathematicians and MTEs has often focused on the products of collaboration (e.g., curricular materials, standards, teacher preparation programs), or the perceptions and/or achievement of students involved in courses or programs developed by collaborating mathematicians and MTEs. However, few studies have focused on the actual dynamics of such collaborations.

For example, Williams (2005) studied an innovative master's degree program for secondary mathematics teachers designed by a mathematician, mathematics educator, and master mathematics teacher. The program, entitled A Partnership in Preparing Master Mathematics Teachers ( $P^2M^2T$ ), was funded by the US Department of Education Fund for the Improvement of Post Secondary Education. The purpose of Williams' study was to determine the factors of the program to which students attributed changes in their beliefs and instructional practices. Through the triangulation of survey and interview data collected from the students in the program, Williams discovered four factors that were most influential in changing students' beliefs and instructional practices: (a) collaboration with other teachers and course instructors, (b) specific connections to the secondary classroom, (c) pedagogical methods encouraged and employed by the

instructors, and (d) reflection on their own beliefs and instructional practices. These results reiterate the findings from the first section of my literature review that indicated the importance of teachers learning mathematics that is connected to the content they will teach in their classrooms as well as the importance of seeing models of good instruction from instructors at the college level.

The  $P^2M^2T$  program was “innovative” in that its creation combined the perspectives of individuals from the mathematics and mathematics education communities in an effort to combine content and pedagogy. However, missing from documented reports of the study is information about the interactions among the three individuals who collaborated to create the program. Although detailing the interactions within the collaboration was not the explicit purpose of Williams’ (2005) study, this information would have been beneficial for educators interested in pursuing collaborative efforts in their own institutions, an audience Williams was attempting to reach through his research.

In a subsequent publication co-authored by the project director of  $P^2M^2T$ , the publication’s abstract indicated one of the major goals of the article was to “show how the expertise of three different groups – subject specialists, teacher educators, and classroom teachers – is productively intertwined so that the results of current educational research are transformed into improved classroom practice” (Eaton & Carbone, 2008, p. 261). However, the only mention of the actual dynamics of the collaboration was captured in the following single sentence, “The three members of the teams worked well together and enjoyed the process of developing the courses, and while the conversations and interactions were professional, courteous, and friendly, they did not always conclude

with full agreement” (p. 266). After reading the available literature on the  $P^2M^2T$  collaboration, I am left with many questions about the interactions between the three creators of the program. For instance, what did they agree on? What did they disagree on? How did they reconcile their differences in an effort to create the course curriculum? In what ways did the individual expertise of each of the collaborators influence the resulting program?

Both Williams (2005) and Eaton and Carbone (2008) described the  $P^2M^2T$  program’s course structure using a table with five content strands along the side and five pedagogical strands along the top, leaving the spaces in the middle blank. The intent of the table was to demonstrate how each of the courses integrated content strands with pedagogical strands. For future research, it might be helpful if the authors were to fill in these entries of the table with information about how the mathematician, mathematics educator, and master mathematics teacher contributed to the content of the courses represented by each of the blank boxes, including information about the topics on which they did or did not agree. This would give readers a clearer idea of what actually happened within the  $P^2M^2T$  courses and how the creation of the curriculum was influenced by the collaboration among individuals with varied expertise.

Several other studies have documented the results of collaboration between mathematicians and MTEs, with little attention paid to the actual collaborative process. For example, Koirala et al. (2008) discussed the end-product of a collaboration between a mathematician, mathematics educator, and high school mathematics teacher. The three individuals worked together to develop a performance assessment task and rubric to measure pedagogical content knowledge for secondary mathematics teachers, and they

claimed that the collaborative work was instrumental in the successful development of their tool; however, they did not provide details about the nature of the collaborative process.

As another example, Kehle et al. (2005) described the result of a collaborative effort between the mathematics department and the education department at Indiana University. Members of the two departments came together as part of a NSF-funded Math Science Partnership, and created what they called “linked courses” for their PSMT population. The purpose of the linked courses was to help PSMTs make connections between the mathematics they were learning in their upper-level mathematics courses (i.e., calculus, abstract/linear algebra, probability and statistics, and mathematical modeling) and the mathematics they would teach at the high school level. Evidence from student interviews and course evaluations suggested these linked courses were successful in helping PSMTs make connections across different levels of mathematics, an aspect of teachers’ professional preparation that is sorely missing from most teacher preparation programs (Kahan et al., 2003; NMAP, 2008). However, like the studies I have discussed previously in this section, no information was provided by the authors about how members of each department worked together, the challenges they faced, the contributions made by members of each department, or the overall nature of their collaborative efforts.

Although I have mentioned only a few examples, the majority of literature related to collaboration between mathematicians and MTEs has focused on the resulting products of the collaboration (e.g., courses, curriculum, assessments) or measures of PSMTs’ development in relation to the collaborative efforts (e.g., interviews, course evaluations,

teacher work samples). I do not wish to downplay the importance of such research, as it has contributed significantly to the knowledge base in teacher education, specifically in regards to the development of pedagogical content knowledge; however, I do want to point to the lack of attention that has been paid to the nature of collaborative efforts that have led to the successful development of tools and ideas for the preparation of PSMTs. Future research should consider the similarities and differences that emerge between mathematicians and MTEs as they engage in collaborative work, the roles taken on and contributions made by members of each community, and the affordances and constraints of collaborative endeavors. Such research could aid in a better understanding of what is needed for a more widespread implementation of collaboration between the two communities.

In the next section, I review the literature related to collaborations between mathematicians and MTEs that have occurred through meetings at the national level. The literature related to these national meetings suffers from some of the same gaps as that of the smaller-scale collaborations mentioned in this section, namely an (over) focus on the products of such collaboration with little emphasis on the social or environmental dynamics involved.

#### **National meetings.**

The coming together of well-known and well-respected mathematicians and mathematics educators at national meetings in efforts to develop standards and curricular materials (Common Core State Standards Initiative [CCSSI], 2010; NMAP, 2008; RAND Mathematics Study Panel, 2003) has served as another type of collaboration that has had a strong influence on mathematics education policy. The purpose of collaboration in

these meetings has been to combine various individuals' expertise in an effort to create thorough, cohesive, and mathematically accurate documents intended to have a strong influence on the research and practice within mathematics education domains.

In other types of meetings, mathematicians and MTEs have come together specifically to try to find areas of common ground between the two communities. In these cases, the focus of the meetings was not to create specific standards or curricular materials for use in school mathematics, but to identify areas of agreement amongst the groups. For example, Richard Schaar, a mathematician and active leader in educational reform, believed that many of the disagreements between the two communities arose due to a misunderstanding of vocabulary or language use, a notion that has been demonstrated in the broader literature on interdisciplinary collaboration (e.g., Davis, 1995; Klein, 2005). Therefore he called together a small group of mathematicians and mathematics educators, and they worked together to identify areas of agreement in mathematics education, often clarifying personal meaning of terms that might be misunderstood by others in the group (Ball et al., 2005).

Some of the areas of agreement concerning teaching and teacher knowledge identified by Ball et al. (2005) included ideas that teachers should (a) be able to explain why procedures and algorithms work, demonstrate how different subject matter is connected, and provide appropriate representations of mathematics which help make the subject accessible to students, (b) use their thorough understanding of the subject to make pedagogical decisions on what type of instruction (e.g., direct instruction, structured investigation, or open exploration) will be most beneficial for students who have different levels of background knowledge and who are learning different content

areas, and (c) be life-long learners and continue their own education through professional development opportunities.

In a follow-up to the small six-person meeting discussed above, 50 individuals took part in the “Finding Common Ground” meeting on March 2-5, 2006 at Indiana University Purdue University Indianapolis. The goal of this follow-up meeting was to find common ground among mathematicians and mathematics educators in more specific topic areas, including: standards for teachers, algebra, probability and statistics, technology, and algorithms. The focus group that worked on finding common ground on issues of teaching resonated with the recommendations made in the first meeting, but added that teachers should (a) understand the mathematics beyond the grade levels they teach, and (b) understand and present mathematics in a way true to the structure of the subject (what they called “mathematical integrity”). Moreover, the report recommended departments responsible for mathematics teacher education should (a) integrate the development of pedagogical content knowledge into courses for teachers, (b) actively recruit future mathematics teachers, (c) provide support and reward structures for mathematicians interested in teacher education, and (d) encourage collaborations between mathematicians, mathematics educators, and school teachers (Common Ground Conference Report, 2006).

The areas of agreement resulting from these formal meetings between mathematicians and mathematics educators are crucial to establishing common terminology, promoting trust, and encouraging collaboration between the two groups. The value of such meetings should not be underestimated. However, the reports from these meetings provide little access into the dynamics of the collaborative efforts that

ensued during those meetings. Therefore, again I suggest the need for studies that take into consideration the roles played by members of each community in the process of collaboration as well as the challenges that present themselves in naturalistic interactions between the two groups.

In the next section, I review interview studies that have been conducted primarily by MTEs with mathematicians serving as the research participants. These studies, by their nature, have encouraged dialogue between the mathematics and education communities, and therefore can be considered a form of collaboration between mathematicians and MTEs.

### **Interview studies.**

Several mathematics education researchers have used interviews as a means to gain an in-depth understanding of mathematicians' perspectives on the teaching and learning of mathematics. The authors of these studies have frequently used the findings from interviews with mathematicians to suggest similarities or differences between members of the mathematics and mathematics education communities, and to describe the relationship that exists between these two groups. However, because mathematicians have typically been the only interviewees in these studies, the authors' connections to the mathematics education community often seemed to be based on anecdote or theory, and not empirical evidence. Moreover, while the interactions between mathematics education researchers and their mathematician interviewees represent a type of collaboration, it is not necessarily one in which the MTE and mathematician perceive themselves as equals in the collaboration because the MTE is usually in the position of authority and the mathematician is the research participant.

As an example of one such study, Burton (1999, 2002, 2004) interviewed 70 research mathematicians about how they come to know mathematics, and from their responses she proposed several goals of mathematics learning that are common across all mathematical communities, from school-based mathematics to university-level mathematics, and between students, teachers, mathematics educators, and mathematicians. Burton found that although the instruction in a typical mathematics classroom emphasizes the transmission of objective knowledge from teacher to student, research mathematicians did not view their subject as a set of objective knowledge bits. Instead, mathematicians viewed their work as a cultural and interactive experience in which one builds his or her own meaning, very similar to the type of learning experiences advocated by the mathematics education community (e.g., NCTM, 2000).

Burton (1999, 2002, 2004) suggested mathematicians' professional work as researchers provides a good example of the natural way of coming to learn mathematics, and she reiterated mathematicians' notion of the importance of identity, agency, collaboration, flexibility, and pleasure to the learning of the discipline. Furthermore, Burton (2002) posited there are many more commonalities than there are differences among the two communities in their goals and perspectives on the learning of mathematics, and through this work she attempted to highlight those similarities so that "a climate of trust and respect" (p. 173) might be established across groups.

In another study, Nardi et al. (2005) interviewed six undergraduate mathematics professors in a university in the United Kingdom with the goal of investigating mathematicians' "spectrum of pedagogical awareness." The researchers in this study observed the tutorial sessions (akin to "office hours" in the U.S.) held by the university

instructors throughout their 8-week semester. After the undergraduate students left each session, the researcher and mathematician reflected (through interview discussions) on the students' learning and the instructors' pedagogy that occurred during the tutorials.

A major finding from this study was that through a reflective discourse on practice, mathematicians were able to raise their awareness about pedagogical issues in their instruction. This is particularly important when considering the role of mathematicians in the reform of teacher education because "reform of pedagogical practice can only follow from developing pedagogical awareness in the first place" (Nardi et al., 2005, p. 286). The authors suggested that this type of interview-based, reflective research demonstrates "the potential of a closer collaboration between mathematicians and mathematics educators" (p. 310), serving as a type of professional development for the mathematicians involved.

Nardi (2008) conducted focus group interviews with mathematicians in an effort to better understand their thoughts about students' learning of mathematics, specifically at the university level. Using data from these interviews together with data collected in several other previous studies she had conducted (including Nardi et al., 2005), Nardi (2008) composed a book called *Amongst Mathematicians*, consisting of a series of fictional dialogues between two characters, a researcher in mathematics education (RME) and a mathematician (M). Although the narratives are fictional, they are grounded in data from the interviews and are intended to capture the overall essence of the mathematicians' perspectives on undergraduate students' learning of mathematics.

Most of the dialogue in Nardi's (2008) book is focused on particular content areas or aspects of student learning (e.g., function, limits); however, one of the chapters is

devoted to dialogue illustrating what Nardi referred to as the “fragile, yet crucial” (p. 257) relationship between mathematicians and researchers in mathematics education. In that chapter, RME and M discussed “the stereotypical perceptions of mathematics, mathematicians and educational research that tantalise [*sic*] their relationship” (p. 257). Some of the major issues stemming from the discussion between RME and M about their relationship included (a) differences in epistemology between RME and M, (b) the value of engagement in qualitative data related to students’ mathematical learning and university mathematicians’ pedagogical practices, (c) the barriers to communication between the two communities due to differences in expectations for research products and dissemination, and (d) the importance of RME’s content knowledge as a facilitator of discussions with M about mathematics at the university level. In the following paragraphs I will briefly address each of these four issues.

Nardi (2008) depicted a distinct difference in epistemology between RME and M, and cited this as one of the major issues that drives a wedge between the two groups, “The main bone of contention in the suspicion, even hostility often characterising [*sic*] the relationship between mathematicians and researchers in mathematics education is the substantially different epistemologies of the two communities” (p. 264). The types of research (and knowledge) that have traditionally been valued in the mathematics community are of a postpositivist orientation, with quantitative, experimental methods serving as the leading source of truth (Goldin, 2003; Nardi, 2008; Sfard, 1998b). Conversely, in mathematics education, researchers are typically concerned with the cognitive and social aspects of mathematics learning, with social constructivism serving as a primary epistemological stance in the field (Goldin, 2003; Nardi, 2008; Sfard,

1998b). As Nardi expressed when summarizing Sfard (1998a), “M and RME can work together ...but never-ever should their methods be confused: M is concerned with abstract ideas, RME with human beings” (p. 264).

Several authors have discussed these epistemological differences between mathematicians and mathematics educators and subsequently suggested possible solutions to the epistemological divide. For example, Goldin (2003) argued that the education community’s “ultrarelativist” (p. 174) epistemological stance often leads to an a priori dismissal of concepts such as “objectivity, reliability, validity, empirical verifiability, truth, and...falsifiability” (p. 182), concepts that are valued in the natural sciences and mathematical community. He argued that unless the two communities can accept that all perspectives (i.e., epistemological stances) towards research have something to contribute to our understanding of mathematics teaching and learning, rather than dismiss one another’s epistemological stance, then the divide between the two communities will only increase. Goldin did not suggest that educational researchers change their epistemological stance for one that is more “objective” but rather that they recognize the value of postpositivist knowledge formation in addition to other approaches to mathematics education research.

Whereas Goldin (2003) wrote to an audience consisting primarily of educators in *Educational Studies in Mathematics*, Ralston (2004) wrote about the epistemological divide between mathematicians and educators to an audience consisting primarily of mathematicians in the *Notices of the American Mathematical Society*. In that article, Ralston admonished mathematicians for their “arrogance” (p. 405) towards mathematics educators and educational research. In an argument paralleling Goldin’s argument that

mathematics educators too often dismiss the epistemological stance of mathematicians, Ralston suggested that mathematicians commonly reject a priori the assumptions and perspectives of mathematics educators, believing that the only valid form of knowledge production is the “theorem/proof mathematics research or the scientific method paradigm of the physical sciences” (p. 409). Ralston suggested that instead of dismissing such perspectives, mathematicians should work collegially with mathematics educators in an attempt to offer constructive criticism in places where a mathematicians’ deep knowledge of the subject can be useful.

Sfard (1998b) argued that because the epistemological differences between the two groups yield incommensurable beliefs about mathematical knowledge, the best one can do is inquire into “what kind of collaboration these two communities could create and what contributions each one of them might make in order to promote what seems to be their mutual goal: finding ways of enhancement of human learning and creativity” (p. 506). Nardi’s (2008) approach to bridging the communities (aligned with Sfard, 1998b) is founded on the idea that involvement and engagement of mathematicians and mathematics educators in discussion and deliberation on issues related to teaching and learning in mathematics education will help members of the two communities better understand each other. She acknowledged that the topic areas she proposed for discussion with mathematicians in her studies were “safer” (p. 272) topics, such as student learning and pedagogical practice, and that it may be harder to engage in open, productive discussions about topics such as equity in mathematics learning or gender distribution across mathematics departments.

A related benefit that stemmed from mathematicians' engagement in Nardi's (2008) study was an increased level of pedagogical awareness (replicating results from Nardi et al., 2005). As M reflected on his experiences participating in the reflective discussions with RME, he acknowledged the value of such discussions, stating,

May I say that it is in these discussions exactly that these sessions have proved enormously valuable already. There are things I will teach differently. There are things that I feel like I understand better of mathematics students than I did before. And I appreciate the questioning aspects of the discussion and I realize how one should be liasing [*sic*] with the other lecturers simultaneously lecturing the students and discussing what things we are doing that confuse them. (p. 260)

He also explained,

I think now I don't have any more answers than when I started but certainly I don't take things for granted anymore, from colleagues or from students. I think I am much more open-minded on what might be going on inside other people [*sic*] brains. The material that you have got here has given the evidence that sure, it is fascinating glancing in other people's head. And I have become much more conscious about the spoken word. (p. 262)

Through discussions about students' thinking and learning in mathematics (as represented in samples of student work and transcript data from tutorial sessions), and reflections on the pedagogical tendencies of other university mathematicians (as represented in transcript data from tutorial sessions), M was able to better relate to the needs of his students, recognize the power of the university professors' spoken word, and reflect on possible pedagogical adaptations he could make to his work in the classroom.

Moreover, M explained how these discussions made it impossible to ignore pedagogical issues, and to “face the music” (Nardi, 2008, p. 262) with respect to the reality of undergraduate students’ learning needs.

Nardi (2008) wrote of the many issues related to research writing and dissemination that hinder the possible interaction/collaboration between M and RME. There is specific language used in educational research which was “indecipherable” (p. 280) by M due to a high level of education-specific jargon. In addition, the articles that are generally read by M are not the same as those read by RME. RME explained the issue, “So the mechanics of the problem seems to be that both mathematicians and mathematics educators need to publish in and read journals in their own areas...and there is precious little time for reading each other’s journals. The two worlds don’t meet a lot...unfortunately...I think this is at the heart of the problem” (pp. 284-285).

Finally, this study demonstrated the importance of mathematical content knowledge of the RME involved in studies at the undergraduate (or higher) level. M admitted he was put at ease because RME (in this study) was a “mathematician” herself and hence very knowledgeable about the subject. However, he would have been more reluctant to participate and/or see value in the study if RME was less mathematically sophisticated, “I admit that your being a mathematician alleviated some initial suspicion” (p. 270). Moreover, the study illuminated a distinction in the field between two types of researchers in mathematics education, those who have graduate-level mathematical training and those who do not. Through the character of RME, Nardi (2008) expressed her concern about this issue,

You know, I sometimes feel there is a sort of class distinction within mathematics education between the people who are mathematicians and the people who are not. The people who are not mathematicians have a kind of disregard for the other one because they think they don't know enough about educational psychology, students' needs, pedagogy. And the former accuse the latter of not knowing the mathematics in the first place. (p. 267)

The dialogic format used by Nardi (2008) and the interview methodology used in all three studies reviewed above is quite revealing and provides a unique depiction of the similarities and differences between the two communities that arise within conversations about undergraduates' learning of mathematics. This program of research provides a valuable first step in the understanding of similarities and differences between mathematicians and mathematics educators in how they think about the teaching and learning of mathematics. However, as illustrated through the reflective questions Nardi (2008) suggested her readers consider while reading through the narratives between M and RME (i.e., "What can we learn about student learning from M's contributions to this dialogue? What can we learn about M as a pedagogue [his perceptiveness, sensitivity etc.] from this dialogue?" [p. 39]), the main focus of her book (and similarly the main focus of the other studies by Burton [2002, 2004] and Nardi et al. [2005]) was related to mathematicians' perspectives of student learning. There was considerably less focus on the voice and perspectives of mathematics educators emphasized throughout these studies. I believe the field can benefit from research that takes a closer look at the teaching and learning philosophies of both mathematicians and mathematics educators, utilizing a more balanced representation of voices of members from each group.

One of the most frequently employed methods of collaboration between members of different disciplines in higher education is team-teaching (Davis, 1995). Although little empirical research has been conducted on team-teaching collaborations between mathematicians and MTEs, the broader literature related to interdisciplinary team-teaching in higher education contains significant insights related to this type of collaboration. In the following section, I explore the literature related to interdisciplinary team-teaching.

### **Team-Teaching**

In their review of the literature on collaborative teaching, Nevin et al. (2009) delineated five approaches to collaboration within educational arenas, the last of which will be the focus of this proposed study.

The approaches include (a) *collaborative consultation*, where educators with particular expertise (e.g., content knowledge, disability category knowledge, pedagogy knowledge, etc.) provide advice to the another [*sic*] educator; (b) *supportive co-teaching*, where one educator takes the lead and others rotate among students to provide support; (c) *parallel co-teaching*, where co-teachers instruct different heterogeneous groups of students; (d) *complementary co-teaching*, where one educator does something to supplement or complement the instruction provided by the other educator (e.g., models note taking or paraphrases the teacher's statements); (e) *team-teaching*, where educators are partners who share responsibility for planning, teaching, and assessing the progress of all students in the course. (p. 570)

Team-teaching has been used at all levels of instruction, from elementary school to graduate programs. The prior research in this area includes studies of team-teaching between (a) special education teachers and general education teachers in the K-12 school systems (Hourcade & Bauwens, 2001; Welch, Brownell, & Sheridan, 1999); (b) university faculty in special education and general education (Patterson, Syverud, & Seabrooks-Blackmore, 2008); (c) pre-service teachers and mentor teachers (Roth, Tobin, Carambo, & Dalland, 2005); (d) graduate students and university faculty (George & Davis-Wiley, 2000); (e) instructors from the same university departments (Lehmann & Gillman, 1998; Lester & Evans, 2009); and (f) instructors from different university departments (Anderson & Speck, 1998; Cruz & Zaragoza, 1998; Davis, 1995; Moore & Wells, 1999; Podeschi & Messenheimer-Young, 1998; Robinson & Schaible, 1995; Vogler & Long, 2003).

The purposes for team-teaching are as varied as the types. For example, the first and second types (listed above) generally reflect the need for experts in special education and those in general education to work together to ensure the optimal education for students with special needs who are often placed in general education classrooms under mandates for inclusion (Individuals with Disabilities Education Act [IDEA], 2004; No Child Left Behind Act [NCLB], 2001). In the third and fourth type, an experienced teacher acts as a mentor to an individual who is newer to the teaching profession, and therefore the team-teaching serves as a type of professional development or initiation into teaching. In the last two types, the main purpose of team-teaching is to combine the expertise of several different individuals with the underlying assumption that multiple perspectives will enhance instruction.

For the purposes of my study, I primarily review the team-teaching literature related to faculty members from different departments who collaborate in order to develop and implement interdisciplinary courses. In defining interdisciplinary, I follow Davis (1995) in his conception that interdisciplinary team-teaching is inclusive of faculty from different disciplines as well as faculty from different specializations within professional fields. In this regard, a mathematician and a MTE can be thought of as having different specializations (mathematics content and mathematics pedagogy) within the professional field of teaching mathematics.

### **The impact of interdisciplinary team-teaching.**

In this section, I draw on the literature related to interdisciplinary team-teaching in higher education to identify some of the areas of consensus about the impact of team-teaching in that context. The majority of literature on team-teaching in higher education is anecdotal, offering personal reflections of faculty experiences in collaborative teaching partnerships, and therefore, I draw largely from this source in the literature. However, when possible, I draw on the few empirical studies that have been conducted related to the nature and impact of team-teaching (e.g., Albrecht, 2003; Anderson & Speck, 1998; Lester & Evans, 2009; Preves & Stephenson, 2009). From this review of the literature, I found significant overlap of findings across the studies, related to the nature and impact of team-teaching, that emerged in two categories: (a) faculty development in the team-teaching context, and (b) student learning in the team-teaching context.

#### ***Faculty development in the team-teaching context.***

One of the most frequently cited benefits of team-teaching mentioned by faculty was that working as a team encouraged instructors to reflect on their practice, often much

more frequently than would be the case in a solo taught course (Lester & Evans, 2009). Moreover, when reflections were voiced out loud in a conversation between team members, instructors focused on both their individual and shared experiences, thus adding another dimension to their reflection (Crow & Smith, 2005). As explained by Podeschi and Messenheimer-Young (1998), “Teaming is like looking in a mirror being held by your teaching partner, and then learning to talk about what each is seeing” (p. 215). In a phenomenological study of their own lived experiences collaboratively teaching an undergraduate psychology course for pre-service teachers, Lester and Evans (2009) identified five major themes that permeated their collaboration. One of these themes, *The presence of another pushed us to go deeper*, suggested that team-teaching created an environment in which reflection was inevitable, the result being the instructors’ increased professional growth as educators.

Another theme that emerged from Lester and Evans’ (2009) study, *You build something bigger*, suggested that through their collaboration, a bigger (and better) course developed. Likewise, in a team-teaching collaboration between three faculty members, one each from a Department of Secondary Education, Special Education, and Educational and Counseling Psychology, the “cross-fertilization of teaching techniques, information, and philosophies” (Moore & Wells, 1999, p. 230) resulted in a comprehensive, integrated course for preservice secondary teachers. Lehmann and Gillman (1998), two mathematics instructors who team taught three different courses in a single semester, found that through collaboration they were able to develop better lesson plans and activities for their students than they had previously created in their solo-taught courses,

explaining that “The benefits we have so often proclaimed for students in collaborative learning also hold true for faculty” (p. 99).

In a similar vein, throughout the literature numerous authors discussed the benefits of team-teaching as a source of professional development (Albrecht, 2003; Crow & Smith, 2005; Lester & Evans, 2009; Patterson et al., 2008). Moore and Wells (1999) explained that because they constantly had a peer in the room, they felt as if they were held accountable for using best practices throughout all class sessions. Robinson and Schaible (1995), who wrote about their experiences team-teaching twelve different interdisciplinary courses (together and with other instructors), found that although faculty may be aware of the best practices for teaching as laid out in the higher education research literature (e.g., inquiry-based, student-centered instruction), it was often easy to fall back into less productive pedagogical habits if not held accountable to a peer in the classroom.

### ***Student learning in the team-teaching context.***

In this section, I discuss the aspects of team-teaching authors have cited as relevant to student learning. Although the focus of my inquiry is not the impact of team-teaching on student learning, I found it important to review this part of the literature so I could better understand the broader context of the team-teaching environment, and the potential issues that may arise within Dejan and Angela’s collaboration.

One of the most frequently cited benefits of team-teaching from the student viewpoint is the ability to see and hear multiple perspectives. In a reoccurring team-teaching collaboration at the University of North Florida, anywhere from two to nine special education faculty members worked together each semester to team-teach an

introductory course for prospective teachers (Patterson et al., 2008). Although all of the collaborators worked together to plan the course, the actual implementation was not as collaborative; most class sessions were taught by an individual faculty member in his or her area of expertise. Nevertheless, through the presentation of many different topics within special education, students indicated that they were able to see the “big picture” (p. 20), instead of simply seeing the material from the perspective of one professor. Likewise, Moore and Wells (1999) suggested students in their class benefitted from hearing three points of view on educational issues.

In a team-taught writing institute for K-12 inservice teachers, Anderson and Speck (1998), collected student data from various sources, including journals, exit slips, portfolios, self-evaluation data, and answers to writing prompts about the team-teaching collaboration. They found that although students appreciated the differences in content expertise between their two instructors (an education specialist and an English content specialist), they also found it helpful to be able to reflect on the varied instructional techniques used by each instructor.

For pre-service or in-service teachers, faculty team-teaching collaborations can serve as a model for collaboration and for instruction. In their role as students, pre-service and in-service teachers are often expected to work in collaborative groups and to build upon their prior knowledge using the experiences, perspectives, and knowledge of their peers (Darling-Hammond & Bransford, 2005). Likewise, in their role as teachers, these individuals increasingly need to be able to work collaboratively with other educators due to mandates for inclusive classrooms (IDEA, 2004). Moreover, teachers are expected to implement inquiry-based, student-centered instruction in their own

classrooms, a type of instruction they have rarely experienced as students themselves (Sowder, 2007). Because team-taught courses are based on a collaborative model, the instruction provided by team teachers often leads to classrooms in which collaboration is valued among students and teachers, providing a model that helps pre-service and in-service teachers think metacognitively about alternative modes of teaching (Anderson & Speck, 1998).

Through team-teaching, faculty often find themselves in situations where they need to make pedagogical decisions or resolve a conflict in front of the class (Preves & Stephenson, 2009). Although making pedagogy explicit and bringing disagreements to the fore can create tension within the classroom, the tension is often outweighed by the potential for students to reflect on their own pedagogical strategies and to learn ways to dialogue and settle disputes with colleagues (Lehmann & Gillman, 1998; Moore & Wells, 1999; Podeschi & Messenheimer-Young, 1998; Robinson & Schaible, 1995).

One aspect of team-teaching for which the results in the literature are mixed is the way students view the evaluative processes in a team-taught classroom. Some students valued having a choice of instructors to approach for extra help or mentoring as well as the additional time that is afforded by two or more instructors offering office hours (Podeschi & Messenheimer-Young, 1998). However, other students were confused when they had to satisfy the expectations of multiple instructors, and found it more beneficial to have one source that could consistently answer all of their questions about assignments (Patterson et al., 2008; Robinson & Schaible, 1995). When students were in small groups, they benefitted from having more instructors in the room who could circulate between the groups and provide feedback (Lehmann & Gillman, 1998); however, if feedback was not

consistent across instructors, students became frustrated (Robinson & Schaible, 1995). Similarly, if assignments were graded by more than one member of the teaching team, students could receive feedback that had more depth and breadth, having been assessed by instructors with varied perspectives and expertise (Anderson & Speck, 1998); however, if instructors graded separately, and inconsistently, students became discouraged by mixed messages (Robinson & Schaible, 1995).

### **Theoretical considerations related to team-teaching.**

In his book *Interdisciplinary Courses and Team-teaching*, Davis (1995) noted that because there are so many models and definitions for team-teaching, it is more important to focus on the level of collaboration than on an explicit definition that holds in all cases. He offered a framework for evaluating the degree of collaboration in interdisciplinary team-taught courses. The framework delineates four aspects of team-teaching (planning, content integration, teaching, and evaluation), each of which exist along a continuum from lower to higher degrees of collaboration. Given this framework, an individual team-taught course might be rated high on degree of collaboration in planning and content integration; however, if one instructor is responsible for most of the actual teaching during class sessions and grading of assignments, then it would be rated low in teaching and evaluation. Davis argued that “optimal arrangements for interdisciplinary integration and for team-teaching involve higher levels of collaboration” (p. 8), and that therefore the goal for interdisciplinary partnerships should be to achieve high degrees of collaboration along all four continua.

Anderson and Speck (1998) discussed the problematic nature of the extant literature that overwhelmingly asserts the effectiveness of team-teaching, but which has

yet to provide a definition or characterization for the term that helps to explain the asserted effectiveness of the approach. Whereas most characterizations of team-teaching in research literature (including Davis, 1995) focus on the logistics of the collaboration (e.g., number of people collaborating, roles played by members of the collaboration), Anderson and Speck (1998) argued that a more useful conceptualization of team-teaching would be based on the theoretical assumptions guiding such collaboration, assumptions they posited (based on their prior experiences and knowledge of the literature) are commonly related to constructivist learning principles.

In other words, Anderson and Speck (1998) argued that instructors collaborating on a teaching team tend to gravitate toward a classroom environment that is characterized by discussion, openness to multiple perspectives and contrasting ideas, “dispersion of authority” (p. 681), and collaborative work amongst teachers and students—leading to a classroom environment in which learning is modeled by the instructors according to constructivist principles. They believed this tendency toward a classroom based on constructivist principles could explain the overwhelming success of team-teaching partnerships that have existed under a wide variety of logistical contexts, stating, “the great heterogeneity of the various circumstances on which descriptive reports of team-teaching are based becomes less perplexing when those reports are interpreted as affirmations of constructivist principles” (p. 680), rather than affirmations of a particular configuration of the team-teaching structure.

### **Team-teaching between mathematicians and MTEs.**

In my search of the literature, I found four references related to team-teaching collaborations between mathematicians and MTEs (Grassl & Mingus, 2007; Heaton &

Lewis, 2011; Sultan & Artzt, 2005; Thompson et al., in press). All four of these articles are reflective, anecdotal accounts written by the individuals who worked together to team-teach. None of the authors/collaborators employed a systematic, empirical study of their team-teaching collaboration, although some did collect data (e.g., interviews with students, surveys). Nevertheless, the reflective accounts of these four teaching teams provide valuable insight into the experiences of team-teaching partnerships within the context of mathematics teacher preparation. In the following sections, I provide a review of each of these articles, and conclude with an analysis of the similarities and differences across cases, keeping in mind the theoretical considerations related to team-teaching I reviewed from Davis (1995) and Anderson and Speck (1998).

***Team-teaching in a mathematics sequence for prospective elementary teachers.***

Heaton and Lewis (2011), a female MTE and a male mathematician, respectively, wrote about their ten-year partnership working together under the auspices of an NSF-funded “Course, Curriculum, and Laboratory Improvement” grant to improve the mathematical preparation of prospective elementary teachers at their institution. Through their partnership, Heaton and Lewis developed and implemented the curriculum for a four-course “Mathematics Semester” required of elementary teachers that included one mathematics content course, two mathematics pedagogy courses, and a teaching practicum.

The purposes of the pedagogy courses, taught by Heaton, were to help teachers (a) see mathematics from a child’s perspective, (b) teach the mathematical topics important in the elementary curriculum, and (c) develop a classroom environment conducive to students’ learning of mathematics. The purposes of the mathematics content

course, taught by Lewis, were to (a) provide a model of effective mathematical instruction, focusing on communication, problem solving, and reasoning and proof, and (b) develop teachers' mathematical "habits of mind" (p. 395).

Although Heaton and Lewis (2011) taught their courses as solo instructors, they worked together to plan and integrate the sequence of courses. There was one integrated syllabus for the four-course sequence, and several course assignments were "shared" between the mathematics and pedagogy courses. These assignments were graded jointly by the two instructors. Furthermore, Heaton used Lewis' model of mathematical instruction as a point of departure for her class discussions related to effective mathematical pedagogy. The instructors suggested that the students, who were typically anxious about taking mathematics courses and interacting with mathematicians, found a more welcoming environment in their course sequence due to the partnership between a mathematician and a MTE, stating that the partnership "helps ease the students' resistance to the mathematician's expectations" (p. 395).

Through their collaboration, Heaton's pedagogy courses became "more mathematical" (p. 399) and Lewis's mathematics courses developed "a much stronger connection to the work of teaching elementary teachers" (p. 399). The instructors attributed positive changes in their own professional development, as well as in the learning of their students, to their strong commitment to collaboration across the years.

A few things strike me about the partnership described by Heaton and Lewis (2011). For one, Lewis, the mathematician, appeared to have a thorough knowledge of educational literature, modeling best practices in regards to communication, problem solving, and reasoning. Because many mathematicians have little training in pedagogy

(Darling-Hammond et al., 2005; Nardi et al., 2005), I found myself questioning the degree of familiarity Lewis had with the educational literature before engaging in collaboration with Heaton, and how their partnership helped him to develop in his own pedagogical practices (if at all).

In addition, although Heaton and Lewis documented the configuration of their courses, and the areas in which they collaborated (i.e., planning, grading), they provided little information about how their backgrounds in mathematics and mathematics education affected the dynamics of their partnership, or how their perspectives on teaching and learning differed. The implicit assumption underlying the article was that Heaton and Lewis were in agreement as to the needs of teachers and the structure of their mathematical program. However, as my review of the literature has suggested thus far, it is not typical for two people coming from the mathematics and mathematics education communities to be in such agreement. In order to learn from the experiences of mathematicians and MTEs who have engaged in successful collaborations such as Heaton and Lewis, I believe it is important for future research (and reflective accounts) to attend to the actual collaborative process, rather than solely on the configurations and outcomes of such partnerships.

***Team-teaching in an abstract algebra course.***

Grassl and Mingus (2007), a male mathematician and a female MTE, respectively, wrote about their experiences working collaboratively to design and teach a “reformed” abstract algebra course under the impetus of an NSF-funded teacher education collaborative grant. The purpose of the grant was to “shift from the traditional instructional paradigm to a learning paradigm” (p. 581) within the mathematics

department at their university, and to subsequently increase the number of undergraduate students from underrepresented groups who decided to pursue mathematics teaching. Grassl and Mingus provided a primarily anecdotal account related to the factors they perceived as contributing to the success of their collaboration; however, the instructors also conducted interviews and collected written evaluations in an effort to better understand student perspectives on the course.

Grassl and Mingus (2007), in reflecting on their “reformed” abstract algebra course, cited two factors that were the greatest contributors to the reformed nature of the course: the use of team-teaching and the use of collaborative group work. In fact, the authors stated that “team-teaching was the most dramatic and unusual aspect of our course design” (p. 584). The instructors’ acknowledgement of the peculiarity of team-teaching in a university-level mathematics classroom resounds with the larger issue of a lack of communication and collaboration between mathematicians and MTEs.

Grassl and Mingus (2007) used written evaluations and interviews as sources of information to better understand the students’ viewpoints on the collaboration. Unfortunately, the instructors were the ones to conduct the interviews, and therefore it is likely student responses were biased due to the power structures between interviewer and interviewee. Notwithstanding this limitation, the results from the evaluations and interviews indicated students benefitted from their instructors’ engagement in team-teaching because they could (a) see contrasting perspectives on and styles of instruction, (b) hear alternative explanations about course content, (c) experience the presence of a female instructor, which tended to soften the tone of the typically male-instructed mathematics classroom, and (d) engage in a “family-like atmosphere” (p. 584).

From the instructors' perspectives, the benefits of team-teaching included (a) the ability of one instructor to focus attention on students' reactions while the other instructor was the lead, (b) the skill of the MTE in addressing common student misconceptions, and (c) the skill of the mathematician in ensuring a strong content focus. Moreover, the incorporation of collaborative group work and inquiry-based instructional strategies was something the mathematician had not implemented in his classes prior to the collaboration with the MTE. As a result of this change to the course design, an additional benefit was that pre-service teachers (who constituted 75% of the class population) were able to "experience first-hand the types of classroom atmosphere and strategies they will be expected to implement in their teaching" (Grassl & Mingus, 2007, p. 591).

Throughout the article, Grassl and Mingus (2007) provided information about the different roles each instructor played within the context of the classroom, highlighting the MTE's role in identifying student misconceptions, encouraging classroom discourse, and designing activities for group work, and the mathematician's role in leading class lectures and ensuring a strong content focus. However, they provided no information about the way they planned for courses or worked collaboratively on assessment for the course. Moreover, there was no discussion about the content-based or pedagogical similarities or differences that arose between them. After reading this article, I am still left with many questions about the process and dynamics of the instructors' collaboration. Although the article provided an informative description of the classroom interactions and the potential benefits of team-teaching in an upper-level mathematics course, it provided little insight into how the instructors navigated their collaborative experience.

*Team-teaching in a freshman calculus course.*

In their article, provokingly titled, “Mathematicians Are from Mars, Math Educators Are from Venus: The Story of a Successful Collaboration,” Sultan and Artzt (2005), a male mathematician and a female MTE, respectively, wrote about their experiences team-teaching a first-semester university calculus course. Artzt had invited Sultan to join her in working on an NSF-funded “Teaching Improvement through Mathematics Education” grant, in which high school seniors were recruited into a preparation program for mathematics teachers. Because their university had not been overly successful retaining students interested in teaching mathematics, Artzt believed changes were needed in the initial courses for mathematics majors so that students would not leave the major early on. In this article, Sultan and Artzt provided first-person reflective accounts of their experiences working together to improve the entry-level calculus course at their institution.

In their team-teaching collaboration, Sultan and Artzt (2005) worked together closely to plan the course; however, the actual classroom teaching was conducted solely by Sultan, the mathematician, while Artzt sat in the classroom and observed. The two instructors agreed Artzt’s role in the classroom would be twofold: (1) she would speak up when she believed students had questions or misconceptions about the topics under consideration during class, and (2) she would observe Sultan’s instruction and make suggestions (during instructor meetings) about how he could modify his typically lecture-style approach to a more student-centered instructional approach. For example, when Sultan wanted to revert back to his lecture-style of instruction, Artzt suggested he ask questions to draw on students’ prior knowledge rather than provide definitions up front.

In addition, when Sultan got stuck in one of his class discussions because the students had no response to his question, Artzt suggested he have the students work together in small groups to discuss the question and share ideas with one another. In this way, Artzt's role could be viewed as a consultant more so than as a partner-teacher.

Sultan, who had been teaching mathematics courses for many years, did not initially see a need to change his pedagogical style, but felt he lacked a connection to his students, and believed that by taking Artzt's advice about modifying his instruction, he might be able to better engage his students and keep himself more engaged in the teaching process at the same time. He explained his early hesitancy towards engaging in this project, his initial understanding of his modified role in the classroom, and his reliance on Artzt for support:

The students felt special that they were in this program and were very enthusiastic about beginning. I, on the other hand, was really quite nervous about this new method of instruction. It was to be student based. I was to try to let the students discover the concepts, and my main role was to be a facilitator. I was not supposed to give them all the answers. They had to do all the discovery, and I had to make the mathematics relevant. And Alice [Artzt] would be sitting in on all my classes to help me do it. (p. 52)

After the first class session in which Sultan used inquiry-based methods of instruction, he was amazed to find students demonstrated such a wide range of sophistication in their understandings of basic mathematical notions (e.g., with respect to the graph of the speed of a falling object), notions of which Sultan had previously assumed his students had a good understanding. He discovered how much of students'

understanding (or misunderstanding) is hidden when the instructor conducts lecture-style instruction, explaining,

What happened to me was somewhat of a revelation. I thought the question was straightforward. When I saw the variety of answers, it suddenly dawned on me, that when I normally taught, I pretty much had in mind that most of the class had one sense of things: my sense! (p. 50)

Sultan's reflections made it clear that through his engagement in this collaboration with Artzt, he learned a great deal about pedagogy and student learning, and was also able to provide a more exciting, engaging, and thought-provoking environment for his students. Although there were many successes that resulted from Sultan and Artzt's collaboration, the two instructors also experienced moments of great frustration.

One of the most frustrating obstacles for the two instructors was the sacrifice of content coverage in exchange for inquiry-based, collaborative class discussion. Sultan found that with each classroom activity or inquiry-based discussion, he was falling further behind in the scheduled curriculum, and became frustrated because he viewed it as his responsibility to prepare the students for the next course in the calculus sequence. Likewise, Artzt was frustrated because she believed in the inquiry-based methods she was promoting to Sultan, but knew that with the content coverage cloud hovering over Sultan's head, he would never fully buy into her approaches. In this regard, the two instructors decided they would need to make a compromise. As Sultan explained "I would try as much as was practical to make the course student centered, but she had to

trust my judgment that when it was time to move on, I be allowed to move on” (p. 52). In the end, this compromise seemed to work out well for the two collaborators.

In the conclusion of their reflective article, Sultan and Artzt (2005) highlighted the importance of trust, respect, and the willingness to change as important contributing factors for a successful collaboration. Furthermore, they acknowledged the complexity of the process of collaboration itself, “If there is one thing that we have learned it is that collaboration is a complex process, and the key word is ‘process’” (p. 53). Sultan and Artzt’s realization of the complexity involved in their collaboration as a mathematician and a MTE lends credence to the importance of further empirical investigations into the dynamics of such collaborations.

#### ***Team-teaching in a geometry course for PSMTs.***

The last reflective account related to team-teaching between mathematicians and MTEs I reviewed is from a team-teaching collaboration of which I was a part. In a book chapter to be published in the 2012 NCTM Yearbook, *Professional Collaborations in Mathematics Teaching and Learning: Seeking Success for All*, Thompson, Beneteau, Kersaint, and Bleiler (in press), a female MTE, female mathematician, female MTE, and female doctoral student studying mathematics education (myself), respectively, reflected on their experiences participating in a team-teaching collaboration in a geometry course required of PSMTs. In the article, each of the four authors reflected on their individual experiences as part of the team.

Aside from working together to create course schedules that avoid conflicts for PSMTs who take courses in both the mathematics and education departments, mathematicians and MTEs at the institution in this study had not historically engaged in

much collaboration. Recently, several grant opportunities provided venues for greater discussion and collaboration between members of the two departments. This particular teaching team was funded through the NSF-funded KnoTSS (Knowledge for Teaching Secondary School) grant.

Thompson and Beneteau were the two instructors of the course, sharing responsibility for planning, teaching, and assessment. Kersaint and Bleiler observed during all class sessions, and participated in weekly course planning meetings. The instructors had several key objectives for the geometry course. In particular, they believed PSMTs should:

- (a) Learn mathematics using inquiry-based approaches as recommended by the mathematics education community (e.g., Martin, 2007; NCTM, 2000);
- (b) reason about and make sense of mathematics for themselves, often within a structure of collaborative groups;
- (c) write mathematical proofs, and use the language of mathematics appropriately. (Thompson et al., in press)

The use of inquiry-based approaches, the utilization of collaborative group work, and the emphasis on communication and language were not typical features of mathematics content courses at this institution, and therefore, much of the focus of the individual reflections from the four authors were related to the innovative nature of this course, and what they learned from engaging in their collaborative “learning community” (p. 1). Across the four reflections, the authors found several commonalities that characterized what they had learned through their collaborative work.

For one, Thompson et al. (in press) cited the importance of taking time to develop trust and respect amongst team members. In particular, the two co-instructors explained they needed time to build trust regarding each others' willingness to engage in the others' area of expertise, stating,

Catherine [Beneteau] needed time to recognize that Denisse [Thompson] was both mathematically competent and interested in engaging in the mathematics.

Denisse needed time to realize that Catherine was willing to try different pedagogical strategies, even if she was not sure they would work. (p. 16)

They also found team-teaching was instrumental in supporting an inquiry-based classroom environment (cf. Anderson & Speck, 1998). Through their engagement in inquiry-based instruction in a mathematics content course, the team members believed they grew in their own professional development. For example, the mathematician learned what "constructivism" was and how to employ some pedagogical strategies to encourage an inquiry-based classroom. The MTEs realized the challenges of covering the required content of a mathematics course while at the same time maintaining an inquiry-based approach to instruction.

Some of the challenges to collaboration included (a) the extreme time commitment required to plan a team-taught course, (b) the sacrifice of personal space within the classroom, as both instructors were accustomed to teaching alone, and (c) the development of shared meanings in relation to terminology common to one community and not the other (e.g., educational acronyms such as NCTM) as well as the development of shared meanings in relation to course objectives. Although both the time commitment and the need to develop shared meanings were a challenge for this team, they

acknowledged that the time spent discussing and planning the course led to significantly more reflection than typically occurs in a solo taught course. They found this to be particularly valuable in terms of their professional development.

The reflective accounts portrayed in Thompson et al. (in press) provided an initial look into the meanings members of a teaching team attributed to their collaborative work. Moreover, their account provided valuable insights into the affordances and constraints of team-teaching within the context of mathematics teacher preparation. I believe it is crucial to now take these types of reflective accounts and use empirical methods, informed by specific theoretical and methodological lenses, to bring an even deeper understanding of the collaborative process to light.

*Analysis of the four team-teaching reflective accounts.*

The four reflective accounts I have reviewed in the sub-sections above demonstrated the wide variety of logistical configurations “team-teaching” can take within the context of mathematics teacher preparation. In Table 1, I use Davis’ (1995) framework to rank the four team-teaching collaborations as “higher” or “lower” in their degree of collaboration along the four continua of (a) content integration, (b) planning, (c) teaching, and (d) evaluation. I have based these rankings only on what was reported in the articles I reviewed.

Table 1

*Degree of Collaboration Along Four Continua within Four Mathematician/MTE Team-Teaching Collaborations*

|  | Content Integration |       | Planning |       | Teaching |       | Evaluation |       |
|--|---------------------|-------|----------|-------|----------|-------|------------|-------|
|  | Higher              | Lower | Higher   | Lower | Higher   | Lower | Higher     | Lower |
| Heaton & Lewis (2011): Math Semester for Elementary Teachers |                     | x     | x        |       |          | x     | x          |       |
| Grassl & Mingus (2007): Abstract Algebra                     |                     | x     | x        |       | x        |       | N/A        |       |
| Sultan & Artzt (2005): Freshman Calculus                     |                     | x     | x        |       |          | x     |            | x     |
| Thompson et al. (in press): Geometry for PSMTs               |                     | x     | x        |       | x        |       | x          |       |

First, note that I ranked all four partnerships as “lower” on the content integration continuum. In following Davis’ (1995) characterization of content integration, this ranking seems appropriate. Davis explained,

In courses with a lower level of content integration, faculty members bring their subject into the planning process and eliminate some of it so as to allow other colleagues to teach some of *their* subject. Certain trade-offs are made and a serial order of presentations is established. If higher levels of content integration are to

occur, that is, if a type of content integration is to take place that more nearly approximates the ideal, a very different and more complicated process must take place. The faculty will be obliged to invent a new subject, not just present the old subject in a different form. (p. 48)

All four of the team-teaching partnerships were focused on teaching mathematics courses using novel instructional approaches. None of the authors seemed to suggest that they aimed to teach a new subject, but rather that they hoped to provide a model of mathematical instruction that resonated with the findings from educational research about best pedagogical practices. Of course, this characterization of “content integration” becomes a little messy when the expertise of one of the team members is itself pedagogy. In that sense, the lines become blurred with respect to how one might characterize content integration; however, for the purposes of this table, I followed Davis (1995) in the strictest sense.

I ranked all four teams as “higher” on the planning continuum. It seemed the teams found planning to be a particularly important part of their experiences in collaboration. As expressed by the mathematician in Thompson et al. (in press) in regards to the team’s planning sessions,

One of the things I most enjoyed about the collaboration was the preparation for class. We each reviewed the mathematics in the sections we planned to cover before our meeting, shared ideas about what concepts were important, and brainstormed about how they should be taught and the activities we might incorporate.... I found the mathematical and pedagogical challenges of the preparation intellectually stimulating. (p. 6)

I ranked both Heaton and Lewis (2011) and Sultan and Artzt (2005) as “lower” on the teaching continuum of collaboration. Heaton and Lewis taught separate courses, the mathematician teaching the content course and the MTE teaching the pedagogy courses within a Mathematics Semester for elementary teachers. Sultan and Artzt (2005) described a team-teaching collaboration in which the mathematician acted as the course instructor, and the MTE acted as an observer/consultant in the background. Therefore, neither of these two partnerships entailed high degrees of collaboration in the actual classroom teaching. On the contrary, Grassl and Mingus (2007) described the active involvement of both instructors during all class sessions, with the mathematician presenting lectures and ensuring content focus, and the MTE focusing on student misconceptions and communication. Similarly, Thompson et al. (in press) described a high degree of collaboration between the two co-instructors in their classroom teaching. In fact, the co-instructors created notes for each class session outlining who would be responsible for each segment of instruction, with the goal of sharing equally the instructional responsibilities in the classroom.

Finally, along the evaluation continuum of collaboration, I ranked Sultan and Artzt (2005) as “lower.” Although Sultan and Artzt do not make explicit reference to their grading procedures, it was clear through reading their article that the MTE provided most of her “consulting” advice with respect to the planning and delivery of the course; there was no mention of the MTE’s role within evaluation of the course assignments. Grassl and Mingus (2007) provided no information about their evaluation procedures, and although each instructor was responsible for office hours, and the implicit message throughout the article implied that each instructor shared responsibility for all course

activities, I did not feel comfortable ranking their degree of evaluative collaboration as either lower or higher.

I ranked the remaining two teams as “higher” on the evaluation continuum. Heaton and Lewis (2011) made explicit reference to the joint course assignments (across the mathematics and pedagogy courses in their program) for which both instructors worked collaboratively to grade. Likewise, the two co-instructors in Thompson et al. (in press) engaged in close collaboration in evaluation, noting,

[the two instructors] fully participated in grading the PSTs’ [preservice mathematics teachers’] work. Although grading of assignments alternated between instructors, they discussed the graded papers and made any adjustments before returning assignments. This shared responsibility for grading gave each instructor ownership of the course and was key to the collaboration being significant. (p. 5)

In summary, it is clear these four team-teaching collaborations differed significantly in their logistical considerations. Despite the sometimes drastic differences in the team configurations, each of the teams reported success in both student learning and faculty professional development. Anderson and Speck (1998) would attribute this success to the emphasis on constructivist learning principles that resulted from each of the four collaborations. In fact, several of the teams mentioned this phenomenon explicitly in their articles. For example, in Thompson et al. (in press), I wrote, “I believe this type of [inquiry-based] classroom environment was successfully cultivated as a direct result of our collaboration. Our differing levels of experiences as teachers, mathematicians, and teacher educators contributed to the variety of perspectives through

which we viewed the course” (p. 13). Grassl and Mingus (2007) described the reaction of one of their students in response to his ability to experience learning about constructivism through seeing it “in action” (p. 592). The student recognized that “it was one thing to talk about a particular method of teaching students and another to experience that method in context as a student” (p. 592).

In comparing the teams across Davis’ (1995) four continua of interdisciplinary collaboration, I intended to clarify the contextual factors of such collaborations. As I will discuss when I present my conceptual framework (see “Conceptual Framework” below), I position the learning that occurs as a result of such collaborations (learning by students and by instructors) within a situated perspective (Lave & Wenger, 1991), and therefore, by clarifying the contextual and situational aspects of the team-teaching configurations, I believe we can gain greater insight into the meanings team members attribute to their collaborative work.

### **Conceptual Framework**

My review of the literature in Chapter 2 has indicated that prospective mathematics teachers need teacher preparation programs that prepare them to integrate knowledge of content and pedagogy and provide experiences for them to learn mathematics in ways that they will be expected to teach the subject. Calls for collaboration between mathematicians and MTEs are prominent throughout the literature as a suggested means of both creating and optimizing opportunities for prospective teachers to make connections between content and pedagogy. However, research on prior collaborations between mathematicians and MTEs has focused primarily on the products rather than the processes of collaborative efforts. A small selection of reflective

articles related to team-teaching between mathematicians and MTEs has provided some initial insight into the collaborative process; however, none of these accounts have been analyzed using empirical research methodologies. In this regard, I have conducted an interpretative phenomenological case study of a team-teaching collaboration between a mathematician and a MTE as a means to shed light on the nature and process of collaboration between members of the mathematics and mathematics education communities.

Interpretative phenomenological analysis (IPA), my proposed methodological framework, is based on three theoretical tenets: (a) phenomenology, (b) hermeneutics, and (c) idiography. In Chapter 3, I discuss each of these in greater detail. In the remainder of this chapter, I explain how I will use the situated learning perspective (Lave & Wenger, 1991) as a theoretical lens to guide the design, implementation, and interpretation of the proposed study, making connections to the salient issues I have reviewed from the literature in this chapter. I begin by providing an overview of the situated learning perspective. I conclude by drawing connections between the literature I reviewed in this chapter and possible interpretations of that literature through the situated learning perspective. In Chapter 3, I provide an argument for the compatibility of the theory of situated learning and IPA.

### **The situated learning perspective.**

Many authors have elucidated the meaning of the situated learning perspective by contrasting its goals with that of the cognitive learning perspective. For example, Lave and Wenger (1991) explained that whereas the cognitive view of learning focuses on the internalization of knowledge structures, suggesting that “knowledge is largely cerebral”

and that learning is “a matter of transmission and assimilation” (p. 47), the situated perspective focuses on “learning as increasing participation in communities of practice” (p. 49) and that knowledge is therefore “socially negotiated” (p. 50).

Similarly, Greeno (1997) explained, “In the cognitive perspective, learning and development are viewed as progress along a trajectory of skills and knowledge...Alternatively, in the situative perspective, learning and development are viewed as progress along trajectories of participation and growth of identity” (p. 9). Finally, Cobb and Bowers (1999) used metaphors to describe the assumptions underlying the two perspectives. In the cognitive perspective they described “knowledge as an entity that is acquired in one task setting and conveyed to other task settings” (p. 5), and in the situated perspective they described “knowing as an activity that is situated with regard to an individual’s position in the world of social affairs” (p. 5).

The situated learning perspective positions learning “squarely in the processes of coparticipation, not in the heads of individuals” (Hanks, 1991, p. 13). In this sense, an individual’s learning relies on the social situations in which he or she engages, and his or her learning (or meaning-making), is demonstrated through successful participation in such social situations. Learning in the situative perspective is “situated, social, and distributed” (Putnam & Borko, 2000, p. 5). The most important theoretical premise that characterizes the situative perspective is that “meaning, understanding, and learning are all defined relative to actional contexts, not to self-contained structures” (Hanks, 1991, p. 15).

It is important to clarify that the “situation” as conceived by proponents of the situated learning theory is not limited to the physical, contextual situation in a strict

sense, but comprises what Lave and Wenger term “legitimate peripheral participation” (p. 29). Legitimate peripheral participation encompasses the interconnectivities between individuals, communities, activities, and physical objects. I find van Manen’s (1990) conceptualization of what it means to be situated in our lifeworld to be particularly illuminating in attempting to understand legitimate peripheral participation; he explained, “the experiences of lived time, lived space, lived body, and lived human relation” (p. 18) are all key components of our situated experiences in the world. That is, an individual’s situatedness does not rely only on the physical space in which he or she resides, but also on the time, body, and relationships through which he or she participates.

In the following section, I draw connections between the situated learning perspective and how it might be used to interpret some of the findings from the research I have reviewed in this chapter and to inform the design of my study.

### **Interpreting my review of the literature through the situated learning perspective.**

In the first section of this chapter (i.e., The Professional Preparation of Secondary Mathematics Teachers), I found that although historically PSMTs have been prepared almost primarily in mathematical content (through enrollment in upper-level university mathematics courses), research shows content knowledge is necessary, but not sufficient in order to be an effective mathematics teacher (Begle, 1972; Monk, 1994). In addition to developing content knowledge, teachers need to (a) engage in tasks that help them “decompress” mathematics and integrate pedagogy (Adler & Davis, 2006; Ball & Bass, 2003), (b) learn mathematics in ways that help them draw connections to the mathematical content they will teach at the secondary level (Hodge et al., 2010; Kahan et

al., 2003; NMAP, 2008), and (c) be able to reconcile differences between the pedagogical techniques used in their mathematics courses as compared to those espoused as best practices in their pedagogy courses (Ferrini-Mundy & Findell, 2001).

PSMTs have progressed through their typically lecture-focused, teacher-centered educational experiences, serving in an “apprenticeship of observation” (Lortie, 1975), and therefore have obtained little to no experience participating in contexts that exemplify inquiry-based, student-centered instructional approaches. Therefore, under the situated perspective, one might posit that if PSMTs are presented with an opportunity to think about and engage in activities that integrate content and pedagogy within their university mathematics courses, they would be better prepared to integrate this knowledge in future social interactions, such as in their future classrooms. In effect, this theory provides a rationale for why teachers need to experience learning reform mathematics “in situ”, not just abstractly within their methods courses (Korthagen, 2010; Putnam & Borko, 2000).

In addition, PSMTs’ years of experience as observers in classrooms has provided them with insight into the processes of teaching that occur within the classroom but has kept hidden many of the peripheral and backstage elements of teaching that are important in order to fully understand and be effective as members of the professional teaching community (Lortie, 1975). Preves and Stephenson (2009) demonstrated that team-teaching often actuates a classroom context in which many of the typically backstage moments of teaching come front-stage due to instructors’ verbal exchanges about pedagogical decisions in front of their students. Therefore, the situated learning perspective would posit that PSMTs’ participation within a course taught by two

instructors could provide them with further insight into the oftentimes hidden aspects of the teaching profession.

In the second section of this chapter (i.e., Collaborations between Mathematicians and MTEs), I found most prior studies related to collaborative efforts between these two communities have focused on the products of collaboration, rather than the actual dynamics of collaboration. I have argued throughout the chapter that in order to learn from these collaborative efforts, we must know about the situated perspectives, understandings, and meanings of individuals as they interact within these particular collaborative contexts.

In my review of the literature, I identified key differences between mathematicians and MTEs in relation to (a) epistemology (Goldin, 2003; Nardi, 2008; Ralston, 2004), (b) cultural norms (Nardi, 2008; Nardi et al., 2005; Burton, 2004), and (c) communication and language use (Burton, 2002; Nardi, 2008; Thompson et al., in press). The communities of mathematics and mathematics education could be conceived as “communities of practice,” (Wenger, 1998) or “discourse communities” (Putnam & Borko, 2000, p. 5), and “these discourse communities provide the cognitive tools—ideas, theories, and concepts—that individuals appropriate as their own through their personal efforts to make sense of experiences” (p. 5). Therefore, when considering the experiences of Dejan and Angela, it will be essential to draw on their perceptions and identities as members of their respective communities in mathematics and mathematics education, and attend to potential differences in their epistemology, cultural norms, or language use.

Finally, in the third section of this chapter (i.e., Team-teaching), I found that through team-teaching, instructors tended to experience success in their development as professionals. Because the team-teaching context encourages reflection, discussion, and collaboration between partners, the situated learning perspective would posit that this “distribution of cognition” (Borko & Putnam, 2000, p.5) across team members explains the attainment of professional advancement amongst co-instructors. As explained by Borko & Putnam (2000),

The notion of distributed cognition suggests that when diverse groups of teachers with different types of knowledge and expertise come together in discourse communities, community members can draw upon and incorporate each other’s expertise to create rich conversations and new insights into teaching and learning. (p. 8)

This perspective is also in alignment with the theory posited by Anderson and Speck (1998) that instructors collaborating on a teaching team tend toward a classroom environment characterized by discussion, openness to multiple perspectives and contrasting ideas, “dispersion of authority” (p. 681), and collaborative work amongst teachers and students. Because instructors in a teaching team naturally model the social and distributed aspects of cognition (both of which are situated in the context of their classroom community) as they engage in collaborative teaching, the situated perspective would posit that students, as active participants in that classroom community would also begin to share in the social and distributed aspect of knowledge construction that began with the instructors. In this sense, the dynamics between instructors affect the dynamics

of the classroom community as a whole, thus explaining why team-teaching situations frequently lead to increased student learning.

In summary, I will use the situated learning perspective as a theoretical lens to guide the design, implementation, and interpretation of this study. I assume that learning, meaning, and understanding are situated in communities of practice, and that through engagement in these communities, individuals develop and evolve. As Lave and Wenger (1991) explained, “Knowing is inherent in the growth and transformation of identities and it is located in relations among practitioners, their practice, the artifacts of that practice, and the social organization and political economy of communities of practice” (p. 122). From this perspective, learning and meaning are situated within communities of practice. Therefore, in order to understand the meaning making of Dejan and Angela during their team-teaching experiences, I will pay particular attention to their understandings and identities as members of their respective communities of practice in mathematics and mathematics education.

### Chapter 3: Method

Qualitative research methodologies do not rely on strict, prescribed research steps, but instead are characterized by certain “ways” of coming to know through iterative cycles of deep engagement with the data (Smith et al., 2009; van Manen, 1990). In this study, I was guided by the tenets of interpretative phenomenological analysis (IPA), which has its roots in phenomenology, hermeneutics, and idiography (see “Rationale for Using Interpretative Phenomenological Analysis” below for an extended discussion of these three theoretical tenets). In my methodological approach, I follow the spirit of van Manen (1990) who explained,

the methodology of phenomenology is such that it posits an approach toward research that aims at being presuppositionless; in other words, this is a methodology that tries to ward off any tendency toward constructing a predetermined set of fixed procedures, techniques, and concepts that would rule-govern the research project. And yet, it is not entirely wrong to say that phenomenology and hermeneutics as described here definitely have a certain *methodos*—a way. (p. 29)

As van Manen (1990) proceeded to explain, researchers learn about the “way” of phenomenological methods through their engagement with research that provides insights into the history and traditions of the approach. As the researcher in this study, I recognize the importance of engaging in the current literature and the research communities that are “doing” interpretative phenomenological work. Therefore, I draw

on my close reading of texts, such as van Manen's (1990) *Researching Lived Experience* and Smith et al.'s (2009) *Interpretative Phenomenological Analysis*, as well as my engagement in a particularly insightful workshop about phenomenology I attended at the University of Georgia on June 9-10, 2011, which was offered by Dr. Mark Vagle. From my experiences with these texts and communities of practice, I have gained a greater awareness of the *methodos* (van Manen, 1990) that affords access to a deep understanding of lived experience. In this chapter, I describe the methods I employed to gain access to the lived experiences of Dejan and Angela as they engaged in team-teaching.

### **Purpose of the Study**

The purpose of this interpretative phenomenological case study was to gain an understanding of the lived experiences of a mathematician and a MTE as they engaged in a team-teaching collaboration within the context of prospective secondary mathematics teacher preparation. Participants in the team-teaching collaboration in this study were a mathematician (Dejan) and a MTE (Angela) who worked together to plan, implement, and assess PSMTs enrolled in a mathematics content course (Geometry) and a mathematics methods course (Teaching Senior High School Mathematics) during the Fall 2010 and Spring 2011 semesters, respectively.

The following research question served to guide the inquiry:

- In what ways do a mathematician (Dejan) and a MTE (Angela) make sense of their experiences engaging in a team-teaching collaboration within a mathematics content course (Geometry) and a mathematics methods course (Teaching Senior High School Mathematics) for PSMTs?

The following sub-questions serve to highlight specific aspects of Dejan and Angela's team-teaching experiences, and in turn provide insight into the overarching question stated above:

1. In what ways do Dejan and Angela make sense of their similarities or differences in relation to their perceptions of teaching and learning?
2. In what ways do Dejan and Angela make sense of their roles within the team teaching collaboration?
3. What do Dejan and Angela perceive as the affordances, if any, of their experiences in the team-teaching collaboration?
4. What do Dejan and Angela perceive as the constraints, if any, of their experiences in the team-teaching collaboration?

### **Research Design**

I employed an interpretative phenomenological case study design (Smith et al., 2009) to examine the ways Dejan and Angela made sense of their experiences engaging in a team-teaching collaboration. The case study can be described as instrumental (Stake, 1995) because one of my primary goals was to explore a broad issue (i.e., collaboration between mathematicians and MTEs in the context of preservice teacher education) using a specific case (i.e., a team-teaching collaboration between a mathematician and an MTE) to illustrate the issue, rather than to explore the case for its intrinsic value alone.

To explore this case, I analyzed data from the Knowledge for Teaching Secondary School (KnoTSS) NSF DR K-12 grant (#0821996), a project developed to examine the nature and process of team-teaching collaborations between mathematicians and MTEs at several sites across the United States. The original intent of the KnoTSS study, as

conceptualized by its principal investigator Dr. Rebecca McGraw at University of Arizona, was to conduct qualitative analyses (including discourse analysis) of the dialogues between collaborating mathematicians and MTEs during their team-teaching experiences, in order to better understand the nature and process of collaborative work. This study focuses on only one of the KnoTSS team-teaching partnerships (Dejan and Angela's). Moreover, my study differs from the larger KnoTSS project in that I employ an interpretative phenomenological lens to gain a deeper understanding of Dejan and Angela's perceived experiences throughout their collaboration.

### **Rationale for Using Interpretative Phenomenological Analysis**

I used IPA as a methodological framework to guide my data collection and analysis (Smith et al., 2009). IPA is a qualitative research approach originated in the field of psychology based on three theoretical tenets: (a) phenomenology, (b) hermeneutics, and (c) idiography.

Phenomenology, the first theoretical tenet of IPA, is concerned with the study of lived experience. Edmund Husserl, who is considered the founding father of phenomenology, was interested in discovering the essence of a phenomenon, and even strived to understand the nature of consciousness as a person is engaged in experience (Smith et al., 2009). For the purposes of this research, and IPA research more generally, phenomenology is viewed and employed as a lens through which researchers can focus on the lived experience of individuals in a particular time and setting. Given that I am interested in understanding the lived experiences of a mathematician and a MTE as they progress through their team-teaching collaboration, the phenomenological lens is appropriate.

The second theoretical tenet of IPA is hermeneutics, the theory of interpretation (Smith et al., 2009). Although hermeneutics was originally conceived as the study and interpretation of important texts such as the Bible, its role in contemporary research is more broadly conceived to describe the interpretation of a wide variety of texts such as interview transcripts or spoken interactions in naturalistic settings (van Manen, 1990). IPA employs hermeneutics as a means to interpret the texts, which portray research participants' phenomenological experiences. As explained by Smith et al. (2009), "IPA is concerned with examining how a phenomenon appears, and the analyst is implicated in facilitating and making sense of this appearance" (p. 28). Therefore, as the qualitative researcher in this study, my role is to attempt to make sense of Dejan and Angela's lived experiences within their team-teaching collaboration and at the same time recognize that Dejan and Angela themselves are attempting to make sense of their own experience. Therefore, a "double hermeneutic" (Smith et al., 2009, p. 3) forms the basis of this study.

Finally, the theoretical tenet of idiography serves as another major influence for IPA research. Idiographic study, as opposed to nomothetic study, is concerned with uncovering the particularity of a specific phenomenon. With an emphasis toward particularity, rather than generalization, IPA is concerned with providing thick, rich description of the phenomenon under study as well as situating that description within the perceived experience of particular individuals in specific contextual settings (Smith et al., 2009). In this study I provide an in-depth look into one particular case of a team-teaching collaboration, and hence the inquiry is supported by an idiographic epistemology.

### **IPA compared to more traditional approaches to phenomenology.**

In comparison to more traditional approaches to phenomenology (e.g., Husserl, 1970; van Manen, 1990), in which phenomenological research is conceptualized as “the study of the lifeworld—the world as we immediately experience it pre-reflectively rather than as we conceptualize, categorize, or reflect on it” (van Manen, 1990, p. 9), IPA is focused on lived experiences of individuals as those experiences are reflected on and interpreted by the individuals themselves. As explained by Smith et al. (2009), in conducting IPA research, “we are concerned with where ordinary everyday experience becomes ‘an experience’ of importance as the person reflects on the significance of what has happened and engages in considerable ‘hot cognition’ in trying to make sense of it” (p. 33).

There are subtle differences in analytic focus between traditional phenomenological approaches and the IPA approach. Smith et al. (2009) offered an example of the research questions and key features that characterize the two different approaches. For instance, if a traditional phenomenological researcher was interested in researching the phenomenon of anger, he or she might ask, “What are the main experiential features of being angry?” (p. 45) focusing on “the common structure of ‘anger’ as an experience” (p. 45). However, if an IPA researcher was interested in researching the phenomenon of anger, he or she might ask, “How do people who have complained about their medical treatment make sense of being angry?” (p. 45), focusing on “personal meaning and sense-making in a particular context, for people who share a particular experience” (p. 45).

In this study, the practices of teaching (i.e., planning, instruction, and assessment) can be considered ordinary experiences for Dejan and Angela. However, these ordinary experiences took on a particular significance as extra-ordinary when Dejan and Angela decided to engage in them collaboratively. I attempted to capture Dejan and Angela's active meaning-making of these experiences by engaging them in reflective interview conversations.

### **Compatibility of IPA and the situated learning perspective.**

In Chapter 2, I described the situated learning perspective, and illustrated how I would utilize it as the theoretical lens through which I design, implement, and interpret the results from my study. I believe the situated learning perspective is consistent with the theoretical tenets of IPA. In contrast to the cognitive learning perspective, which positions learning and knowledge inside the mind of an individual, the situative perspective positions knowledge within the social interactions and experiences of individuals engaged in activity. Therefore, the situated perspective would naturally lend itself to phenomenological approaches to research since

one of the basic moves of such approaches [e.g., phenomenology] has been to question the validity of descriptions of social behavior based on the enactment of prefabricated codes and structures. Instead, the focus on actors' productive contributions to social order has led naturally to a greater role for negotiation, strategy, and unpredictable aspects of action. (Hanks, 1991, p. 16).

Moreover, van Manen (1990) suggested "phenomenological research finds its point of departure in the *situation*, which for purpose of analysis, description, and interpretation functions as an exemplary nodal point of meanings that are embedded in

this situation” (p. 18). Therefore, in exploring the lived experiences (phenomenology) of Dejan and Angela as they are situated within a particular team-teaching collaboration in the context of secondary mathematics teacher preparation (idiography), I use the situated learning perspective as the theoretical lens to guide the design, implementation, and more specifically the interpretation (hermeneutics) of my study.

### **Case Selection**

The team-teaching collaboration under study took place at a large public research university located in the Southeastern United States. The mathematics and mathematics education departments on the main campus have always been separate entities, in both location and university delegation. The mathematics department resides on the west side of campus and is part of the university’s College of Arts and Sciences. The mathematics education department resides on the east side of campus and is part of the university’s College of Education.

In the past, the extent of collaboration between mathematicians and MTEs at this institution has been limited to discussions about course scheduling in efforts to avoid conflicts in the schedules of prospective teachers who take courses in both departments. Within the past five years, Angela was awarded several grants that encouraged mathematics faculty to become involved in issues of K-12 education. Angela secured grant monies through the NSF-funded KnoTSS grant, and worked closely with the project’s Principal Investigator, Rebecca McGraw, to ensure the collaboration became a reality. Angela’s role as instrumental in the funding and organization of this team-teaching collaboration is important as it provides insight into issues of power that emerged within the instructors’ relationship. In Chapter 4, we will see that Dejan was

often willing to agree with many of the suggestions made by Angela, even though his perspectives and ideals may not have aligned with all of those suggestions. It is possible that Angela's role as the authority at this institution with respect to the grant-funded project could have influenced the dynamics between the instructors.

Dejan is a male mathematician who has taught in the mathematics department at this university for 15 years. He earned his pre-doctoral mathematics degrees in Europe, and then moved to the United States to earn his Ph.D. in mathematics. After earning his doctoral degree, Dejan began work at the institution in which he is currently employed. Some of the courses Dejan typically teaches include "service courses" such as Pre-Calculus and Calculus; courses for mathematics majors such as Topology and Modern Geometry; courses taken by mathematics majors as well as PSMTs such as Introduction to Linear Algebra and History of Mathematics; and the Geometry course at this institution that is catered specifically for a PSMT audience. His instructional style is self-described as teacher-centered, with the primary mode of instruction being lectures.

Angela is a female MTE who has taught in the mathematics education department at this university for 11 years. Angela earned all of her degrees in the United States. She earned an undergraduate degree in mathematics and a Master's degree in education. She taught high school mathematics for five years in a large urban school district, and then returned to graduate school to earn her Ph.D. in mathematics education. Angela earned her Ph.D. in an institution in which the mathematics education program was housed in the mathematics department. As a graduate student, she served as a teaching assistant in mathematics courses as well as methods courses for prospective teachers. After earning her doctoral degree in mathematics education, Angela was employed by the current

institution. Some of the courses Angela typically teaches include methods courses for PSMTs such as Technology for Secondary School Mathematics, Teaching Math in the Middle Grades, and Teaching Senior High School Mathematics; masters-level courses such as Current Trends in Elementary Mathematics and Current Trends in Secondary Mathematics; and doctoral-level research courses such as Research in Mathematics Education and Preparing Teachers of Mathematics. Her instructional style is self-described as student-centered, with the primary mode of instruction being inquiry-based.

Dejan and Angela taught together over the course of three semesters (Geometry in Spring 2010; Geometry in Fall 2010; Teaching Senior High School Mathematics in Spring 2011). My data collection and analysis are focused on the latter two semesters of their collaboration. With respect to Davis' (1995) framework for the degree of collaboration along the four continua of (a) content integration, (b) planning, (c) teaching, and (d) evaluation, I would rank Dejan and Angela's collaboration as "higher" along the planning, teaching, and evaluation dimensions, as the instructors each contributed substantially to these three aspects of the course. In keeping with the definition provided by Davis for content integration (see Chapter 2), I would rank Dejan and Angela's collaboration as "lower" on the content integration continuum in the same way as the four anecdotal accounts I reviewed in Chapter 2.

The selection of Dejan and Angela for this study makes use of what Flyvbjerg (2006) referred to as a paradigmatic sampling strategy. Flyvbjerg (2006) described paradigmatic cases as "cases that highlight more general characteristics of the societies in question" (p. 232), and that have "metaphorical and prototypical value" (p. 232). Before I began collecting data during the Fall 2010 and Spring 2011 semesters, I realized Dejan

and Angela could provide a valuable paradigmatic sample. Dejan and Angela demonstrated considerable differences in their ideas about the teaching and learning of mathematics, as evidenced by their first team-teaching collaboration in Spring 2010. Although I had not observed their collaboration in Spring 2010, I had numerous insightful conversations with both instructors about their collaborative experiences, and it was clear their contradictory perspectives on the teaching and learning of mathematics paralleled the salient literature in this area.

Moreover, I attended a workshop in May 2010, in which all the KnoTSS collaborative teams came together to discuss their team-teaching experiences from the previous year.<sup>3</sup> During this meeting, it was clear that among the four pairs of collaborative teams, Dejan and Angela exhibited the most polarized views of mathematics teaching and learning. Therefore, I selected their collaboration as a unit of analysis because I believed it would provide a rich source of data that serves as an exemplar of the possible interactions and dynamics of collaboration between members of the mathematics and mathematics education communities.

### **Data Collection**

In qualitative research, data triangulation helps to ensure credibility and verisimilitude (Patton, 2002; Stake, 2010). Moreover, it is particularly important in case study research to have a wide variety of data sources (Stake, 1995; Yin, 2003). Five

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<sup>3</sup> The KnoTSS collaboration meeting was held on May 18-19, 2010 in Ann Arbor, MI, and was organized by the Principal Investigator of KnoTSS, Rebecca McGraw. At the time, all of the collaborating teams had completed their two semesters of team-teaching except for Dejan and Angela. Dejan and Angela constituted the only team that would team-teach for three semesters (Spring 2010, before the Ann Arbor meeting, and Fall 2010/Spring 2011, after the Ann Arbor meeting).

sources of data, separated into “primary” and “secondary” sources, informed my analysis for this study. The primary data are (a) one-on-one interviews conducted with each instructor (two times each semester) and (b) group interviews with both instructors together (one time each semester). The secondary data are (a) field notes from observations within all class sessions and instructor planning sessions, (b) audio-recordings of all instructor planning sessions, and (c) video-recordings of class sessions (2.5 hours each semester).

IPA methodology aims to understand the lived experiences of participants as they actively reflect on those experiences. Therefore, I decided to use the individual and group interview transcripts as the primary source of data for this study because they contain the most prevalent instances of Dejan and Angela’s active reflection on their experiences. I used secondary data sources (i.e., observation field notes, audio-recordings of instructor planning sessions, and video-recordings of class sessions) to inform the interpretation of the primary data. As an example, the following extract from one of my analytic memos provides insight into the way in which my observation of instructor planning sessions influenced my analysis of Angela’s interview transcripts. This extract was written during the coding phase of my analysis as I pondered the development of the “acceptance vs. appeasement” conceptual code that was emerging from Angela’s data:

My original code here was labeled as "agreement vs. 'just going with it'" and I wanted to find a word that would capture "just going with it." I looked up the word agreement on Thesaurus.com and came upon "concession" or "concede," which seems to get at the "just going with it" aspect of Dejan's actions. My

observations from planning sessions are adding into my interpretation of this. From Angela's words alone, I probably could not move from "just going with it" to "concession" and then to "appeasement" without having firsthand experience of seeing what was actually happening during the collaboration. There were many times when Angela seemed to have a very good rationale for her pedagogy, and if Dejan questioned her use of that strategy, Angela always seemed to have a strong argument for her side. I feel as though this wore down Dejan sometimes, and because he did not have a strong argument for his pedagogy, he could not provide a counter-argument, and therefore decided to concede to (or appease) Angela. This caused tension in the collaboration, because even though Dejan conceded to Angela by claiming that he was in "agreement," his values and perspectives on teaching and learning were actually different and therefore in the class these differences came to bear. (S. Bleiler, CODE DEFINITION analytic memo, 12/04/11)

Another reason I believe it was important to draw on secondary data throughout my analysis was because of the implied understandings I shared with Dejan and Angela due to my extensive participation as a researcher in their collaboration. Because I had observed all of the class sessions and planning sessions, Dejan and Angela omitted certain contextual or background information from their interview responses because they naturally assumed I would understand their implied meaning. However, readers of my study were not so privileged and therefore I needed to draw on secondary data sources in order to clarify background/contextual information implied by Dejan and Angela.

## **Interviews.**

I conducted one-on-one interviews with each instructor at the beginning and end of each semester. Each one-on-one interview lasted approximately 30-45 minutes, and was conducted in the instructors' offices. In addition, I conducted group interviews with both instructors at the end of each semester, each of which lasted approximately 30-45 minutes. I designed all interviews in a semi-structured format, with a core set of questions used as the basis for each interview, but with flexibility built into the design for probing and follow-up questions. I audio-recorded each of the interview sessions on my Olympus VN-5200PC digital voice recorder, and I transcribed each of the interviews using Express Scribe software on my home computer.

I constructed the interview protocols with a working knowledge of the related literature and theory about the phenomenon under study; however, I would not characterize the questions as theory-driven. This is in line with the tenets of IPA, which commit to “exploring, describing, interpreting and situating the means by which our participants make sense of their experiences” (Smith et al., 2009, p. 40), rather than working from a priori categories or theoretical constructs.

During the interviews, I viewed the instructors as “conversational partners” (Rubin & Rubin, 2005, p. 14). That is, as the researcher I set the initial direction for the interview; however, I attempted to word questions in a broad, open-ended fashion so the instructors would feel comfortable answering as if they were in an informal conversation, able to pursue and elaborate on areas of the research topic that were most meaningful to them. I developed interview protocols to guide the content of the interview, and to allow myself (as the interviewer) to be free to listen attentively, as opposed to thinking about

what should be the focus of the next part of the interview. Consequently, I followed the advice of Smith et al. (2009) and recognized that occasionally as an interviewer truly engaged in listening to the participant, “it is preferable to abandon the structure [of the interview protocol] and to follow the concerns of the participant” (p. 64).

The interview protocols for the first and third one-on-one interviews (conducted at the beginning of each semester) were the same for both Dejan and Angela. The purpose of the first and third interviews was to gain an understanding of the goals and expectations of the instructors as they began each semester, and to begin to tap into the ways Dejan and Angela made sense of their similarities and/or differences in relation to their perceptions of teaching and learning (i.e., research question #1). In addition, the first interview protocol contained several questions in the categories of (a) educational background, (b) philosophies on the teaching and learning of mathematics, and (c) understanding of the team member’s discipline, that were intended to provide information to better describe and situate the case.

The interview protocols for the second and fourth one-on-one interviews (conducted at the end of each semester) were slightly different for each instructor based on the observations I made during the class and planning sessions throughout the semester (i.e., secondary data sources). The purpose of the second and fourth interviews was to provide a venue for Dejan and Angela to reflect (individually) on their experiences throughout the prior semester. In particular, I used the second and fourth interviews to dig deeper into how Dejan and Angela made sense of the roles they played within the team-teaching collaboration (i.e., research question #2).

I structured the interview protocols for the group interviews (conducted at the end of each semester) to provoke reflective dialogue between me and the two instructors about their experiences team-teaching throughout the semester. In particular, I used the group interviews to gain a deeper understanding of the perceived affordances and/or constraints of Dejan and Angela's experiences team-teaching (i.e., research questions #3 and #4). Moreover, the group interviews served as a venue for the instructors to reflect on their shared experiences (Crow & Smith, 2005). In Table 2, I summarize the major topics/purpose and timeline for each interview. All of the interview protocols can be found in their entirety in the Appendix.

### **Field observations.**

Creswell (2007) distinguished between five roles an observer can take within a qualitative research study; the researcher can: (a) observe as a participant, (b) observe as an observer, (c) observe as a participant more often than an observer, (d) observe as an observer more often than a participant, and (e) observe as an "outsider" at the beginning and then observe as an "insider" as time progresses. Throughout the data collection process of this study, I took on the fourth of Creswell's categories (i.e., observe as an observer more often than a participant). Although I acted as observer the majority of the time, there were several instances when I took on the role of participant, such as when Angela asked me to assist Dejan in classroom instruction on days when she would be absent because of obligations at professional conferences, when Dejan or Angela asked my advice (either mathematical or pedagogical in nature) during course planning sessions, or when students in either the Geometry or Teaching Senior High School Mathematics course approached me with questions related to their coursework. I do not

believe these instances hindered my position as a researcher in any way, and in fact, I believe they gave me an “insider view” of Dejan and Angela’s experiences.

Table 2

*Interview Schedule, Purpose, and Associated Research Questions of Interest*

| Interview # | Date of interview                   | Purpose  | Research Questions of Primary Interest |
|-------------|-------------------------------------|--|--|
| 1           | Dejan: 09/08/10<br>Angela: 09/02/10 | <ul style="list-style-type: none"> <li>• Overview of educational background</li> <li>• Philosophies on teaching and learning</li> <li>• Understanding of team member’s discipline</li> <li>• Goals and expectations for the collaboration in the Geometry course (Fall 2010).</li> </ul> | RQ #1                                  |
| 2           | Dejan: 12/08/10<br>Angela: 12/02/10 | <ul style="list-style-type: none"> <li>• Reflection on team-teaching in the Geometry course.</li> <li>• Reflection on goals and expectations elaborated in interview #1</li> <li>• Instructor roles</li> </ul>   | RQ #2                                  |
| 3           | Dejan: 01/25/11<br>Angela: 01/18/11 | <ul style="list-style-type: none"> <li>• Goals and expectations for the collaboration in the Teaching High School Mathematics course (Spring 2011)</li> </ul>  | RQ #1                                  |
| 4           | Dejan: 05/20/11<br>Angela: 05/23/11 | <ul style="list-style-type: none"> <li>• Reflection on team-teaching in the Teaching High School Mathematics course.</li> <li>• Reflection on goals and expectations elaborated in interview #3</li> <li>• Instructor roles</li> </ul>   | RQ #2                                  |
| Group 1     | 01/18/11                            | <ul style="list-style-type: none"> <li>• Reflective conversation between instructors about their experiences team-teaching the Geometry course.</li> <li>• Affordances/constraints</li> </ul>  | RQ #3, RQ #4                           |
| Group 2     | 05/19/11                            | <ul style="list-style-type: none"> <li>• Reflective conversation between instructors about their experiences team-teaching the Teaching High School Mathematics course.</li> <li>• Affordances/constraints</li> </ul>  | RQ #3, RQ #4                           |

### *Classroom observations.*

In this study, I observed and took field notes in all class sessions throughout the two semesters of the team-teaching collaboration. Observation data allow researchers to understand the research problem in greater depth than would be possible through key informants' insights alone (Patton, 2002). Therefore, although the primary focus of the proposed study is on Dejan and Angela's interpretation of their experiences during their team-teaching, I used the observation data to provide myself (the researcher) with a deeper understanding of the context within which Dejan and Angela worked together. Through an understanding of the context of the classroom environment, I felt better prepared to interpret Dejan and Angela's understandings of their experiences working together in the classroom.

The research on team-teaching has indicated conflicts between instructors on issues related to content and pedagogy often come to bear in front of the class (Preves & Stephenson, 2009; Robinson & Schaible, 1995). Therefore, during my classroom observations I found it useful to identify topics of conflict that arose during classroom instruction so I was able to ask Dejan and Angela to reflect on those experiences at a later time (e.g., in planning sessions or during interviews).

### *Planning session observations.*

Dejan and Angela met weekly for approximately two to three hours to plan their subsequent class session(s). I observed and took field notes during each of the planning sessions. Literature on team-teaching has indicated planning sessions are crucial to the success of such collaborations (Cruz & Zaragoza, 1998). It is through these planning sessions that instructors make explicit their goals and expectations for the course, and

attempt to uncover and resolve any disagreements before they arise in the classroom (Robinson & Schaible, 1995). I found that throughout the planning sessions, Dejan and Angela were particularly reflective, and attempted to make sense of their similarities, differences, and roles within the collaboration. Therefore, I referred back to the field notes throughout data analysis to inform my emergent interpretations of the primary interview data.

#### **Audio recording of planning sessions.**

Each planning session was audio recorded by Angela, uploaded to a secure, password protected website, and downloaded onto a password protected computer by a member of the KnoTSS research staff at University of Arizona in order to be transcribed. I used my observation field notes as the main source of data related to planning sessions. However, as I read through my observation field notes, there were times when my notes did not provide sufficient context/detail. In these cases, I referred to the transcriptions (transcribed by a member of the KnoTSS research team at University of Arizona) for a more detailed account of the instructors' exchanges.

#### **Video data of class sessions.**

I video recorded two and a half hours of classroom instruction during each semester of the collaboration using the mathematics education department's camcorder. During the Fall 2010 collaboration in the Geometry course, the video recording consisted of two consecutive class sessions (each lasting one hour and 15 minutes). During the Spring 2011 collaboration in the Teaching Senior High School Mathematics course, the video recording consisted of one class session (lasting two hours and 30 minutes). The video recordings did not serve as a primary data source. However, as I proceeded

through the stages of my analysis, and themes began to emerge from the data, I viewed the video recordings to inform my interpretation of the instructors' reflections and to revisit the contextual "realities" of the collaboration.

### **Researcher reflective journal.**

In qualitative inquiry, the researcher serves as the primary research instrument (Patton, 2002; Stake, 2010). Therefore, within the current study it was important for me to be aware of my own experiences, curiosities, and presuppositions. I recorded my thoughts, inclinations, and emerging interpretations during both the data collection and data analysis stages of this research. During data collection, I maintained a separate area within my field notes to record my personal reflections related to my role as the researcher, my initial understandings of the instructors' experiences, and questions/ideas I perceived as particularly relevant to the study. During data analysis, I devoted a specific category of analytic memos (see section on Analytic Memos below) to document my personal relationship to the issues in the study. Taken together, this collection of reflections from both the data collection and data analysis phases of the study constitute my research reflective journal. I frequently re-read and added to my written reflections throughout the inquiry, and found this valuable as means to keep track of my developing interpretations of Dejan and Angela's experiences.

### **Data Analysis**

As explained in the introduction to this chapter, researchers who employ phenomenological inquiry are guided by a focus on the phenomenon of interest, and therefore does not typically follow a strict set of steps or rules that guide the methodological process. Despite the flexibility of IPA, Smith et al. (2009) recognized the

need for a “heuristic framework for analysis” (p. 80) that could be used by researchers new to IPA (like myself) to structure their initial analytic approach. I utilized their step-by-step procedure (described below) as the guideline for my data analysis.

I used ATLAS.ti qualitative data analysis software to aid in the management of this four-step analytic process. The organizational interface for data analysis within ATLAS.ti is called a “hermeneutic unit.” Within a hermeneutic unit, I was able to keep track of primary documents (i.e., interview transcripts), codes, code families (i.e., emergent themes), quotations (i.e., extracts from instructor interviews), memos, and networks (i.e., organizational framework of codes and code families).

As recommended by Smith et al. (2009), I conducted the four-step analysis for each of the instructors’ interview transcripts independently. First, I conducted the analysis of Angela’s four individual interviews. When the entire analysis process for Angela’s individual interviews was complete, I began the analysis of Dejan’s four individual interviews within a new hermeneutic unit. Because I also had group interview data, I needed to make a decision about how to incorporate this data into the analysis. After completing the analyses of Angela and Dejan’s individual interviews, I merged the two hermeneutic units into a single file. That is, I created a single hermeneutic unit that contained the codes from the independent analyses of Dejan and Angela’s individual interviews. Within this merged hermeneutic unit, I began the four-step analysis of the two group interviews. The following extract from one of my analytic memos describes my rationale for this choice and the corresponding procedures I employed:

I contemplated whether I should start my analysis for the group interviews from scratch (i.e., with a blank coding slate), or whether I should code the group

interviews with existing codes from Dejan and Angela's individual analyses. After engaging in a thorough reading of the two group interviews, I see that so much of the discussion/reflection in the group interview was very similar to that in the individual interviews. Therefore, I think the group interviews could provide additional insight into my interpretation of existing codes, and that I could use the existing codes to add to the depth of my (and my readers') understanding of those codes/themes from the individual analyses. However, I will need to make sure that when something "new" arises in my analysis of the group interviews, I will add a new code and actively try to not be restricted by my findings from the individual interviews. My major goal in engaging in the analysis of the group interviews is to inform a broader perspective for my presentation of the instructors' experiences in Chapter 4, thinking primarily about the possible connections across the emergent themes from the individual interviews. I think/hope that some of the exchange between Dejan and Angela in these group interviews will provide insight into the ways Dejan and Angela make connections between their individual points of concern. (S. Bleiler, DAILY RECORD analytic memo, 01/01/12)

#### **Four-step analytic process.**

The first step of the IPA analysis procedure outlined by Smith et al. (2009) is called *reading and re-reading*. During this step, I immersed myself in the primary data by reading through the interviews I collected throughout the Fall 2010 and Spring 2011 team-teaching collaboration. A useful suggestion provided by Smith et al. (2009) was to listen to the audiotapes while reading through interview transcripts. I employed this

strategy and found it to be helpful in that I could attend to the subtle nuances of voice and tone that may have been lost in the typed transcripts alone. During this first step of the data analysis, I also used analytic memoing to write down any initial interpretations, so I could “bracket” (Smith et al., 2009, p. 82) them, and pay closer attention to the data as presented. This allowed me to acknowledge my inclinations and presuppositions, record them, and then attempt to focus on the data at a pre-interpretive level.

Once I read and listened carefully to the transcripts as a whole, I moved on to the second step, *initial noting*. During this step I conducted a close textual analysis in which I read the transcripts line by line, continued to write analytic memos, and assigned codes to meaningful segments according to the following three categories:

- *Descriptive* comments focused on describing the context of what the participant said, the subject of the talk within the transcript.
- *Linguistic* comments focused upon exploring the specific use of language by the participant.
- *Conceptual* comments focused on engaging at a more interrogative and conceptual level. (Smith et al., 2009, p. 84)

I selected meaningful segments of the data according to my interpretation of the natural breaks in Dejan and Angela’s topic of conversation, or implied meaning, within their reflections. I placed no restrictions on the number of codes that could be applied to a particular segment; in fact, most segments had multiple codes. Figure 4 provides a screen shot from ATLAS.ti of the codes I assigned to a small portion of one of Angela’s transcripts. In that segment, I coded the data with descriptive, linguistic, and conceptual codes.

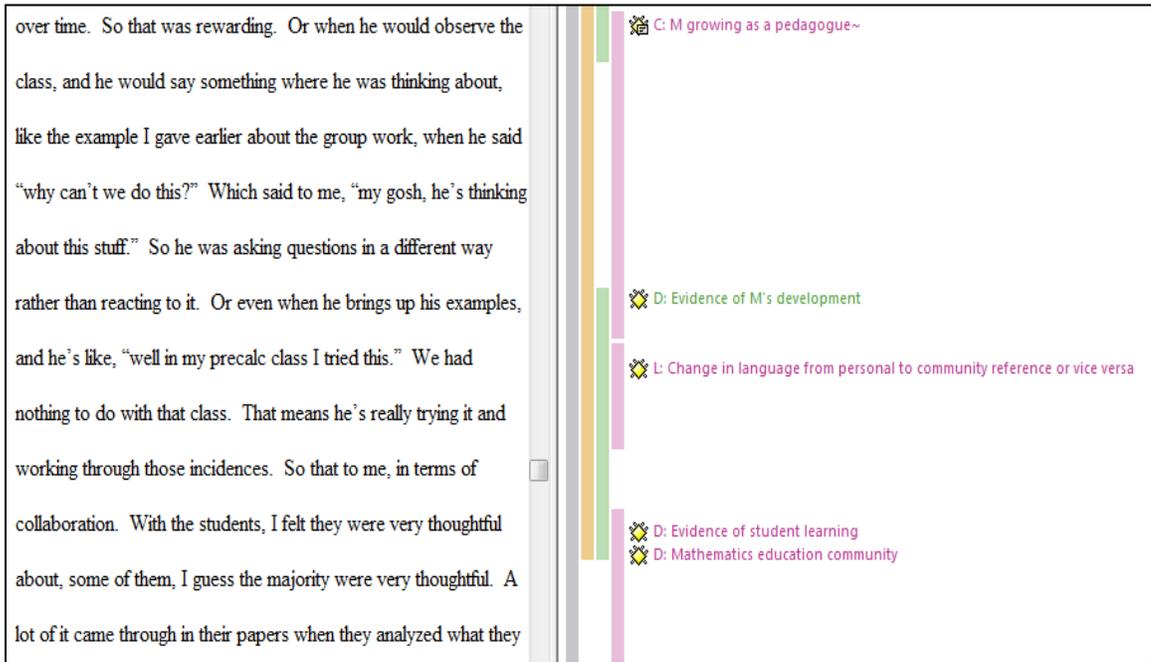


Figure 4. Screen shot illustrating coding scheme in ATLAS.ti

Three meaningful segments are highlighted in Figure 4. I coded the first with a conceptual (C) code titled, “M [Dejan] growing as a pedagogue.” In this segment, Angela recounted an event in which Dejan asked a question about the potential benefits of her pedagogical suggestion. The conceptual code captures Angela’s perception that this was a significant pedagogical development for Dejan. I coded the next meaningful segment with a descriptive (D) code titled, “Evidence of M’s [Dejan’s] development.” I distinguished between the first segment and the second segment because in the first, Angela refers to a specific change in Dejan’s pedagogical actions within the team-teaching course, whereas in the second segment, Angela’s reflection is focused on providing evidence of Dejan’s development in another course. Within the second segment, I also highlighted the portion of the text that reads, “We had nothing to do with that course,” with a linguistic (L) code to identify where Angela’s language indicated a

change from a personal to a community reference. Finally, I applied the descriptive codes, “Evidence of students’ learning,” and “Mathematics education community,” for the third meaningful segment in which Angela redirects her thoughts to a discussion about students (PSMTs) in the course.

The third step, *developing emergent themes*, relied heavily on the thoroughness and detail of the codes and memos I developed in the *initial noting* step. At this stage, I analyzed the memos and codes from step 2, rather than analyzing the verbatim text from the transcripts, in an effort to determine some of the overarching themes that emerged from the data. Smith et al. (2009) explained “themes are usually expressed as phrases which speak to the psychological essence of the piece and contain enough particularity to be grounded and enough abstraction to be conceptual” (p. 92). Whereas the initial noting I conducted in step 2 of the analysis directly reflected and described the voice of the participants, the themes that emerged during step 3 were based primarily on an analysis of my own notes. Therefore, although closely linked with the participants’ voiced experiences, the themes that emerged during this step necessarily contained my voice as the researcher to a greater extent. The emergent themes actualized in two forms, (a) the elaboration/clarification of conceptual codes, and (b) analytic memos labeled as “Emergent Patterns/Themes.” In most cases, these analytic memos constituted an extended discussion of the themes captured by the titles of the conceptual codes.

During the third step of the research analysis, I was particularly cognizant of the hermeneutic circle, in which the analysis of parts is influenced by the whole, and the analysis of the whole is influenced by its parts. By this point in the analysis, I had conducted a holistic reading of the data (step 1), and then conducted a line-by-line free

textual analysis focusing to a greater extent on the individual segments of the data (step 2). As I attempted to search for emergent themes across the data, I found I needed to situate my understanding of Dejan and Angela's experiences in the broader context (i.e., the whole), but at the same time attend to the specific meaning of particular extracts from the data (i.e., the part).

Finally, I engaged in step 4, *searching for connections across emergent themes*. During this stage of the analysis, I attended specifically to the conceptual codes that had developed over the course of my analysis. Taking these conceptual codes as the basis for the emerging themes in my analysis, I attempted to identify patterns and make connections across them. The following extract from one of my "Methodology" memos describes the process I used during step 4:

I am beginning stage 4 of the analysis of Angela's transcripts, entitled, "searching for connections across emergent themes." As described by Smith et al. (2009), in stage 3, the analyst has developed a set of emergent themes, listed in chronological order, in the transcripts (I refer to these as "conceptual codes"). Now, I need to move on to thinking about the connections between those themes. I will engage in processes such as abstraction, subsumption, polarization, and contextualization in order to try to make sense of the connections between the themes.

To begin, I copied all of the "C" codes into the network manager in ATLAS.ti. Then I used abstraction to organize the codes that seemed to be related together in a group. After several rearrangements, I ended up with three groups of

conceptual codes. One of the codes, "External locus of control" did not seem to fit well with any of the groups, so I left it out.

Then I attempted to give an overall name to each of these groups. I already reflected on the name for one of the groups in one of my METAMEMOs, namely, "Moving from appeasement to acceptance." I changed the title of this group slightly to "Pushing Dejan: From appeasement to acceptance." The naming of this first group took the form of subsumption, as one of the initial conceptual codes was "acceptance vs. appeasement." This one conceptual code seemed to encapsulate the meaning for the others in its cluster.

The second group, which I have named "Articulating tacit disciplinary knowledge: Collaboration as a catalyst for reflection on practice," was based on two of the original themes entitled "Collaboration leads to deeper reflection on practice" and "Articulating tacit disciplinary knowledge."

The third group, which contains fewer codes, but that is rich with meaning, is currently named "Interdependence: The influence of mutuality on our collaboration." I am still not thrilled with this title, but it captures the meaning I am intending thus far.

After forming these groups of conceptual codes, I made a separate network file for each group, and added the overall name (what ATLAS.ti refers to as a "code family") into the network view as a node. In this sense, all of the original "C" codes are connected to the larger "code family." At this point, I attempted to write out a thematic description of the first code family, "Pushing Dejan: From appeasement to acceptance," and then added into the network all of

the “D” and “L” codes that were related to the code family. Then I rearranged and sorted the codes in different ways until I got a visual that made sense for how I will present my results.

I engaged in the same process for the next two code families. The only difference was that I added the “D” and “L” codes to the network view of the third code family, "Interdependence: The influence of mutuality on our collaboration," BEFORE writing a description for this family, because there were only three "C" codes that were originally associated with this code family (interdependence, give and take, and invested vs. self-efficacious) and therefore I thought I needed some more codes on my network view to be able to write a good description that takes into account the richness of this code family. (S. Bleiler, METHODOLOGY analytic memo, 12/06/11)

It is important to note that what I refer to in the above extract as “code families,” are what I present in Chapter 4 as the “emergent themes” from the analysis. In Chapter 4, I present the network view for each of these emergent themes together with the thematic descriptions I developed during step 4 of the analysis. The names of some of the emergent themes described in the above extract transformed as I continued to reflect on meanings of the instructors’ experiences. The final emergent themes are presented in Chapter 4.

#### **Analytic memoing.**

I found writing, especially in the form of analytic memos (Saldaña, 2009), to be particularly beneficial as a means of engaging in a deep reflective analysis of Dejan and Angela’s transcripts throughout all four steps of the IPA process. I classified memos into

the following 14 categories, many of which were suggested by Saldaña (2009): Code Definition, Daily Record, Emergent Patterns/Themes, Ethics, Final Report, Future Directions, Metamemo, Methodology, Personal Relationship to Study, Problem, Question/Clarification, Research Question, Superordinate Theme, To-Do. Through the process of writing/memoing I found I was able to clarify ideas and move forward in my interpretation of Dejan and Angela's transcripts. The following memo exemplifies this process. It is a "Code definition" memo in which I attempted to clarify and classify code definitions for Dejan's transcripts.

I had previously assigned a conceptual code titled "lack of autonomy," and it was defined as "Use this code when Dejan refers to a feeling that something in the collaboration and/or teaching led him to feel a lack of autonomy, in which he needed to rely on something or someone else, rather than being able to be self-reliant."

However, when I looked at the four quotations for which I applied this code, the definition did not fit the meaning in the quotations precisely enough. The real issue was not that Dejan was having to *rely* on someone else or something else, but more so that some of the interactions/experiences he had in the collaboration led him to feel he was losing control over his self as a teacher. The difference is, he may have felt he was losing control, and not able to rely on anything to provide him with more support (unlike how I had characterized it earlier, in that he was relying on something particular, like technology or Angela, to provide him with support).

The title of the conceptual code is now, "losing control." I may want to make it more specific, like "losing control of my teaching identity," or "losing control of my teaching authority", or "losing control of my autonomy/independence in the classroom."

Actually, now that I have written that (above), I think there is another theme that is emerging here that has to do with "questioning my teaching identity." This could be used in instances such as when Dejan voices a concern that he used to feel that he was a good teacher, but now that is coming under scrutiny and he is beginning to doubt/question his own abilities. I will add this as a new conceptual code as well. (S. Bleiler, CODE DEFINITION analytic memo, 12/22/11)

I found that by writing such analytic memos my ideas were forced to become concrete. As demonstrated in the extract above, my chain of reasoning emerged *through* writing. I used writing, not only as a means of recording my ideas, but as a means of creating and molding those ideas.

### **Ethical considerations**

Dejan and Angela have agreed to participate in the KnoTSS research study. The KnoTSS study, and this more specific dissertation study has been approved by the institutional review board at the institution under study as well as at the University of Arizona (where the principal investigator for the KnoTSS grant, Rebecca McGraw, is located). The only people with access to the data described above are myself, the KnoTSS research team at the University of Arizona, and the Institutional Review Boards at both universities.

In the current dissertation study and any subsequent publications I will use pseudonyms in reference to the institution and the instructors. For purposes of the larger KnoTSS study, data was collected from students in the form of questionnaires and student work samples. However, because students are not the focus of the proposed study, I did not use this student data to inform the current study. However, I believed it was important to inform the students of my role as the researcher observing in their classroom, and consequently, I assured them their anonymity would be protected in any publication that results from the case study.

### **Credibility and Trustworthiness**

The concept of validity in qualitative research has been depicted in many ways by different experts in the field (Creswell, 2007). According to Patton (2002), the credibility of qualitative research “hinges to a great extent on the skill, competence, and rigor of the person doing fieldwork” (p. 14). In addition to an attempt to be explicit and careful with respect to the description of my methodology throughout this chapter, I use this section to elaborate on some of the specific validation strategies I employed to enhance the credibility and trustworthiness of the research.

For one, I call attention to the section in Chapter 1 in which I discussed my personal role and interest in the research in hopes that the reader would gain a deeper understanding of my perspective as the researcher. I also acknowledged the need to reflect on and make transparent any assumptions, prior experiences, or personal expectations that influenced my analysis of the data. The use of a researcher reflective journal served this purpose for my research.

Following the recommendations of Stake (1995) and Yin (2003), I used triangulation of data sources, collecting five different types of data, in order to provide corroborating evidence for the final themes that emerged. My prolonged engagement in the field should also be considered a validation strategy. I attended almost all class session as well as nearly every planning session, and therefore, I believe I brought a deep understanding of the context and the issues that arose within the case to my analysis of the data.

Finally, I conducted member-checking, or “participant validation” (Smith et al., 2009, p. 54) with Dejan and Angela throughout the data analysis process. At two different times during the analysis, I sent Dejan and Angela documents for participant validation. At the first stage, I sent Dejan and Angela an electronic file that contained the following: (a) the title of the three emergent themes from their interviews, (b) a thematic description for each of the emergent themes, and (c) a list of quotations/extracts from the instructors’ transcripts that were particularly illuminating with respect to each of the emergent themes. I sent an email to each of the instructors asking them for feedback in a first round of participant validation related to the following questions:

- How well do you believe each thematic description captures your actual experience of your co-teaching collaboration?
- Are there elements of the description that seem off-base or misinterpreted?
- Do you feel that there are any major elements of your experience that are missing from my descriptions?
- Do you have any other comments or concerns?

Both Dejan and Angela were satisfied overall with the meanings portrayed in the thematic descriptions. They each had specific questions about the final presentation of the results, which I discussed and clarified with them in a follow-up meeting (on the phone with Angela, and in person with Dejan). In the second stage of participant validation, I followed a similar process by sending Dejan and Angela an initial draft of Chapter 4 and asking again for feedback on the extent to which the document captured their experiences. Instructors provided suggestions for clarifying meaning in particular segments of the presented data. Using this feedback, I revised the draft and molded a narrative that aimed at a closer representation of the perspectives and meanings of both Dejan and Angela within the case.

### **Conclusion**

In this chapter, I described IPA as a research methodology, and explained how I employed this methodology in my study of the team-teaching experiences of Dejan and Angela. The theoretical tenets of IPA research rely on a close textual analysis of the data and a focus on the participants' experiences and meaning making in a particular context. I followed closely the four-step procedure outlined by Smith et al. (2009) to arrive at three emergent themes related to each of the instructors' experiences.

In the results section of my study (Chapter 4), I present my interpretation of Dejan and Angela's experiences in the form of these six emergent themes. In Chapter 4, my discussion is influenced principally by what actually came to life through the data I analyzed. I do not engage in an interpretation of the data that relies considerably on extant literature or theories until Chapter 5. As suggested by Smith et al. (2009), in the

discussion chapter (Chapter 5), I venture “outside” the data and bring in understandings from extant literature to provide insights into the themes presented in Chapter 4.

## Chapter 4: Results

In this chapter, I present the themes that emerged from my interpretative phenomenological analysis of Dejan and Angela’s reflections on their experiences team-teaching a mathematics content and a mathematics methods course for PSMTs. As described in Chapter 3, I used the four stages of IPA to conduct an independent analysis of Angela’s transcripts, and then of Dejan’s transcripts. My analysis resulted in three emergent themes from each of the instructors’ transcripts, as depicted in Table 3 and Table 4. Angela’s emergent themes are titled, “Articulating tacit disciplinary knowledge: Collaboration as a catalyst for reflection on practice,” “Pushing Dejan: From appeasement to acceptance,” and “‘Give and take’: Mutuality as a critical force in our co-teaching relationship.” Dejan’s emergent themes are titled, “Pedagogical transition: Reflecting on my teaching practices,” “Encountering the educational community: Navigating unfamiliar terrain,” and “‘This collaboration is not symmetric’: Disproportionate exchange of intellectual capital.”

Table 3

### *Emergent Themes from Analysis of Angela’s Transcripts*

|         |   |
|---------|---|
| Theme 1 | Articulating tacit disciplinary knowledge: Collaboration as a catalyst for reflection on practice |
| Theme 2 | Pushing Dejan: From appeasement to acceptance   |
| Theme 3 | “Give and take”: Mutuality as a critical force in our co-teaching relationship                    |

Table 4

*Emergent Themes from Analysis of Dejan’s Transcripts*

|         |  |
|---------|--|
| Theme 1 | Pedagogical transition: Reflecting on my teaching practice                               |
| Theme 2 | Encountering the educational community: Navigating unfamiliar terrain                    |
| Theme 3 | “This collaboration is not symmetric”: Disproportionate exchange of intellectual capital |

In an effort to provide a meaningful presentation of these emergent themes, I have organized this chapter into “superordinate categories.” Each superordinate category contains one emergent theme from Angela’s transcripts and one emergent theme from Dejan’s transcripts. In order to make decisions about this organizational structure, I referred back to the research questions guiding my inquiry and grouped the emergent themes according to the research questions for which they provided the most insight. Table 5 illustrates the way I organized the emergent themes into superordinate categories, and the respective research questions I believe are emphasized within each of the superordinate categories.

The goal of an IPA study is to gain deeper understandings of the participants’ experiences as they actively reflect on those experiences. Therefore, as discussed in Chapter 3, I used the four individual interviews (with each instructor) and the two group interviews as the primary source of data for this inquiry. Although I do not provide many extracts from the other data sources collected for the larger KnoTSS study (e.g., transcripts from instructor planning sessions, observation field notes from class sessions, video recordings from class sessions), I drew on these sources throughout my analysis to help clarify contextual descriptions and implied meanings within Dejan and Angela’s interview reflections.

Table 5

*Superordinate Categories, with Associated Emergent Themes and Research Questions*

|                               |  |  |  |
|-------------------------------|--|--|--|
| Superordinate Category        | Increasing Awareness of Our Practice through Interaction across Communities  | Understanding the Educational Community: Angela as coach and Dejan as student                        | Collaborating on (Un)Equal Ground  |
| Angela's Emergent Theme       | Articulating tacit disciplinary knowledge: Collaboration as a catalyst for reflection on practice  | Pushing Dejan: From appeasement to acceptance  | "Give and take": Mutuality as a critical force in our co-teaching relationship   |
| Dejan's Emergent Theme        | Pedagogical transition: Reflecting on my teaching practice   | Encountering the educational community: Navigating unfamiliar terrain                                | "This collaboration is not symmetric": Disproportionate exchange of intellectual capital                                 |
| Research Questions Emphasized | - In what ways do Dejan and Angela make sense of their similarities or differences in relation to their perceptions of teaching and learning?<br>-What do Dejan and Angela perceive as the affordances, if any, of their experiences in the team-teaching collaboration? | - In what ways do Dejan and Angela make sense of their roles within the team teaching collaboration? | - What do Dejan and Angela perceive as the constraints, if any, of their experiences in the team-teaching collaboration? |

In the following sections, I provide a detailed look into Dejan and Angela's experiences during their team-teaching collaboration. To support this portrayal, I include verbatim extracts from the interview transcripts of each of the instructors. To clarify the presentation of extracts, I have made minimal changes to the instructors' quotations,

many of which were requested by Dejan and Angela after I asked them to engage in participant validation. For example, when I transcribed the instructors' spoken words as "gonna," "kinda," and "cause," I changed them into the phrases, "going to," "kind of," and "because" in the final presentation. Also, within extracts, I deleted elements of the participants' quotation I perceived as either irrelevant to the theme under consideration or unnecessary to convey meaning. I indicated the places where such deletions were made by the punctuation "...". Likewise, I inserted text, within square brackets (i.e., [ ]), when I believed a reader may need additional information to clarify meaning. When the instructors placed a strong emphasis on a particular word or phrase during our conversation, I highlighted this emphasis by typesetting the word in italics. Finally, to aid in the contextual understanding of the instructors' spoken words, I indicated places where laughter occurred by noting it as "(laughter)" within regular parentheses.

The remainder of this chapter is organized into three main sections, corresponding to the three superordinate categories. Within each superordinate category, I provide an in-depth portrayal of two emergent themes, one for Angela and one for Dejan. The introductory section for each emergent theme contains an overview of the main components of that theme in both narrative and diagrammatic form. To conclude the presentation of each emergent theme, I provide a brief summary of the main elements of the instructors' experiences in relation to the corresponding theme.

### **Increasing Awareness of Our Practice through Interaction across Communities (Superordinate Category #1)**

The first research question guiding this inquiry is, "In what ways do Dejan and Angela make sense of their similarities or differences in relation to their perceptions of

teaching and learning?” The third research question guiding this inquiry is, “What do Dejan and Angela perceive as the affordances, if any, of their experiences in the team-teaching collaboration?” My analysis of the instructors’ interview transcripts, and more generally my observation of and participation within the collaboration, helped me to better understand the instructors’ experiences with respect to these two questions, which will be illuminated in this section.

Dejan and Angela’s reflections were typically directed toward what they perceived to be vast differences with respect to their views on teaching and learning. Reflection on these differences revealed for Dejan and Angela aspects of their own teaching practices they took for granted. Moreover, in comparing and contrasting their own perspectives with that of their co-instructor, Dejan and Angela found themselves deeply engaged in contemplation and rationalization of their practice. In particular, Angela’s participation led her to reconsider some typical practices within her methods courses, and to provide explicit justifications for her instructional decision making. Dejan found participation in the team-teaching collaboration led to his increased understanding of student needs and to a renewed vision for mathematics instruction in his classroom.

Two emergent themes are depicted within this section of the manuscript. The first, “Articulating tacit disciplinary knowledge: Collaboration as a catalyst for reflection on practice,” emerged from my analysis of Angela’s transcripts and provides insight into Angela’s perception that it was important to be able to articulate the rationales guiding her pedagogical decisions, rationales that she found were often tacitly understood within her community. The second, “Pedagogical transition: Reflecting on my teaching

practices,” emerged from my analysis of Dejan’s transcripts and provides insight into Dejan’s perception of transition with respect to his teaching philosophy and practices throughout the collaboration.

Although the two themes described in this section emerged independently in my analysis of Dejan and Angela’s transcripts, I have organized them together here under the superordinate categorization of “Increasing Awareness of Our Practice through Interaction across Communities,” as I believe each of these themes speaks to how Dejan and Angela’s team-teaching experiences, situated across communities (within a mathematics content and a mathematics methods course), significantly influenced the instructors’ awareness of their own practices. In addition, I believe these two themes provide insight into the larger research questions about the ways in which Dejan and Angela made sense of their similarities and differences in relation to their perceptions of teaching and learning, and what they perceived to be the affordances of their experiences in the team-teaching collaboration.

**Articulating tacit disciplinary knowledge: Collaboration as a catalyst for reflection on practice (Emergent theme 1-Angela).**

Angela perceived her role as one in which she would provide insight into the recommendations and practices of the mathematics education community to a newcomer in that community (her co-instructor, Dejan). She felt a constant pressure to be able to provide a well-articulated and explicit rationale for those recommendations. In attempting to provide a strong rationale, she found it challenging to articulate to an outsider what seemed to be tacit disciplinary knowledge of the mathematics education community. She struggled with the notion that much of her professional decision making

seemed to come from her "gut," and in dichotomizing the dimensions of her pedagogy as art vs. science, strived toward the scientific dimension in order to communicate with and convince Dejan of the community's goals. Through attempts at articulation of the philosophy guiding her and her community's practice, Angela found herself reflecting more deeply about some of the major issues involved in the professional preparation of PSMTs, making greater sense of her own practice through contrast with the practices of her co-instructor.

Figure 5 demonstrates the coding network<sup>4</sup> I developed using ATLAS.ti to organize the main components of Angela's theme, "Articulating tacit disciplinary knowledge: Collaboration as a catalyst for reflection on practice." The theme title is represented by the box in the middle of the diagram and the corresponding codes ("C" codes represent conceptual codes, "D" codes represent descriptive codes, and "L" codes represent linguistic codes) are represented in four clusters around the perimeter, in the following organizational format:

- The clusters on the top and bottom refer to codes that illustrate the major concepts guiding the emergence of the theme. The two codes in the top cluster are codes used in the initial analysis that ended up subsuming the other codes, coming together to form the title of the emergent theme.
- The cluster on the left contains codes that refer to Angela's reflection on her practice within her own community (e.g., mathematics education, College of Education, methods courses).

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<sup>4</sup> Figures 5-10 are network diagrams of the emergent themes and their related codes. In those network diagrams the symbol "M" is shorthand for Dejan as a "mathematician" and the symbol "E" is shorthand for Angela as an "educator."

- The cluster on the right contains codes that refer to Angela's reflection on her practice by contrasting her philosophies/practices with those of her co-instructor Dejan, and those of the broader mathematics community.

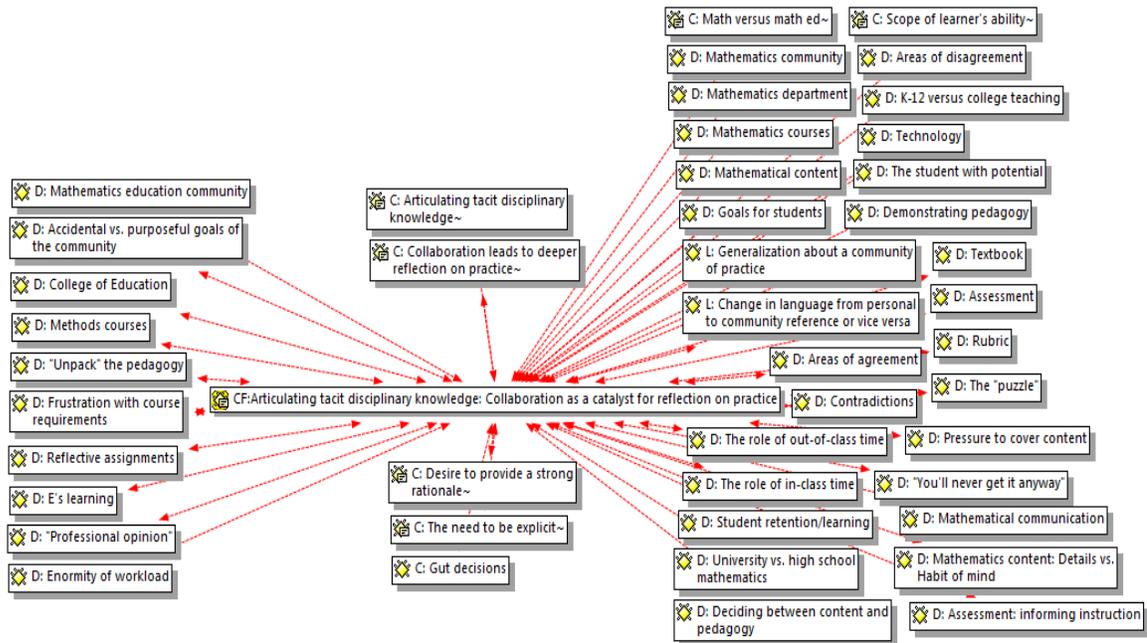


Figure 5. Coding network for emergent theme 1-Angela, “Articulating tacit disciplinary knowledge: Collaboration as a catalyst for reflection on practice”

In the following narrative, I provide a more detailed glimpse into Angela’s perspective as her involvement within the team-teaching collaboration sparked a deeper reflection on her own practices and led her to realize the extent to which tacit disciplinary knowledge guided her practice.

Angela’s collaboration with Dejan caused her to contemplate the lucidity of the goals guiding the mathematics education community. In having to describe and defend her practices to her co-instructor, Angela realized how many of her instructional decisions were guided by implicit disciplinary understandings. Angela believed the

explication of common goals supporting her community's philosophy warranted further consideration.

Okay, I have my gut, and I'm pretty good at some things ... but as a community it made me realize [that] we [mathematics educators] don't articulate those assumptions in terms of what those expectations are in a clear manner, in terms of shared community.... For example, a lot ... of the courses we [teach] are individually developed. [Is] there a common sense of goals that we share across the community? We do, but I think it's accidental almost, rather than purposeful. Do you know what I mean?... So, for some reason, working with him [Dejan] last semester made me realize, there [are] a lot of assumptions in what we do that we don't make explicit. And it made me bothered by it. But I don't know how to address that. (Angela, individual interview #1)

The actual act of team-teaching, and having to negotiate instructional decisions, caused Angela to reflect even further on the need to articulate her rationale for professional practice. Angela felt she needed to develop a rationale that not only would be supported from within her community, but that also would be accepted by her co-instructor whose instructional goals were often more strongly tied to "content coverage."

When you teach a class by yourself, your decision is the decision that's made. You don't have to negotiate with anyone, and you're making the best decision at the time. But when you collaborate with somebody and they are thinking about content coverage then you have to not only negotiate with them, but justify your thinking.... If I were in my own classroom, I would just do it that way because I'm using my professional judgment, because that's how it ought to be done....

[But here] I needed to provide a rationale that would be palatable to him too.

(Angela, individual interview #2)

Angela typically planned her methods courses with the understanding that students may question some of the pedagogy espoused in the course. However, the extent and quality of Dejan's questioning forced Angela to think much more deeply about the reasons supporting her practice.

I think having him in the class versus students [made a difference]. I hate to say it this way, but the students will, you know I plan the talk for them, but there's never a questioning in the same way he questioned. So it's a different level of "How do you justify that?" In particular, I was struck at times when I had a real strong feeling that it ought to be this way, but I could not come up with, at that moment, a rationale to say other than, "Trust me, I'm the expert here." ... It was like, wait a minute, I know because of my expertise, but there is some foundation for it and I need to be able to pull those foundations out when needed to articulate.

(Angela, individual interview #4)

Angela reflected on two conceptualizations of teaching: teaching as art, and teaching as science. She believed communication with Dejan would be more easily facilitated if she were able to speak about her teaching as a science, rather than relying on the art element that so often guided her practice. In fact, accessing and articulating the scientific aspects of her practice seemed to be one of the means by which Angela attempted to offer "palatable" rationales to her co-instructor.

But it's a challenge because, the notion of teaching as an art versus [a science]....

Because if it's an art, in one way, I keep saying it's my gut feeling...then I'm

selling the art notion of it, and that's bad because that's harder to translate to other people. So how do you capture your gut feelings and make that transparent to others [so that they] can learn from it?... Like now that I have, I know it's a gut reaction, how do I tell you about it so that you can internalize and make sense of it and potentially use it? (Angela, individual interview #2)

By the end of the two-semester collaboration, Angela's reflection indicated a more polished understanding of the issue of working from tacitly held ideals in one's community. In particular, she explained how the idea of professionalization of a field necessitates a level of tacit understanding among the experts in that field. Her belief in the importance of explicating such knowledge grew stronger throughout the collaboration as she attempted to share and articulate her understanding of her community with her co-instructor.

You [Dejan] made me realize that as educators we have a hard time communicating to people what we do and why we do it. So it's made me think of, not only making the decision and saying it's a professional opinion. It's being able to say, "Well if it is a professional opinion, that opinion should be based on something, and I should be able to articulate the basis for that." I think that's the professionalization of it, but at the time I couldn't, other than, "This is what I want to do." But I think that's challenging to do all the time because after doing it for some years, it becomes automatic, [how] you are making these judgments. You ... do it so quickly, that there's your rationale, and if forced to, you can articulate it, but it may not be instantaneous. But I think it's important for us, and when I say us, I'm talking about teacher educators, to let people know that there is

thoughtfulness behind what we do. It's not arbitrary. Even though it's a choice I made, it's not an arbitrary choice. It's a choice based on knowledge. (Angela, group interview #2)

Angela's philosophy of mathematics teacher education was driven in part by the idea that PSMTs could benefit from learning mathematics in ways similar to that proposed by organizations such as the National Council of Teachers of Mathematics (2000) in *Principles and Standards for School Mathematics*. However, taking part in this collaboration led Angela to think about some of the challenges of implementing such standards-based practices within a university-level mathematics course, and about how to find a compromise between the ideal of modeling standards-based practices for teachers and the reality of time and structure in a university course.

Given the format for college instruction and the assumptions between the use of class time and use of students' time, I've had to think about that in this collaboration more.... I don't know if I would have thought about it in the same way had I not participated in this arrangement. Because some of the things we do, like for example, the notion about spending time to make sure students understand. As a high school teacher, it worked for me, it made sense for me in my own geometry classroom, but I kept going back like, yeah, I had 180 days. I had constant time to reinforce. And if you think about at the college [level], we have 15 weeks, three [hour] class sessions minus whatever we use for testing. If I focus on just what I do in class, then they [students] know, for lack of a better term, 45 hours worth of stuff. What is it that I really want them to do on their

own, and how do [they] get at that on their own? (Angela, individual interview #2)

Furthermore, Angela recognized that although taking time to focus in depth on PSMT understanding in the university-level Geometry course may have been feasible, it would be challenging for mathematicians to make such structural changes in many of the other courses that serve as prerequisites for future mathematics.

Geometry didn't have a natural next course, but the Calc I, II, and III sequence, you would think, "If I do this, they'll get this really well but I'm shortchanging them here, and they may not get it in the next class, so what do I do?" That would be even trickier. (Angela, group interview #2)

Working with Dejan in the methods course seemed to spur Angela's thinking with respect to her typical practices in such courses. For example, Angela reflected on the extent students' mathematical misconceptions should be addressed within methods courses.

In this class, in the methods course, you sit there and you see their [PSMTs'] misconceptions, and you see it in a different way. So you sit there and on one hand you feel really strongly, "These people are going to teach, they really need to know this." On the other hand, you think, "There's not enough time to fix all the stuff they need to know about the content." So how do you reconcile the two? And it's always a struggle. (Angela, group interview #2)

She admitted that in a typical course, PSMTs' mathematical knowledge, although important, would be secondary to the pedagogical objectives of the day's lesson. Dejan's presence within the methods course problematized Angela's standard practice in this

regard, and caused her to consider a greater balance between mathematics and pedagogy within the methods course.

.... the decision making between this is a pedagogy course versus the math course, and which do you emphasize and why do you do that. So to the extent that I would emphasize the math, I think there were certain times where he [Dejan] would push a little further than I would. I might let something slide, recognizing, my thought would be, “If I go there, will I have enough time to really go there and focus on the mathematics?” So if I get the feeling that there’s an issue, but I don’t have sufficient time or it’s not the major focus of this class, I might let it go. But there were times when he made some comments [about the mathematics] where I thought it was good that they were brought out in class.

(Angela, individual interview #4)

In summary, Angela’s participation in the team-teaching collaboration led her to engage in reflection on her own practices within methods courses, as well as on the expectations she had for the content and structure of university-level mathematics courses. Angela believed it was crucial to be able to articulate the rationale for her instructional decisions in a way that not only aligned with her community’s principles but that was also “palatable” to her co-instructor. She recognized that in order to rationalize her practice, she needed to draw upon what she found to be tacitly held understandings within the mathematics education community. Her reflections illuminated her desire for the mathematics education community to work toward a greater explication of its guiding principles, so to aid in communication with members of outside communities.

**Pedagogical transition: Reflecting on my teaching practices (Emergent theme 1-Dejan).**

A prominent focus of Dejan's participation in the collaboration was his professional development as a mathematics instructor. Through engagement in the collaboration, and especially through discussions with Angela about the practices, expectations, and goals of the mathematics education community, Dejan found himself reconsidering and reflecting on his instructional practices. Dejan began to question his identity and effectiveness as a teacher, something he had previously taken as a personal strength. Dejan considered his teaching philosophy to be in a constant state of change, and was therefore eager and open to learn from Angela, especially with respect to the new perspectives and methods she could "bring" to the geometry course. One of the aspects of Dejan's teaching philosophy that endured the greatest change across the two semesters was his attitude toward and perception of students. Dejan viewed teaching as performance, and was initially focused on himself as the actor at center stage in the classroom, thinking about himself as a conveyor of information. As time progressed and Dejan continued to think about the alternative pedagogical approaches proposed by Angela, he began to recognize the importance of viewing students with a more central role in the classroom.

Figure 6 demonstrates the coding network I developed using ATLAS.ti to organize the main components of Dejan's theme, "Pedagogical transition: Reflecting on my teaching practices." The theme title is represented by the box in the middle of the diagram and the corresponding codes are represented in three clusters around the perimeter, in the following organizational format:

- The cluster on the bottom left corner contains codes that refer to the objects of Dejan's reflection related to his practice as a mathematics instructor.
- The cluster on the right contains codes that refer to the ways Dejan's pedagogical transition manifested and was influenced throughout the collaboration.
- The cluster on the top left contains codes that refer to the characteristics of Dejan's teaching philosophy.

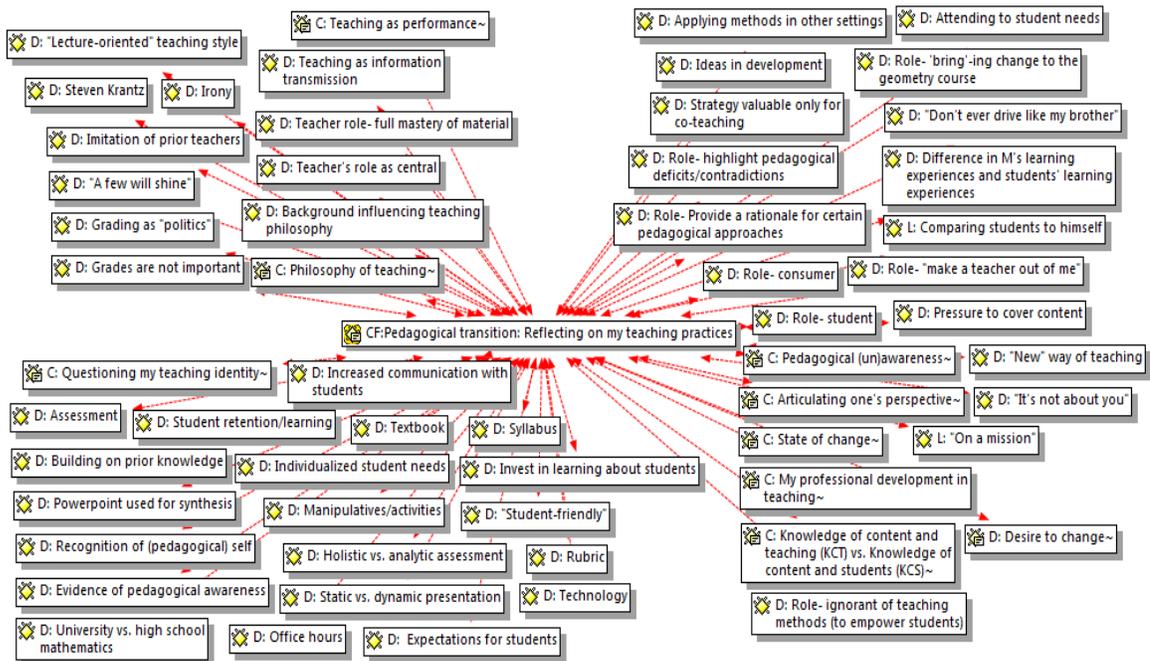


Figure 6. Coding network for emergent theme 1-Dejan, “Pedagogical transition: Reflecting on my teaching practices”

Dejan’s initial engagement in the team-teaching collaboration was motivated by his curiosity about the field of mathematics education and his passion for teaching. Dejan had a desire, especially in the geometry course, to see what new strategies Angela might “bring” to the course. He wanted to “see how the educators will do it” (Dejan, group interview #2), and determine how the strategies Angela proposed could enhance

his teaching. Unexpected were the feelings of doubt and reservation Dejan began to experience with respect to his instructional identity.

You know, I thought, I am a good teacher, and then lately I start questioning that actually.... I had certain methods, techniques, if you call them techniques. Now they are questioned and I see basically valid arguments. I was not told explicitly, “This is crap, come on.” But sometimes I feel it boils down to. (laughter) (Dejan, individual interview #1)

Dejan did not allow feelings of doubt to impede his learning within the team-teaching collaboration. In fact, Dejan’s experiences indicated that a critical analysis of his practice led him to develop valuable insights with respect to his professional development. In the following extract, Dejan described his perception of the professional development cycle within the geometry course.

I felt like, in geometry, I have a guest [Angela]. And then there are many things which can be done differently as far as exposition, and I hope I was kind of open to, “Okay, so let me see what it is you [Angela] can offer.” And then [I] go, like, “Hmm, well that is interesting. I can think of that.” And for many things, I felt like my weak points when I do the presentation were exposed. So there was a lot of room for improvement as far as my teaching. So I saw that as quite beneficial. (Dejan, individual interview #3)

When I asked Dejan to articulate his teaching philosophy during our first interview, he described his view of the classroom as a stage and the instructor as the lead actor. His self-proclaimed “lecture-oriented” approach was characterized by demonstration and transfer of mathematical information.

When I reflect on it [my teaching philosophy], it has an element of show. And, of course, it is, I'm at the center of the stage (laughter). Angela would definitely laugh at this because we reflected on that last semester. And, I laugh at myself also, because a lot of things, you think about, and you realize what you are doing, and what is the root of something, and it is laughable. (Dejan, individual interview #1)

In comparison, when I asked Angela to articulate her teaching philosophy, she provided a characterization of teaching in stark opposition to that of Dejan.

I would say that I don't think teaching is an act to be committed.... Teaching is not how well I deliver, or how well I present. But I think teaching to me is how well you engage students in their learning. So whatever it is you need to do to help them understand and help them make sense of it. So teaching for me is [making] connection with the students and the rapport. (Angela, individual interview #1)

Dejan's interactions with Angela throughout the semester led him to reflect further on his teaching philosophy, which he described as being "in a status of permanent change" (Dejan, individual interview #1). Despite his reflective nature and openness to change, the following extract from Dejan's final individual interview illustrates the enduring nature of his philosophy.

There is a difference between what you reveal as a teacher, and what you know as a teacher, and I admire teachers who know much more but they are going to give you just what you need. And I'm not capable of doing that. You see, a lot of

times I want to tell everything I know. Because you see again, the bad thing, it's about me. Let me show you how. (Dejan, individual interview #4)

In fact, Dejan used this philosophy as a metaphor to help him explain his experience team-teaching in the methods course. During the methods course, Angela occasionally pointed to aspects of Dejan's instruction that could serve as counterexamples to best practice. Dejan appreciated these occasions as valuable learning opportunities for the PSMTs, as evidenced in the following extract.

I felt extremely happy and satisfied, especially when I made a mistake.... It's like a little show, a little theater, and probably when you examine all these tapes you will find this thought, like she [Angela] criticized me because I always think of the classroom as a stage. And unfortunately I said, "Well I'm the main actor" (laughter), and she would say, "No, no, no, no, this is for the audience." The audience is important. But I cannot get rid of that [feeling]. But [there were] a few instances when she would just point to me as, "Don't ever drive like my brother! This is not the way to do it," and I was really happy to be part of that, definitely. For me, I felt like, you know, we were in a comedy or show, even without rehearsing, and in the end you see that it went *really* well, it was *really* great. Ok here is the bad cop, here is the good guy (laughter). (Dejan, individual interview #4)

At the end of the two-course collaboration, I asked the PSMTs in the class to reflect on their experiences as students in the team-taught courses. In reading through these questionnaires, Dejan took note of a particular student's comment who wrote about

the instructors' learning. This quotation illustrates the great extent to which Dejan perceived his experience team-teaching influenced his professional development.

Well I kind of underlined something which, well, for example, this one [referring to a student comment] on the very first page is kind of nice to me, "I think that they [Dejan and Angela] learned more than I did." Wow, that was profound. And I find that true actually. I have that feeling, that I learned, I can definitely say I learned more. If there is such thing as a quantitative measurement of how much you learn, then I would say that yes, I learned more than the students did. (Dejan, group interview #2)

One of the areas for which Dejan believed he learned the most was related to his consideration of student needs within the classroom. In the following, Dejan responded to my question about what he learned from his participation in the team-teaching collaboration during the geometry course.

What did I learn? Okay, okay so, well what is interesting for me is not necessarily interesting for the students, and I should sort of hold my horses. I learned that I should actually know my students, and invest into what it is they actually know. And probably I learned that I should somehow try at least to control my unfortunate weapon, [which] when I'm not happy, or impatient, is irony.... If I expect something to be known, and the student is not knowing that, then I am kind of nervous, and it's unfortunate. I have to find a way to be more student-friendly, more humane. (Dejan, individual interview #2)

Throughout our conversations, Dejan described several specific occasions in which the lessons he learned from participating in the collaboration actualized as

differences in his approach to dealing with students. The following is an example of such an occasion when Dejan's actions demonstrated a more "humane" approach to talking with students during office hours.

Okay, so today was a typical example. No office hours [were scheduled]. They [students] can get [a meeting with me] by appointment. I have this student coming and he is asking, "What is this little circle between this f and g?" I said, "Well that's a sign for composition." [He responded], "So what is a composition?" So this is a Calculus student, and this is Pre-calculus material.... Well what I learned is, previously I would have reacted, "I cannot believe it!" or something like that and make a big [deal]. But now it's kind of like, "Hey, don't worry, we'll fix that. It's just you do in succession two different things." (Dejan, group interview #1)

Another element of Dejan's learning was related to the ways in which he selected problems for students in the geometry course. Whereas previously Dejan would choose the problems that were most interesting to him personally, his discussions with Angela caused him to rethink this practice. Dejan began to place more focus on the learning needs of the students in the course. The following extract illustrates how Dejan viewed his problem-selection process in the past.

Now I'm much more aware about the problems I will choose. Previously it would be, yes, what is interesting for me, but this time...it is *why* is this problem important for the students? What is it that I want to accomplish with this problem? Previously it was like you are in a store with candies and you're like, "Oh look at that!" You don't care about the rest, and you want to open that, to

have it for yourself. It's very selfish. So I'm a consumer of that, rather than a provider of something.... I wouldn't generalize it to all mathematicians but usually that is how I behaved previously. Now I'm aware.... Just because the material itself is very interesting, or the problems pose a challenge, and you are so much into it, you forget about the students. It is very selfish behavior, like, "Well who cares about you guys? Look at this nice problem. Think about that!" (Dejan, group interview #2)

Dejan spoke about how his participation in the collaboration forced him to acknowledge some of the pedagogical issues related to his practice that were easy to overlook before his encounters with Angela.

Well, you see, what is rewarding is that I'm aware of all these issues which previously were just buried. A lot of times I might have been aware of them, but I just didn't want to be aware, and I would find an excuse like, "Well I don't have time for that," or "This is definitely much more interesting." I may try to sell, "Well this is much more interesting for the students," but basically it is much more interesting for me, okay? But this time...as I said, I have to stop being selfish from that perspective. It's not about me. This teaching process is about the students. (Dejan, individual interview #4)

Dejan rarely made generalizations from his practice to that of mathematicians in general. However, the following extract depicts a strong belief Dejan seemed to hold about mathematicians' unawareness of the strategies and principles proposed by the mathematics education community and the benefit of having someone like Angela approach mathematicians and ask for change.

We [mathematicians in the department] have not paid attention to teaching, unless she [Angela] was actually involved in some sense. I mean, it started a long time ago when she came to the department and said, “Well,” again in this not so direct way, “we need a different type of approach to the education courses, not just the way you have dry, definition, theorem.” But I can assure you, I can assure you this definition, lemma, theorem thing, it is so easy to go on that. And I would say that it is not that mathematicians don’t *want* the other way, they don’t *know* the other way. (Dejan, individual interview #1)

By the end of the two-course collaboration, it was clear Dejan had endured significant changes related to his perception of students. He began to recognize the a priori knowledge students’ bring with them to courses, and this led him to plan a novel approach to his future geometry courses that would take advantage of PSMTs’ pedagogical knowledge.

But you know, what I was thinking is, my next geometry class, what will happen? ... I think that I would like to position myself in the role of someone who is totally ignorant about the teaching methods, and empower them [PSMTs]. Like, “You are the educators. You are coming from this side. You are powerful... How can this be applied? What can be done?” I think that type of geometry course, that type of dynamic, they will have their ground. We are into this [mathematical content] and this is how it should be done [pedagogically]. It will work! Because usually they feel kind of totally lost. There is no single thing that they can claim, “Okay, I am good at this,” in the geometry class. But [instead it is] usually, “Oh I have forgotten this,” and “Oh what is that?” and they feel

insecure. There must be a piece of something which will give them security so that [they can say]...“Okay tell us these fancy things about triangles and circles, whatever, and we will think about how that should be presented to our [students].” (Dejan, group interview #2)

In summary, although Dejan’s perception of teaching as performance endured throughout the collaboration, his discussions and interactions with Angela led him to reconsider the role of the students, or “audience,” within the classroom. In particular, Dejan learned the importance of selecting mathematical problems that aligned with the learning needs of students and of approaching teaching from a caring perspective. Moreover, Dejan anticipated ways he could use what he learned from the collaboration in his future teaching practices, proposing a course in which PSMTs are positioned as pedagogical experts who have significant knowledge to contribute to the classroom community.

### **Understanding the Educational Community: Angela as Coach and Dejan as Student (Superordinate Category #2)**

As I engaged Dejan and Angela in reflective conversations about their experiences team-teaching throughout the two-semester collaboration, the answer to my second research question, “In what ways do Dejan and Angela make sense of their roles within the team teaching collaboration?” became increasingly clear. Both instructors were consistent in their view of Angela as a coach and Dejan as a student during their collaboration. When I asked Dejan how he viewed his role in the collaboration, he did not hesitate to describe himself “as a student” (Dejan, individual interview #2 and #4). Furthermore, in describing Angela’s role in the collaboration, he explained, “I feel really

that Angela is on a mission to find someone in the math department and to train professionally this person to help the College of Education” (Dejan, individual interview #2).

Similarly, Angela described her perception of Dejan’s role, “He was, in a lot of ways, like a student.... He showed the excitement of students when they have an ‘aha’ moment.... He was a learner, and he was excited about learning, so I was excited about that” (Angela, individual interview #4), and of her own role, “I started to see our relationship as, I was coaching him in a way, but it was a gentle coaching within a co-teach model, where I had the opportunity to model as we were co-teaching” (Angela, individual interview #2). Although this student/coach distinction in roles was not something either of the instructors anticipated, it turned out to be a key characterizing feature of their collaboration.

Two emergent themes are depicted within this section of the manuscript. The first, “Pushing Dejan: From appeasement to acceptance,” emerged from my analysis of Angela’s transcripts and provides insight into the ways Angela made sense of her role as a coach, pushing Dejan to better understand the expectations of the mathematics education community. The second, “Encountering the educational community: Navigating unfamiliar terrain,” emerged from my analysis of Dejan’s transcripts and provides insight into the ways Dejan made sense of his role as a student, encountering and navigating many new and unfamiliar practices and principles of the mathematics education community.

Although the two themes described in this section emerged independently in my analysis of Dejan and Angela’s transcripts, I have organized them together here under the

superordinate categorization of “Understanding the Educational Community: Angela as Coach and Dejan as Student,” as I believe each of these themes speaks to the larger question about the ways in which Dejan and Angela made sense of their roles within the team-teaching collaboration.

**Pushing Dejan: From appeasement to acceptance (Emergent theme 2-Angela).**

Throughout both semesters of the team-teaching collaboration, Angela perceived her role as a coach to Dejan, pushing him to think differently about his own pedagogical approaches in order to increase his understanding of the needs and expectations of prospective secondary mathematics teachers. Throughout this process, Angela introduced and provided rationales for the use of pedagogical strategies recommended by the mathematics education community (e.g., the integration of technology, formative assessment, and collaborative group work). Although Dejan listened and would often verbally agree to Angela's explanations and rationales, Angela found his agreement to be in the form of appeasement rather than acceptance. Dejan's words and actions demonstrated skepticism, indicating to Angela that he had not truly accepted these new pedagogical approaches. As someone heavily involved in teacher professional development and coaching, Angela recognized change takes time, so she continued to push Dejan's thinking, seeking compromise between her ideas and those of her co-instructor, and aiming for incremental, rather than extensive, progressions.

Figure 7 demonstrates the coding network I developed using ATLAS.ti to organize the main components of Angela's theme, “Pushing Dejan: From appeasement to acceptance.” The theme title is represented by the box in the middle of the diagram and

the corresponding codes are represented in four clusters around the perimeter, in the following organizational format:

- The cluster on the top left refers to the codes that describe the key issues for which Angela pushed Dejan's thinking, or the key issues for which Angela perceived Dejan had progressed in his pedagogical thinking and actions.
- The cluster on the top right refers to codes that describe how Angela perceived Dejan's progression as she pushed his thinking throughout the semester.
- The cluster on the bottom left refers to codes that describe Angela's rationale for pushing Dejan throughout the collaboration.
- The cluster on the bottom right refers to codes that describe how Angela engaged in pushing Dejan throughout the collaboration.

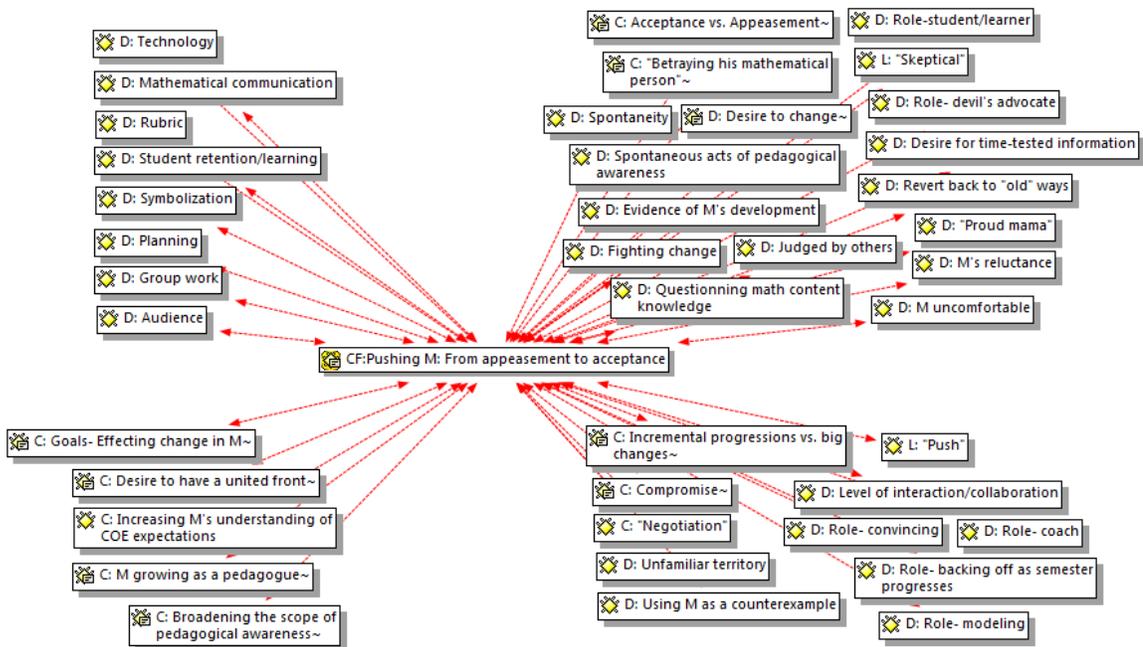


Figure 7. Coding network for emergent theme 2-Angela, "Pushing Dejan: From appeasement to acceptance"

In the following narrative, I provide a more detailed glimpse into Angela's perspective as a coach pushing Dejan toward acceptance and understanding of the guiding principles of the mathematics education community.

During our interviews together, Angela frequently reflected on her experiences pushing Dejan to think differently about mathematics education. Her reflections suggested three reasons she wanted to push Dejan throughout the collaboration. The first of these was her desire to broaden the scope of Dejan's pedagogical awareness. The following quotation was Angela's response to my question about her goals for herself in the collaboration. After I posed this question, Angela found it challenging to articulate goals for herself and kept coming back to her goals for Dejan.

So part of it, okay, there are two things going on in my head, I do have goals for myself, and what I was going to say has a lot to do with Dejan, and I'm thinking, well that's not really goals for myself, that's goals for Dejan. If I can, let me go ahead and say this. Dejan is interested in teaching, okay? He is like that student with potential that you really want to work with, so in a sense, I feel he's like that. I feel my relationship with him is like that. Not that I think he needs to be fixed, but because he is thinking about these things, I think a goal is to give him cause for thinking about more....So that's my goal for working with Dejan. (Angela, individual interview #1)

In a later interview, Angela went on to explain in greater depth why she believed it important to push Dejan to think differently about his own practices and how discussions about pedagogy within the methods course may facilitate his reflection in this regard.

He's still kind of skeptical.... Because when we were working on the geometry course, we didn't have time to unpack all of the pedagogy behind it. In this [methods] course, we're talking about the pedagogy itself and the rationale for why to do it and what's [the] benefit for students. We're doing that as part of class. I'm hoping as we talk about that, he'll see, ... fill in the gaps...in terms of, "Okay, not only did she tell me to do it, suggest that it be done, but okay, now I understand for myself why it can potentially benefit students." So if he can get that far, I think it would be impressive in terms of his own practices, because he wants to do some things, but he's not convinced yet. And he hasn't had enough of the rationales, I don't think. And I think this class may provide opportunities for the rationales. (Angela, individual interview #3)

Angela's second reason for pushing Dejan was to increase his understanding of the expectations for prospective teachers in the university's College of Education. She believed that as an insider in the mathematics department, Dejan could have a greater influence on promoting change than she could as a mathematics educator.

I think if he has, as a mathematician, a better understanding of what we need our students to do as teachers, he can then, not be an advocate for, but he can, you know, share that [information]. He can be a mathematician talking to other mathematicians about the College of Ed students' needs. Because I think sometimes when it comes from us, it's like, "Sure of course, what else would she say?" But to hear it from another mathematician, the potential for that. (Angela, individual interview #3)

In addition to increasing Dejan's understanding of the expectations in the College of Education, Angela also spoke more broadly about helping Dejan to understand the principles and ideals of the mathematics education community. I asked Angela, "Would you recommend to faculty in other institutions that mathematicians take part in a methods course like Dejan did? Do you think it is valuable enough?" She responded,

I think it is, but I think it's valuable to the extent that it's helping them [mathematicians] understand us [mathematics educators] as a field, and some of the things we say. And I think part of our challenge with communicating with them [is] they have no context for what we're saying. And they may not have many opportunities to think about, or read the literature.... So when we say it, it's just foreign. There's just no way for them to interpret it. (Angela, individual interview #4)

In pointing to the communication barriers prevalent between the two communities, Angela further supported her rationale for pushing Dejan to become acclimated with the mathematics education community. The third reason Angela had for pushing Dejan throughout the collaboration was related to her belief that if she and Dejan displayed a united front as team-teachers, they would be better equipped to convince PSMTs of the need to think differently about mathematics teaching and learning. The following quotation was in response to my question about whether Angela believed having a mathematician in the methods course was worthwhile for the students in the course.

I think so in the sense that it communicates the message that we are not two separate bodies. You know, the fact that you have a math educator and a

mathematician saying, “We really want you to teach students to communicate mathematically. We really want you to do this. It’s okay to work in groups.” And they have the support from both groups. I think it’s an easier sell than having the students experience, “Well that’s what they say in education, and that’s what they say in math.” So having that together I think communicates a strong message in terms of, “Oh, this might be really where the field, the entire field is going.” (Angela, individual interview #4)

In addition to displaying a united front in order to send a stronger message to PSMTs, Angela also believed this was important because of the practical challenges of team-teaching. She “didn’t want the teachers to experience two different realities” (Angela, individual interview #1). As they team-taught the methods course, Angela found it important to devote time during instructor planning sessions to ensure she and Dejan had a common understanding of the topics to be covered in the upcoming class session. She spoke often about the need to “convince” PSMTs of pedagogical approaches different from what many of them experienced in their own education. Changing PSMTs’ beliefs and persuading them to think about teaching and learning mathematics in ways consistent with the reform movement in mathematics education were mainstays of Angela’s role as a teacher educator. Therefore, she felt the need to ensure she and Dejan were on the same page, even if it meant Dejan’s agreement with such principles actualized in the form of appeasement and not acceptance.

During planning meetings...he’s reading and reacting, so, I’m doing with him what I would do with the students during class. But I need him to do it with me outside of class so we’re not doing it in class in front of the students. Do you

know what I mean? So it's like "Ask me everything now. Do you really understand why this makes sense? What is it that you're skeptical about? Let's talk it though. What are the ideas?" So really answering all of his questions before we do it in class, so that by the time we get to it in class, even if he doesn't believe it, I can say, "You don't have to believe it, but we need to do this for these reasons..." A lot of this, again, because we are trying to sell this [pedagogical strategies] in a lot of ways, I think it might be detrimental if we have those clashes in class. (Angela, individual interview #3)

At the end of the team-taught Geometry course, I asked PSMTs in the course to provide written feedback on an open-ended questionnaire about their perceptions of the team-teaching collaboration between Dejan and Angela. The student responses indicated many of them perceived significant differences between the two instructors, and several students wrote about the disagreements they viewed between Dejan and Angela in class throughout the semester. As Angela reflected on these student comments, she was surprised by their reactions because she recalled relatively little disagreement that arose during class sessions as compared to the level of disagreement in planning sessions.

And we actually did not disagree a lot [in class]... there were sometimes when we met and we talked about some things we disagreed on, but we decided not to mention it in class, so that's [student perceptions] still surprising to me....Yeah, because we had disagreed more during our planning meetings, but by the time we got there [to class], we kind of agreed on most things. Well not agreed on most things, but agreed on what we were going to focus on. (Angela, group interview #2)

At the end of the methods course, Angela reflected on similar comments submitted by the PSMTs. However, this time Angela's surprise about student reactions appeared to stem from her belief that because she and Dejan were members of different professional communities, the students should have expected differences between them.

You know, I was surprised about the extent to which they made a big deal about the fact that we disagreed about things. It was almost that they wanted a unified front no matter what, and I thought that was surprising.... But that's, well it's interesting because you expect there would be some disagreement because it's a math educator and mathematician, but for some reason it was uncomfortable for them, because I think they were looking for answers. How do I do it and what's the right way? (Angela, group interview #2)

Something Angela reflected on frequently was her perception of Dejan's "skepticism" about adhering to the practices and beliefs of the education community. In the following extract, she attributed Dejan's skepticism to his membership in the mathematics community of practice.

I think he really wants to do that [engage in practices of the mathematics education community], but I always get the feeling it's, this is my word not his, if he enjoys himself too much doing education things, [he] feels he's like betraying his mathematical person.... It's almost like, "What would the other mathematicians think? Would they be okay with it if I don't define this term?" You know, these little things. So even choosing the book for Geometry.... We agreed on the book. Well, he gave in. But I think that the book, because it was [published by] AMS [American Mathematical Society], and [written by]

Hadamard, reputable mathematician, he thought, “Okay, I can do this without looking like I betrayed my [mathematical person]”. (Angela, individual interview #1)

In taking on the role of a coach in their partnership, Angela sometimes became frustrated because she “wanted the progression to be linear” but found that Dejan’s progression was characterized by “a lot of zig-zag and grappling” (Angela, individual interview #2). Furthermore, Angela shared with me a barrier to her ability to coach Dejan that she perceived had its greatest influence during their first semester of collaboration (Spring 2010). During that semester, in order to legitimize her recommendations to Dejan, Angela felt she needed to prove herself mathematically. Before Dejan would accept that her suggestions were not a means of evading discussions about the mathematics itself, she believed she needed to demonstrate her mathematical competence.

I think last year when I recommended some things, he thought I was recommending [them] because I didn’t know the math.... So later on in the semester I began telling him... “Here’s the math, and now here’s why I don’t want you to do it [this way].” It was like, “Okay, let’s establish I know this.” And then, in talking with him, he was like, “Well I know so and so.” I said, “You ought to. You are a mathematician.” I said, “You know more math than us. Let’s establish that. We will get some place where you will know more. That does not bother me at all. What I want you to understand is that I know some too.” So we kind of negotiated that, but I think he feels okay with my math

enough [now]. Before it was like, “Was she saying that because she doesn’t know?” (Angela, individual interview #1)

Angela explained that her overall strategy throughout the collaboration was to push Dejan toward incremental progressions as opposed to extensive changes in his pedagogical approaches. As an example, the following quotation depicts Angela’s plan with regards to integrating instructional technology into the geometry course.

I could do technology, but I’m going to be very thoughtful about pushing it in because it will be very new to students and technology doesn’t make sense unless you build on it.... If I [were] working with him for multiple years, I could probably integrate it more slowly over time, but I think if I went high technology, that would throw him off more.... So I think my goal is to introduce it and say, “See, there are some things you can do with it.” You know, little things here and there, rather than big lab kind of activities for students. (Angela, individual interview #1)

Throughout our interviews, Angela cited evidence of Dejan’s incremental progression in his pedagogical practices. In the following two extracts, Angela identified several such incremental changes she observed during the geometry course (first quotation) and the methods course (second quotation).

Never would I claim that he’s constructivist...but highlighting several things such as wait time, asking students questions, giving students time to think. And I think we saw evidence of that being used consistently throughout the class. (Angela, individual interview #2)

What was rewarding was all of those little miniscule incidents when he had those pedagogical insights. It was like, he would say things, and it was particularly rewarding because it wasn't because I kind of set him up for it, [but] when it came out naturally. When it was like, oh over that year and a half, a few things did seep in over time. So that was rewarding. (Angela, individual interview #4)

One of the aspects of Dejan's professional learning for which Angela believed their collaboration had a significant effect was his perception of students as active contributors and constructors of knowledge in the classroom. When I asked Angela what she believed Dejan had learned from the collaboration during the geometry course, her first inclination was to speak about Dejan's view of students. Although it was clear to Angela that Dejan was thinking about students differently, she did not know if he accepted that his views were different as a result of his different approach in the classroom.

I think Dejan learned to pay attention to students.... And I don't know, I struggle with this because he still thinks these are the brightest kids he's taught, so I don't know if he's sold on the fact that they might not be, that the way he's interacting with them contributes to what they're doing. But I think for the first time, he realized that the students have something to contribute, and it does not have to come from him always. Because if you think early on...there was this assumption that they were a blank slate. Literally, "They don't know it yet because I didn't tell them." And I think this time around, he had students who did proofs in ways that are different [from how] he would have done it. And he was genuinely shocked, and I could see it in the little excitement. He says, "That's even more

elegant than the way I thought about it!” I think he learned that the students have something [to contribute] and the students may think about it differently. (Angela, individual interview #2)

By the end of the collaboration, Angela was happy to report what she perceived to be a significant action on the part of Dejan, reflecting the influence Dejan’s participation in the collaboration had on his understanding of the particular needs of the College of Education students.

He’s gone to the math department and said, “We need to do something different for these people.” That to me is huge, that he’s recognizing they’re a different audience for mathematics and their needs are different from others. (Angela, individual interview #4)

In summary, Angela clearly perceived her role as a coach throughout the two semesters of the team-teaching collaboration. Her multifaceted rationale for pushing Dejan to think differently about teaching and learning mathematics included (a) her desire to satisfy Dejan’s interest in improving his own practice, (b) her goal to help Dejan understand the expectations for PSMTs within the College of Education and the mathematics education community, and (c) her hope to forge a partnership between a mathematician and a MTE in which both instructors send a single coherent message to PSMTs about the teaching and learning of mathematics. Before she could move forward in her role as coach, Angela felt she first needed to prove her mathematical competence to Dejan. After successfully achieving this step, Angela spent a good deal of time during the collaboration working to ensure she and Dejan had a united vision for each class session. Moreover, Angela impelled Dejan’s pedagogical development by proposing

incremental changes to his practice and providing justifications for those changes based on the learning needs of students.

**Encountering the educational community: Navigating unfamiliar terrain (Emergent theme 2-Dejan).**

Dejan found himself faced with many unfamiliar ideas and practices of the mathematics education community during his collaboration with Angela. The novelty of these practices led Dejan to feel a loss of control and autonomy in his role as instructor. Taking on the role of co-instructor during the methods course was particularly disorienting for Dejan because as he was teaching PSMTs about methods for teaching high school mathematics, he was at the same time attempting to make sense of those methods himself. Another tension perceived by Dejan manifested as a clash with respect to the epistemological basis for knowledge formation in the mathematics community versus that in the education community. As Dejan engaged in reading educational literature and the methods course textbook, he was perplexed by the interpretive and verbose nature of the texts. Contrasting this with his experience reading mathematics text, which is characterized by its objective and compact nature and is supported by hundreds of years of scientific discoveries, the immaturity and ambiguity of educational/methods literature was a chief source of discontent in Dejan's encounter with the educational community.

Figure 8 demonstrates the coding network I developed using ATLAS.ti to organize the main components of Dejan's theme, "Encountering the educational community: Navigating unfamiliar terrain." The theme title is represented by the box in

the middle of the diagram and the corresponding codes are represented in three clusters around the perimeter, in the following organizational format:

- The cluster on the top left contains codes that refer to the feelings/emotions perceived by Dejan as he encountered the educational community through his participation in the team-teaching collaboration.
- The cluster on the top right corner contains codes that refer to the differences Dejan perceived between his experiences as a mathematician in the mathematics community and his understanding of the education community.
- The cluster on the bottom contains codes that refer to the ways Dejan encountered and navigated the unfamiliar information and practices of the educational community.

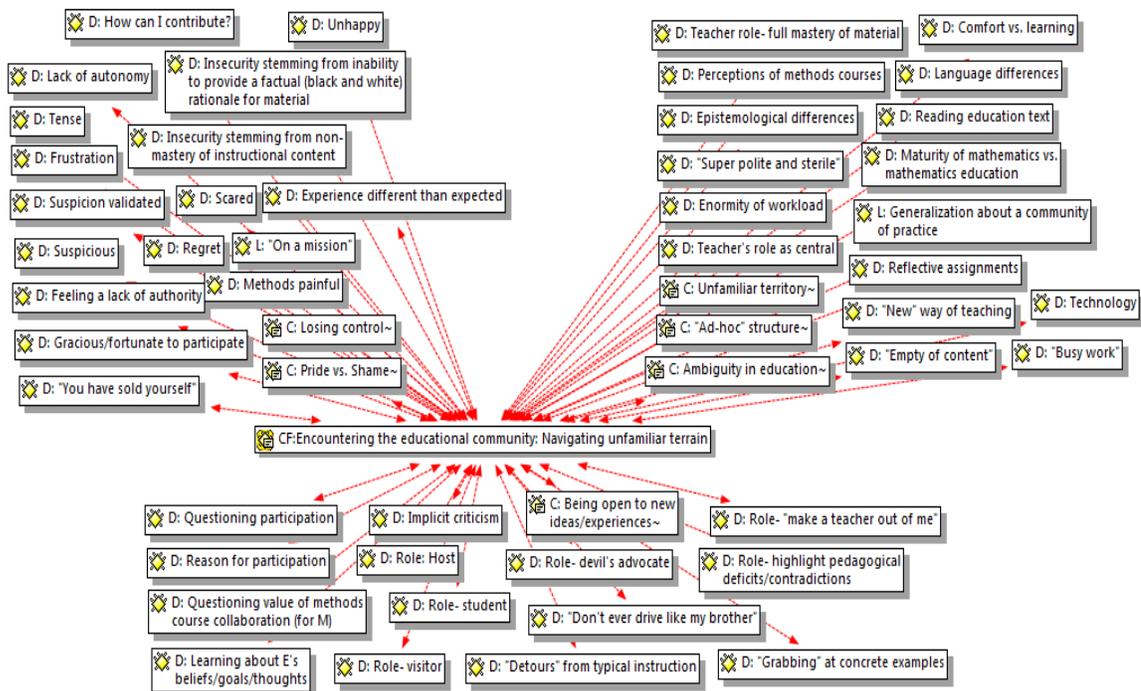


Figure 8. Coding network for emergent theme 2-Dejan, “Encountering the educational community: Navigating unfamiliar terrain”

In the following narrative, I provide a more detailed glimpse into Dejan's perspective as he navigated the unfamiliar terrain of the educational community. The majority of quotations for this theme come from the second part of the collaboration when the instructors worked together to team-teach the "Teaching High School Mathematics" methods course, as this was the part of the collaboration when Dejan encountered the most new ideas.

Dejan had little prior experience with pedagogy/methods courses before having to serve in the capacity of co-instructor in the second part of the collaboration with Angela. When I asked him during our first interview how he would describe an education course, his response indicated a perspective aligned with his more general perspective on teaching, that methods courses likely help teachers think about how to demonstrate the content of mathematics.

My diploma had an emphasis in education, which means you take one or two courses relevant for teaching and teachers. But that was so long ago, I just completely forgot what was in these courses.... I imagine what happens in these classes is that, here is a certain body of knowledge, material...how do we present this material to high school students or elementary kids? Make them engage in this material? What kind of methods do I use to demonstrate certain theorems? Why are these relevant? What will they show? How do I respond to this type of questions from the audience?... I'm not sure if that is happening, but that is pretty much it. Well, I mean, well when I said, "That's pretty much it," it's like, "What else?" (laughter) (Dejan, individual interview #1)

Dejan frequently reflected on the insecurity he felt as an instructor in the methods course due to his lack of familiarity with the ideas espoused in the course. Unlike his experiences teaching mathematics courses, Dejan found it difficult to substantiate the content of the methods course because he did not feel he had a mastery of its “material.”

This semester was, I wouldn't say [it was] very stressful for me, but I just, I wasn't happy.... This unhappiness is because I felt like I am not on top of things. I don't know what will happen in class. Things I would prepare the previous day, looking at the book, I'm just, I'm not sure that first I agree with these things, or sometimes when I agree, if someone kind of scratches a little bit and challenges me on this and that, I don't have a right reference. I don't know why it's correct. What's the prevailing attitude? (Dejan, group interview #2)

Furthermore, as Dejan progressed throughout the semester of the methods course, he faced an epistemological struggle stemming from his perception that the evidence used to support the material in the methods course could not be supported by hard facts.

It is definitely this feeling of insecurity about the roots of things. I felt like, I'm in the classroom and in front of this audience, and I felt like I will be challenged on any of these things I went through last night, or the previous few days.... I cannot support any of these with facts. It was frustrating for me, and I think that was the source of this unhappiness. (Dejan, individual interview #4)

Dejan found his experiences teaching the methods course to be most similar to his prior experience teaching a History of Mathematics course, because there was much more “talk” in these courses than in most mathematics content courses. Dejan described the methods course in contrast to his usual experience as an instructor of mathematics.

It's a different type of course. You don't just go and state the theorem and spend the class proving the theorem, or put a problem on the board and then discuss, "Well what do you think?" It just goes naturally. There is a flow.... But this time, like in History, you have to make a story. I felt like there is so much talking about this, and a lot of times I kind of talk, then I pause in my mind, I listen to myself, and in the back of my mind something says, "What a nonsense! I can't believe it you are saying this. Do you believe in this? How do you support this? Oh my gosh, look at this sentence." I examine my own sentences and a lot of times I am kind of caught because I will start a sentence which I don't know how to finish eloquently, and it's awkward. (Dejan, group interview #2)

The above quotation suggests Dejan struggled with his position as an authority in the methods course because he was questioning the pedagogical stance promoted in the course at the same time as he was teaching this stance to the students in the course. Although his job as methods instructor was to model and promote the constructivist teaching philosophy that guides the reform movement in mathematics education, his own teaching philosophy did not align with these perspectives, and therefore he felt uneasy in his role as co-instructor of the course.

I go to my math class and, I'm not going to say I know everything, but when it comes to Calculus, I've taught the history. I know a little bit about history. I know the mathematics behind that. I know every single problem in that Calculus book. I can think of, in a second, any questions they [students] ask me, so I feel confident and good. And that moment I focus on the material and as a reward, I'm looking at their faces, their reactions, the students, the people, and I feel good

really. That's pretty much it. Here [in the methods course], oh my gosh, I don't know what I'm talking about. As I said, I'm listening and questioning myself at the same time. I'm looking at their faces and a lot of times I would see, "What is this guy doing here?" (Dejan, individual interview #4)

Moreover, as Dejan reflected on the times when he engaged in some of the pedagogical strategies suggested by Angela, he voiced concern that such strategies led him to feel a lack of control in the direction and flow of the class.

I keep thinking about the use of technology.... We're not, okay let's not distribute the blame...I'm not familiar with this more dynamic software. Things should move...they are static there. I have a feeling that when I am on the blackboard with my crayons, I control things and they are more dynamic. You see, I have a circle, I have a line. This line is going this way, no no no, it could go this way, no I immediately change the situation. And I have more freedom. I feel kind of like I am in my domain. But when it comes to PowerPoint, or maybe something more complicated, there are always issues. Why is this not showing up? Why is the computer not responding to this? Why is the machine not responding the way I want it to respond? And later on you find out why it is, but you lose valuable time. (Dejan, individual interview #1)

In addition to feeling like he was losing control in the classroom, teaching the methods course caused Dejan to perceive a loss of autonomy in his role as an instructor. During our final group interview, Dejan expressed this feeling to Angela.

And I felt tense, totally. Not knowing where to go with the material, and basically, okay, I wasn't afraid that the students would challenge what I say

because rarely students do that, but the fact that I don't have a backing on everything I say, on anything I say, that made me extremely uncomfortable. And it made me basically rely completely on you [Angela]. So whatever you say goes. So you see, it's not going to be challenged. (Dejan, group interview #2)

Although Dejan found himself relying on Angela to a great extent throughout the methods course, he also relied on alternative coping mechanisms for making sense of all the new information he encountered while reading the course textbook, such as that described in the following:

I mean, for methods, I am still kind of, I feel, well I'm not going to say completely lost, but I'm just grabbing these examples which are very concrete. Okay this table or this algebra problem or geometry problem, and I hang to this and in my mind I say, "Okay, this is something to which I can contribute." But the rest, it has so much information and I feel completely lost. (Dejan, group interview #1)

Even in the geometry course, Dejan felt a loss of autonomy because he viewed Angela as the authority who best knew the needs of the students in the College of Education, and therefore he often conceded to her recommendations because the course was designed specifically for PSMTs.

If that is what she wants, after all this class is for College of Education students, and if she wants that, she will get that. So in some sense, I kind of lost ownership of the class and I was there to please her. But then, that's part of my psychology. I usually want people to be happy. (Dejan, individual interview #2)

Dejan frequently compared the practices in the education community with those of his more familiar mathematics community. For example, in the following quotation we see Dejan's perception of the differences in the type of knowledge valued by each community. In response to my question about what advice Dejan would give someone considering team-teaching a methods course, he directed his advice to a "fellow mathematician."

So I would just advise my fellow mathematician to be prepared. There will be a lot of this busy work.... We [mathematicians], I wouldn't say we pride ourselves, but a lot of times we think that our problems are more kind of, you have to find a clever way around this.... [For] example, how did Gauss find the sum of the first consecutive 100 numbers? He put it in this way and put it in that way, and then he added everything, and this was "Wow, ingenious." Every mathematician is usually [asking], "Is there a clever way around this and we can save time and do it quickly?" But a lot of times, there was no quick way [in the methods course]. You have a pile here, you have to read everything. And that was time consuming.  
(Dejan, group interview #2)

Another area in which Dejan compared his experiences in mathematics and in education was related to reading the literature in the respective disciplines. He became frustrated reading educational literature because he found it to be verbose and inadequate in its capacity for conveying concise information.

I tried to actually access a few [education] journal articles, but I have a hard time reading that. I mean I do read, but I have to reread, and I never underline things [when reading mathematics], but this is the first time that I will have to underline.

Okay, in all this big paragraph here, a lot of things are said in a very eloquent way, poetic way. I admire that, definitely,.... But then, when it comes to getting information, it's a lot of times just very little. You underline, okay, you would like to know black and white. In this paragraph he says, "A is equal to B." Fine, okay, underline. We go further. Math text is kind of a little different. (Dejan, individual interview #4)

Furthermore, Dejan's reflection on his reading of educational literature suggests an epistemological misalignment between the support provided to back findings in education research and forms of scientific validation he is accustomed to in mathematics.

I don't want to be negative (laughter), but I feel like a lot of that [educational literature] is kind of just empty of content. As I said, put in a very nice, eloquent way and poetic way, but again, when it comes to just raw information. Okay, so what's the claim here and what is the support? How do you support this idea? In a statistical way, or? (Dejan, individual interview #4)

Dejan was accustomed to reading mathematical text, which is not only formatted within a clear structure, but is also supported ontologically by this structure. He perceived educational literature to be lacking in such structure.

It's just difficult for me to see the structure. There's so many things going on, and I have a difficult time. You see, let's say that I have read 50 pages, and I'm into a new section, and then you ask me, "Okay so, without looking at this section, can you tell me in global what would be the structure of this section?" Okay, first I would do this, and then I would do that, and I don't have that feeling. It's all a

surprise. Even though there must be a structure, I haven't gotten that. (Dejan, individual interview #3)

Moreover, Dejan became frustrated with the immaturity of educational literature, which in comparison to mathematics literature, he perceived to lack historical reliability.

Here, I have the impression that everything starts in 1999, or early 1997.

"According to Smith, 97, this is true." Okay, well let's see. Where was this Smith? (Dejan, individual interview #4)

Whereas most of Dejan's reflections indirectly implied an epistemological distinction in values between research in education and in mathematics, the following quotation depicts Dejan's direct acknowledgment of such epistemological differences.

In this [mathematical] situation, if you are wrong, you're wrong. I say "Oh, I didn't see that," or, "I didn't know that." But somehow the questions about methodology [in education], I have heard so many times, "Oh you are right and you are right."... The truth about the subject is so complex, and no single answer can exhaust, and no matter what you say, it would be just one portion of it, one aspect of it, and there are many different aspects. So in some sense, both can be right, and both can be wrong at the same time. Sometimes I feel that this is kind of, well, it could be abused in some sense. Like, you feel like everything goes. Any type of statement is okay, is valid, sometimes. But this is ignorance from my side, talking about it. Because I don't have clear criteria about validation of the methodology, of the statements, you see? (Dejan, individual interview #2)

Aside from trying to make sense of educational literature for his personal learning, the interpretive nature of such literature made it difficult for Dejan to grade

assignments in which PSMTs attempted to synthesize the main ideas of an educational reading.

You read a few times... and then you see, “Okay, what is the main idea in this part? What’s the main idea in this part? In this part?” And I put them aside, and then when I grade, because the students were supposed to read that [same text], and I hear all sorts of stories. I don’t know, were we reading the same thing? They’re commenting on something, so how do I grade, again, the ideas? (Dejan, group interview #2)

In summary, Dejan’s experience during the team-teaching collaboration was characterized by a feeling of a lack of control and autonomy within the classroom. The novelty of the instructional strategies proposed by Angela pushed Dejan outside of his comfort zone. Moreover, because the material being taught to students in the methods course was new to Dejan, he struggled with the fact that he needed to take on the role of an instructor in the course when he felt like a student, learning the material alongside the PSMTs. Dejan’s reflections provided insight into how his background as a mathematician influenced his perception of the new information he encountered in the mathematics education community. In particular, Dejan became frustrated with the literature base in education, as many texts he encountered were written from an epistemological framework different from his own.

### **Collaborating on (Un)Equal Ground (Superordinate Category #3)**

The fourth research question guiding this inquiry is, “What do Dejan and Angela perceive as the constraints, if any, of their experiences in the team-teaching collaboration?” In our interview conversations, both Dejan and Angela reflected on a

similar issue they perceived to be a constraint of their collaborative experience. When Angela reflected on the issue, she used the term “give and take” to describe the exchange between the instructors that while present during the first part of their collaboration (i.e., Geometry), she perceived as deficient during the second part (i.e., Teaching High School Mathematics). With a similar perspective, Dejan believed their collaboration was lacking in an exchange of intellectual capital, with the majority of the instructors’ conversational exchanges centered on pedagogical methods and relatively few focused on issues related to mathematical content. Both instructors struggled when they felt their contributions to the collaboration were imbalanced.

Two emergent themes are depicted within this section of the manuscript. The first, “‘Give and Take’: Mutuality as a critical force in our co-teaching relationship,” emerged from my analysis of Angela’s transcripts and provides insight into the ways Angela viewed mutuality as an important aspect of collaborative work. The second, “‘This collaboration is not symmetric’: Disproportionate exchange of intellectual capital,” emerged from my analysis of Dejan’s transcripts and provides insight into the ways Dejan perceived asymmetry of intellectual exchange in his partnership with Angela.

Although the two themes described in this section emerged independently in my analysis of Dejan and Angela’s transcripts, I have organized them together here under the superordinate categorization of “Collaborating on (Un)Equal Ground,” as I believe these two themes illuminate the instructors’ perceptions that balanced contribution within their partnership was of critical importance. These themes also address the larger research question about the constraints perceived by Dejan and Angela throughout their team-teaching experiences.

**“Give and take”: Mutuality as a critical force in our co-teaching relationship  
(Emergent theme 3-Angela).**

In comparing their experiences co-teaching Geometry (a mathematics course) and Teaching Senior High School Mathematics (a methods course), Angela perceived a significant difference in the dynamics and interactions within their co-teaching relationship. She believed there was a mutuality in their relationship during the mathematics course that was absent during the methods course. Whereas the instructors were both familiar with geometry, and felt confident contributing their respective disciplinary expertise to the geometry course, Angela perceived that Dejan's lack of familiarity and expertise with educational methods seemed to be a key factor leading to his discomfort and reluctance to contribute to the planning, teaching, and assessment of the methods course.

Figure 9 demonstrates the coding network I developed using ATLAS.ti to organize the main components of Angela's theme, “‘Give and Take’: Mutuality as a critical force in our co-teaching relationship.” The theme title is represented by the box in the middle of the diagram and the corresponding codes are represented in three clusters around the perimeter, in the following organizational format:

- The cluster on the left contains codes that refer to issues of mutuality that arose in Angela's reflection on co-teaching of the methods course, “Teaching Senior High School Mathematics.”
- The cluster on the right contains codes that refer to issues of mutuality that arose in Angela's reflection on co-teaching of the mathematics course, “Geometry.”

- The cluster on the top contains codes that refer to issues of mutuality that arose in Angela's reflection on co-teaching in both the mathematics and methods courses.

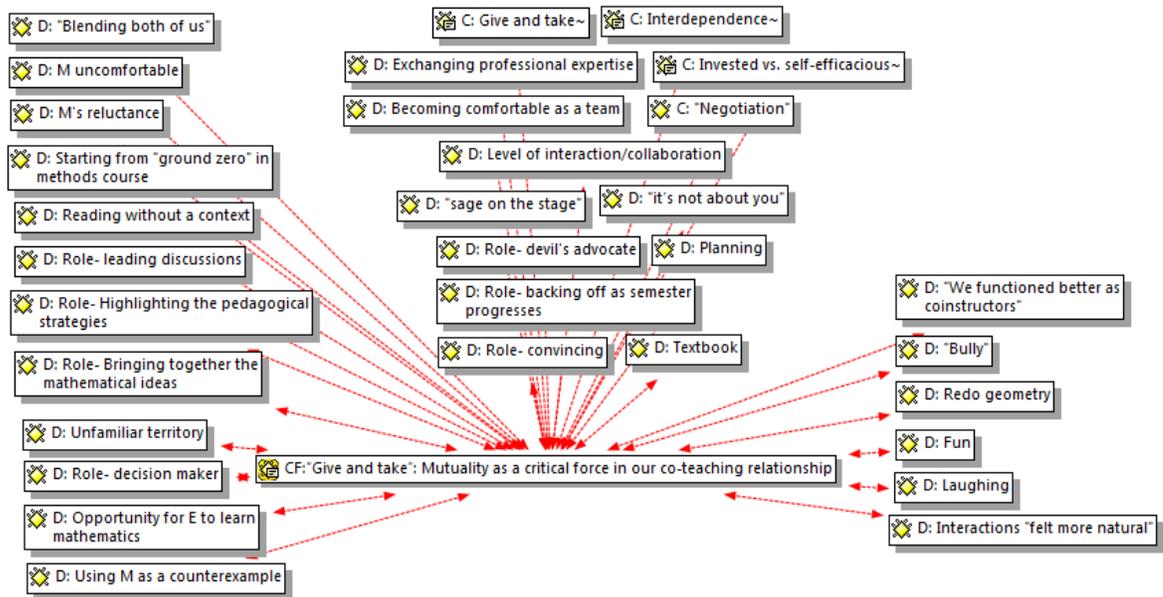


Figure 9. Coding network for emergent theme 3-Angela, “Give and Take’: Mutuality as a critical force in our co-teaching relationship”

Throughout our conversations, Angela repeatedly spoke of the differences between the geometry and methods course with respect to the instructors’ ability to participate in a “give and take.” The most prominent of her reflections was centered on the idea that whereas in the geometry course both instructors had expertise they could contribute to the development of the course, a commensurate level of expertise contribution did not exist between them in the methods course. In the following extract, Angela explained why she believed this was the case.

When we did the geometry class together, I [had] taught [high school] geometry, or at the very least I knew geometry. So in terms of the extent to which it was foreign to me, it was much smaller. This [methods course] was totally new to

him, and he was ... intimidated by that, so there was this reluctance to be a part of it. Just through casual conversations last semester, [he] was like, “How am I going to contribute? I don’t know anything about that?” (Angela, individual interview #3)

During our final group interview, Angela explained to Dejan how she perceived the reciprocity of their relationship in the geometry course versus that in the methods course. Angela’s description highlighted her perception that within the methods course, she was the provider and Dejan was the receiver of methods-related expertise.

In geometry...we talked about things and we disagreed. But we were both focused on the content. I think in the planning sessions this year [in the methods course], I was more providing you [Dejan] with the content. So it wasn’t a give and take. It was more, “Here’s what you need to do. Here’s what you need to think about. Here’s what might happen, just in case.” So, it was more me giving rather than the two-way [interaction]. (Angela, group interview #2)

The greater level of mutuality during the geometry team-teaching led Angela to reflect on the more jovial nature of that semester’s collaboration.

We laughed a whole lot more in the geometry collaboration. We did. And I’m not saying we didn’t enjoy ourselves now.... I think part of it, with the geometry, is [there was] more give and take between the two of us.... We both had buy-in to the course. We both had our views about the course. We both can contribute to the course. So we talked about it, disagreed about it. Here [in the methods course]...it was more questioning and answering rather than disagreement. (Angela, individual interview #4)

Likewise, Angela referred to Dejan's view of teaching as performance as an explanatory factor for why she perceived the nature of the methods course was relatively less convivial.

He feels, like he keeps saying that I "pull him by the nose" or whatever, that expression he uses. He feels he's not adding anything to the course. Now if you think about Dejan, he's a definite sage on a stage, and he used that analogy. He doesn't feel like he's on the stage in this class, in this arena. There is nothing for him to say, "I'll take over because I'm on the stage here." (Angela, individual interview #4)

Angela viewed herself as the primary planner during the methods course. In addition to planning the course activities for PSMTs, Angela spent time during planning sessions in attempts to ameliorate Dejan's discomfort by helping him anticipate some of the key issues that might arise in the subsequent class session.

I think, because Dejan wasn't comfortable, I played a large part in the planning and what occurred in the class, because I don't think he took a big part in the decision making. I would provide a rationale for what I did so he would understand why I'm choosing to do those things, but I think in addition to doing more of the planning, I was thoughtful about, or at least I tried to be thoughtful about what he might need to know, to anticipate, in terms of what might occur in the classroom. So I tried to also cover that during the planning sessions. (Angela, individual interview #4)

Another element of mutuality on which Angela reflected was the instructors' comfort in sharing ideas and providing suggestions to each other about the structure and

content of the courses. Angela perceived that this type of mutuality relied heavily on development of their relationship over time, and was less a product of instructor expertise. In the following extract, Angela compared the instructors' experiences team-teaching geometry during their first semester (Spring 2010) and the semester in which I observed (Fall 2010). She perceived an increased level of comfort between herself and Dejan across those two semesters.

Last time [in our first experience team-teaching Geometry] it was, "You are on, I am on," never the two should interact.... And partly I think, like last time, I admitted to him, I was really reserved, because I didn't want to say things. I never knew how he would take it, or the reaction, because we were so different. This time things felt more natural. So he would say things, or I would chime in, in terms of, "Oh highlight this." Well he would say I'm a bully (laughter), but I think he was okay with it, and then [he would] come back and say, "Well thank you because I wouldn't have thought to do that." You know, those kind of things. Or I even say, "Dejan, what's going on here?" So there was much more ease with that interaction. Not that it happened all the time, but there was no hesitation that if you saw something happen that you couldn't do that. (Angela, individual interview #2)

Angela reflected on one of her experiences during the geometry course that provided insight into a related issue of mutuality in the instructors' relationship in that course. Whereas in the first geometry collaboration (Spring 2010), the instructors used a text that was familiar (and preferred) by Dejan, in the second geometry course (Fall 2010) the instructors used a text that was new to both instructors. Angela explained how

this common level of (un)familiarity with the text led her to perceive that the instructors stood on “fair ground.”

I think the use of the new book...even though Dejan didn't like, it provided a fair ground to discuss what we wanted to include in class. It allowed us to talk about some other issues where[as] when he had more familiarity [with the text in the prior semester], it was more like he was defending the book, rather than talking about it openly. So we had disagreements, but it was about [the fact that] this is a new book to both of us. (Angela, group interview #1)

In our final group interview, I asked the instructors if they would change anything about the way they worked together collaboratively. Both Dejan and Angela responded with an indication that if possible, they would devote more time to their collaboration. Angela acknowledged that finding more time in a day is not always feasible, and therefore she attempted to think of an alternative suggestion for addressing the mutuality issue the instructors faced during the methods course. She advised that if other mathematicians and MTEs planned to collaborate within a methods course, it may be helpful for the mathematician to observe a methods course before participating as a co-instructor.

I think if the person can sit in the class once. You know, not have any responsibilities except to be [an] observer and see [the course]. I think the advantage might be you [Dejan] would have, like in planning for [the methods course], you would have your end of the conversation. Because you could say things like, “Well you know, when this happened last year, last class, here's what I noticed, what was going on here.” You know, there would be some different

questions asked. Whereas this time, because you have no understanding of what we did...you couldn't come up with questions to ask, or you didn't have anything to say. Like, "The students said this before, what were they thinking, or how can we direct their thinking?" I think that would give more insights for the quality of the discussion or the quality of planning. (Angela, group interview #2)

In summary, Angela perceived a significant difference with respect to her interactions with Dejan during the methods course as compared to the geometry course. Angela had previously taught high school geometry, and therefore she was familiar with the content of the geometry course and was able to provide insight into the knowledge PSMTs would need to teach that subject. Conversely, because Dejan was much less comfortable with the pedagogical content taught to PSMTs in the methods course, Angela felt she needed to provide Dejan with the information he would need to teach this content to PSMTs. Whereas Angela perceived the instructors had a balanced "give and take" of expertise within the geometry course, she believed that such mutual exchange was lacking from their collaboration during the methods course.

**"This collaboration is not symmetric": Disproportionate exchange of intellectual capital (Emergent theme 3-Dejan).**

In collaborating with Angela, Dejan perceived a tension between his interest and focus on mathematical content and Angela's focus on more process-oriented instructional goals. Dejan viewed the teaching of mathematics content as an end in itself and viewed successful teaching as that which sparks student enthusiasm in the content matter of mathematics. Therefore, he struggled with what he perceived as Angela's "brushing over" the mathematical content as she expressed a lack of time for or curiosity in some of

the mathematical questions that to him were most interesting. Although Dejan acknowledged that the needs of PSMTs were different than the needs of other undergraduate mathematics students, he found it difficult to ignore questions related to the details of the content and structure of mathematics for which his preparation as a mathematician had trained him to attend. Overall, Dejan perceived there was a disproportionate exchange of intellectual capital between himself and Angela. As partners in team-teaching, he expected Angela would contribute her pedagogical expertise to their discussions and that he would contribute his mathematical expertise. However, Dejan suggested such intellectual exchange rarely occurred, and that instead most of the instructors' discussions centered on methodological issues. Moreover, Dejan felt he was learning much more from Angela than she was learning from him in their partnership, influencing his perception that "this collaboration is not symmetric."

Figure 10 demonstrates the coding network I developed using ATLAS.ti to organize the main components of Dejan's theme, "'This collaboration is not symmetric': Disproportionate exchange of intellectual capital." The theme title is represented by the box in the middle of the diagram and the corresponding codes are represented in three clusters around the perimeter, in the following organizational format:

- The cluster on the bottom left corner contains codes that refer to Dejan's perception and experience of the disproportionate exchange of ideas between himself and Angela.
- The cluster on the bottom right corner contains codes that highlight the context for Dejan's perceptions of the disproportionate exchange of ideas, situating his

own perspectives within a content-focused lens, and Angela's perspectives within a process-focused lens.

- The cluster on the top contains codes that can inform both the bottom left and bottom right clusters, describing Dejan's perception of a disproportionate exchange in the collaboration, as well as informing the context for his understanding of this disproportionate exchange.

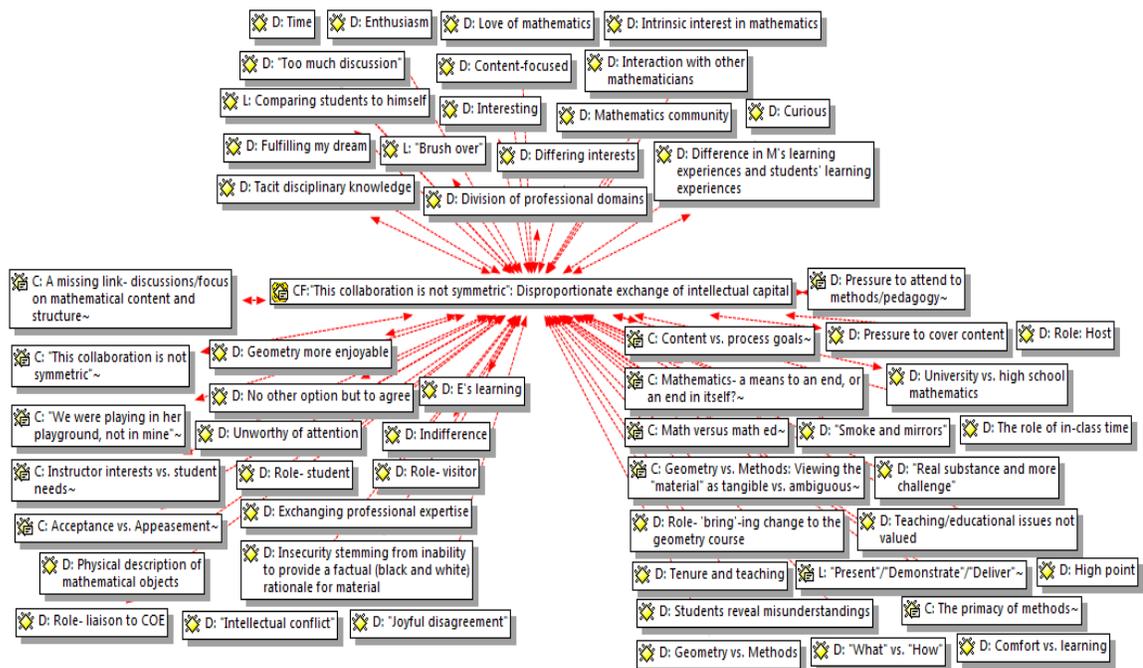


Figure 10. Coding network for emergent theme 3-Dejan, “This collaboration is not symmetric’: Disproportionate exchange of intellectual capital”

Throughout our conversations, Dejan repeatedly reflected on the primacy of pedagogy/methods as a topic of discussion between himself and Angela during both semesters of the team-teaching collaboration. Missing from the collaboration, in Dejan’s view, were discussions about the content matter of mathematics. What Dejan originally anticipated with respect to the reciprocity of their relationship was different from what actualized throughout the collaboration, as evidenced in the following extract.

I thought it was going to be kind of an equal exchange, in the sense that, “Okay, I’ve seen this material, I know some things you don’t know. I know axiomatic methods for Euclidean geometry, models of Euclidean geometry in which lines are not ‘straight.’ Do you know that? Or I know this and that and different types of [geometries]. And I know the power of this argument, and some questions which are connected with logic.”... And okay, I can tell you about these things, and you [can] tell me how you present this to [students], or what kind of manipulative you use, and why that is important. And I thought that is going to be the way of the collaboration, meaning I am stronger in the material but you are much stronger in the techniques. So it is like we have two separate domains, and there is very little intersection, and we will benefit from exchanging. But then in practice, you know, I feel like, well, she is not asking me about models of geometry in which lines are not “straight,” or things like with logic or this or that.... So I learn much more from her, I feel like, than she does from me. Actually, I think this collaboration is not symmetric in some sense. (Dejan, individual interview #1)

Although he believed each instructor had valuable expertise to contribute to the collaboration, Dejan felt he did not have the opportunity to contribute his expertise because the primary focus of their discussions was centered on issues of pedagogy. Dejan had many questions related to mathematical content and structure he perceived to be worthy of attention, but felt these were rarely addressed in the instructors’ discussions. Dejan recounted the approach to their collaboration as a division, rather than an exchange, of intellectual capital.

I put a divide between okay, this is your domain, and that is my domain, and I don't see any [exchange between us related to] the science of geometry, or the significance of the structure, what should be done first, and what should be done later. Certain theoretical aspects of, why is this important? Why this book? Why this approach? Why this model? We never actually had that exchange. Not never. I wouldn't say never. I don't record everything, but we rarely had that [exchange]. Usually, it's kind of a division of labor. Okay, you do this, and I'll do this, and we follow that path, the path which is laid in the book.... So we were playing in her playground, not in mine. (Dejan, individual interview #2)

Throughout the collaboration, Angela emphasized the importance of making decisions about the topics of focus in the course based on the students (i.e., the “audience”) and their particular learning needs. In the following extract, Dejan described an example of a mathematical question that was of interest and importance to him as a mathematician, but that he perceived MTEs would consider “irrelevant” because of the audience and purpose of the class.

For example, on page 5 here, he [Hadamard, the textbook author] says, “We can also define the sum of two arcs on the same circle or on equal circles by moving them end to end.” That's it. So, well, in math, this...has all sorts of problems. If the arcs are overlapping, or their sum is more than one complete circle, what do you do then? So, even if you take an arc and take a complement of an arc, add them, you get the whole circle. Is the whole circle an arc? It's not.... If you want to have an arc, you need to have two distinguished points, etc. These are interesting questions which I think mathematicians would like to think about.

Let's put it nicely (laughter). And for educators, that's irrelevant. It's not productive use of the time at all. (Dejan, individual interview #1)

Dejan admitted that although he may have disagreed with Angela about pedagogical decisions for their team-teaching courses, he often decided to go along with Angela's decision so that, practically speaking, they could move forward in their team-teaching responsibilities. In the following extract, Dejan described why going along with Angela's decisions about pedagogy was not particularly problematic for him, but alluded to the idea that if the decisions were mathematically-based, he may have found agreement to be a greater challenge.

Well, we are arguing, or we have conflicting views on matters which are, most of them are methodological. And that is, again, unfortunately, that is the lower level on my scale of values. Then I would say, "Well okay, is this something worth arguing or clashing about?" So I would say, "Okay." But if it was really, wow, on the first level of values about does this constitute a proof? How do we do something mathematically correct? Incorrect? Is this a good definition? Well I don't know, like I said, we never had these type of discussions, so I don't know how I would [react]. (Dejan, individual interview #2)

In later interviews, Dejan continued to reflect on his feeling that something was missing from the collaboration. In addition to his perception that the instructors did not engage in conversations related to mathematics, he also voiced concern that the instructional strategies espoused in the methods course were rarely supported by mathematical rationales.

Because I would say my primary focus, or interest I would put it, not focus, but interest, is the [mathematical] material. I am kind of really curious to see...what will be the exposition of, let's say, geometry? I don't know, sometimes I feel like I wish my questions were answered readily. Like...what is the pedagogical value of this example specifically? If it's kind of combinatorial? In how many ways can you do this and this and this? Rather, some of what happened so far I see only as an instrument for students to socialize, to make friends, conversation, collaborate.... But if someone else is asking, why do you choose this specific example? Because of the material? Or because of the content or the mathematics which will be developed? I don't see the reason, I don't know the answer.

(Dejan, individual interview #3)

Furthermore, Dejan worried that the lack of focus on mathematics during class discussions about pedagogy could be a disservice to PSMTs who he believed needed to critically examine the purposes of proposed instructional approaches.

The first thing which comes to mind is that they should, the students should see somehow the limitations of all these different strategies and approaches to teaching. They should see, or be capable of seeing, how much of that is designed so that this social component of learning, of being in class, of being part of a group is emphasized, and not to confuse that with the challenges of the material itself, of the mathematics, of the mathematical structure, etc. (Dejan, individual interview #3)

Throughout the methods course, Dejan repeatedly explained how he felt like he was not "invested" in the course. At the end of the semester, I asked him if there was

anything that could have been changed so that he would have felt a greater investment as instructor in the course. Again, his response indicated a need for discussions that integrate a greater level of mathematical focus.

Maybe a discussion about, okay...I will just go with the example of quadratic functions.... Maybe [it would help to have] a little discussion about, what is the nature of this function? Which characteristics and properties are best as a showcase for these functions so that the student will immediately get the idea or the nature of the function? So this connection, which will presumably happen at that moment between the educator and mathematician, I think that it will be beneficial for both. So that's powerful, "Well, okay, you think the main characteristics of quadratic functions are A, B, and C, but C is actually the most suitable for these kids or this age group."... That type of discussion. (Dejan, individual interview #4)

In summary, throughout both semesters of the team-teaching collaboration, Dejan perceived a deficiency in exchange of intellectual capital between himself and Angela. Coming into the collaboration, Dejan expected he and Angela would have discussions in which he could share his mathematical expertise and at the same time Angela would share her pedagogical expertise. On the contrary, Dejan found the majority of their conversations were focused on "methodology," and that Angela did not ask Dejan many questions about mathematical content. Dejan viewed this lack of reciprocity between mathematics content and mathematics pedagogy as problematic for the PSMTs in the course as well. In fact, he believed it was important for PSMTs to consider the

mathematical implications and recognize the mathematical limitations of the strategies proposed in the methods course.

## **Conclusion**

In this chapter, I presented an in-depth portrayal of Dejan and Angela's experiences during their team-teaching collaboration within a mathematics content and a mathematics methods course. In the first section, I used the superordinate category, "Increasing Awareness of Our Practice through Interaction across Communities," to organize the presentation of Angela's emergent theme, "Articulating tacit disciplinary knowledge: Collaboration as a catalyst for reflection on practice," and Dejan's emergent theme, "Pedagogical transition: Reflecting on my teaching practices." Dejan and Angela both found that through their participation in this team-teaching collaboration, they engaged in a deep level of reflective thought and rationalization of their perspectives on teaching and learning mathematics. In particular, the instructors' reflections indicated that through a comparison and contrast of their practices across their respective communities, they gained a greater awareness of their own practice.

In the second section, I used the superordinate category, "Understanding the Educational Community: Angela as coach and Dejan as student," to organize the presentation of Angela's emergent theme, "Pushing Dejan: From appeasement to acceptance," and Dejan's emergent theme, "Encountering the educational community: Navigating unfamiliar terrain." Dejan and Angela both acknowledged the coach-student relationship that characterized their team-teaching relationship. Angela pushed Dejan to think differently about his traditional views of teaching and learning mathematics by providing opportunities for him to make incremental changes to his practice. One of her

major goals was for Dejan to better understand the principles supporting the mathematics education community so he would be better equipped to recognize the needs of PSMTs. As Angela presented Dejan with information to aid his learning about mathematics education, Dejan found that his epistemological stance was not the same stance used as a basis for many of the documents he read in the educational literature. Dejan found it difficult to truly accept many of the principles and practices proposed by Angela, as they were often in opposition to his own beliefs about the teaching and learning of mathematics.

Finally, in the third section, I used the superordinate category, “Collaborating on (Un)Equal Ground,” to organize the presentation of Angela’s emergent theme, “‘Give and take’: Mutuality as a critical force in our co-teaching relationship,” and Dejan’s emergent theme, “‘This collaboration is not symmetric’: Disproportionate exchange of intellectual capital.” Both instructors repeatedly reflected on the issues that emerged within their collaboration when their perceived levels of contribution to the partnership were imbalanced. Angela spoke of the importance of “give and take,” and how a lack of mutuality was a constraint to their collaboration, especially during the methods course. Likewise, Dejan perceived an imbalance in the exchange of intellectual capital between the two instructors, and believed he learned more from Angela than she learned from him during their collaboration.

In the next chapter, I engage in a concentrated interpretation of the themes presented here. I use Lave and Wenger’s (1991) theory of situated learning as my interpretive lens for making greater sense of the instructors’ experiences as depicted in their verbatim extracts in this chapter. I also compare and contrast the findings from this

inquiry with findings from the broader literature base in order to provide implications for practice and for future research.

## **Chapter 5: Interpretation and Discussion**

In recent years, experts and organizations involved in mathematics education have emphasized the importance of collaboration between mathematicians and MTEs as a means of improving the professional preparation of mathematics teachers. While several such collaborative endeavors have been documented in the extant literature, most research reports have focused on the products, rather than the process, of collaboration. The purpose of this interpretative phenomenological case study is to gain an understanding of the lived experiences of a mathematician and a mathematics teacher educator as they engaged in a team-teaching collaboration within the context of prospective secondary mathematics teacher preparation. Participants in this study are a mathematician (Dejan) and a MTE (Angela) who worked together to plan, implement, and assess prospective secondary mathematics teachers enrolled in a mathematics content course (Geometry) and a mathematics methods course (Teaching Senior High School Mathematics).

I employed interpretative phenomenological analysis (Smith, Flowers, & Larkin, 2009) as the methodological framework. Consequently, I attempted to make sense of Dejan and Angela's experiences as they engaged in active reflection on those experiences. The themes that emerged from my analysis illustrate (a) how crossing community boundaries led to Dejan and Angela's increased awareness of their practice, (b) the roles of coach and student taken on by Angela and Dejan throughout the

collaboration in an effort to increase Dejan's awareness of the needs of PSMTs, and (c) the influence of mutuality as a driving force in the instructors' collaborative experiences.

In Chapter 4, I presented the emergent themes from my analysis of Dejan and Angela's team-teaching experiences. In that chapter, I portrayed the instructors' perceptions in a way that closely mirrored their own spoken reflections. In Chapter 5, I present an interpretation of Dejan and Angela's experiences using Lave and Wenger's (1991) theory of situated learning, together with Wenger's (1998) subsequent theoretical examination of communities of practice, as my interpretive lens. In particular, I view Dejan and Angela's meaning making as "an integral and inseparable aspect of social practice" (Lave & Wenger, 1991, p. 31), and their identities as members of the mathematics and mathematics education communities of practice, respectively, as an essential aspect of their meaning-making.

Throughout this chapter, I frame my interpretation to a large extent around the concept of "community of practice," defined by Lave and Wenger (1991) as "a set of relations among persons, activity, and world, over time and in relation with other tangential and overlapping communities of practice" (p. 98). Moreover, in a community of practice, "participants share understandings concerning what they are doing and what that means in their lives and for their communities" (p. 98). Although this concept is central to Lave and Wenger's theory of situated learning, they did not expound upon it in their seminal work, *Situated Learning: Legitimate Peripheral Participation*. Therefore, in this chapter I also draw extensively on Wenger's (1998) *Communities of Practice: Learning, Meaning, and Identity*.

It is important to clarify the way in which I view the representativeness of Dejan and Angela as members of their respective communities of practice. In this regard, I find Hemmi's (2006) description of her conceptualization of the students and mathematicians in her study to be particularly instructive; she wrote, "I consider the mathematicians and the students as participants in the community of mathematical practice and interpret their utterances, not entirely as their own opinions but to some extent as reproduction of views belonging to the community, utterances that are influenced by the social, cultural and historical context of the same mathematics environment but also from other possible environments" (p. 68). In a related fashion, I view Dejan and Angela's verbal statements neither as representative of the mathematics and mathematics education communities of practice nor of Dejan and Angela solely as individuals, but as representations of their understanding of "being" within their respective communities.

In Chapter 2, I provided an overview of the situated learning perspective. In this chapter, I build on that overview by expanding upon the notions of meaning and community of practice. Then, I present an interpretive analysis of Dejan and Angela's perceptions and meaning-making throughout their team-teaching experiences with a particular focus on their identities as a mathematician and a MTE. From this interpretation and from my review of the literature offered in Chapter 2, I draw several implications for practice. Finally, I present a discussion about the lessons I learned by conducting this dissertation study and my suggestions for future research.

### **A Situated Theory of Learning**

After reading through the presentation of themes in Chapter 4, one may question how a theory of learning is appropriate to provide insight into the ways Dejan and Angela

made sense of their team-teaching experiences. Of course, it was clear from the instructors' reflections that Dejan perceived his role as a "student" and Angela perceived her role as a "coach," but this was only a slice of their experience as a whole. In Lave and Wenger's (1991) situated theory of learning, learning takes on a broader meaning, where "learning," and its synonym "meaning-making," are considered inherent elements of social participation. Learning is not restricted to the act or process that occurs when someone is in a teacher/student relationship and "learns" a particular skill or gains a particular understanding through interaction with another. Instead, the situated learning theory, which has been influenced by and also informs social learning theory, posits learning as moving "toward full participation in the sociocultural practices of a community" (Lave & Wenger, 1991, p. 29).

As I explained in Chapter 2, the view of learning as "situated" does not imply learning is restricted to or results from engagement in a particular activity within a particular situation. Instead, learning is a characteristic feature of participation in the shared time, space, history, and culture of a community of practice (Hanks, 1991; Wenger, 1998). Learning is a dynamic process that is both influenced by and influences the structure, principles, and understandings of a community. When individuals engage in practice, they do so within social organizations, and therefore those organizations shape the individuals' learning. Conversely, as individuals gain new understandings, their learning shapes the social organizations for which their membership and engagement are constitutive (Lave & Wenger, 1991; Wenger, 1998).

At the core of the situated learning theory is the synonymous relationship linking the terms "learning" and "meaning." In much of the educational literature, "learning" is

more closely linked with the term “schooling,” and is relegated to a particular process or activity (Lave & Wenger, 1991). However, under the situated learning theory, “our ability to experience the world and our engagement with it as meaningful – is ultimately what learning is to produce” (Wenger, 1998, p. 4). Because I am interested in the ways Dejan and Angela made sense (i.e., meaning) of their experiences, the situated theory of learning provides an informative lens for interpretation in this study.

In my analysis, I view Dejan and Angela as members of distinct communities of practice, in much the same way as they viewed themselves. I view Dejan as a member of the professional community of mathematicians, and I view Angela as a member of the professional community of MTEs. As explained by Hanks (1991), “learning is a process that takes place in a participation framework, not in an individual mind” (p. 15). Consequently, in this analysis, I position Dejan’s meaning-making within the participation framework of the mathematics community of practice and Angela’s meaning-making within the participation framework of the mathematics education community.

Wenger (1998) made a distinction between “communities of practice” and “constellations.” The former is a community characterized by (a) mutual engagement, (b) a joint enterprise, and (c) a shared repertoire (see section “The three dimensions of a community of practice” below). The latter is a group that has stake in a joint enterprise and a shared repertoire, but that is “far removed from the scope of [mutual] engagement of participants” (p. 126). At first glance, Dejan and Angela’s communities of practice might be more aptly described in reference to their actual academic departments within their institution (i.e., the mathematics department and the mathematics education

department). These (departmental) communities of practice are guided by the styles and discourses of broader constellations. In Dejan's case, such constellations include the university's College of Arts and Sciences and the broader community of professional mathematicians. In Angela's case, such constellations include the university's College of Education and the broader community of professional MTEs.

However, because Dejan and Angela regularly positioned themselves as members of the broader mathematics and mathematics education communities, it would be restrictive within this analysis to limit the discussion to Dejan and Angela's experiences as members of their departmental community of practice. Moreover, Dejan and Angela's practice was characterized and influenced by engagement with other mathematicians and MTEs, respectively, across geographic locale. This form of non-geographically situated mutual engagement within communities of practice is common in academia. For this reason, I take the broader mathematics and mathematics education communities as the communities of practice for which Dejan and Angela see themselves as members, but I also recognize that a considerable part of the daily mutual engagement experienced by Dejan and Angela within these communities is relegated to their respective departmental roles.

When Dejan and Angela came together to team-teach, they formed what I will refer to as a "community of interest." A community of interest brings together members of different communities of practice for a particular (and usually temporary) purpose, in what can be considered a "community of representatives of communities" (Fischer, 2001, p. 4). As I consider Dejan and Angela's meaning-making during their team-teaching experiences, I focus primarily on their perspectives from the point of view of their

membership within their respective communities of practice because I believe these perspectives are what can provide insight into the larger phenomenon of collaboration between mathematicians and MTEs.

In the next two sections, I provide an overview of the most important theoretical components of Wenger's (1998) theory related to situated learning and communities of practice. First, I explore the concept of meaning as a duality between participation and reification. Then, I examine the three fundamental dimensions of a community of practice (i.e., mutual engagement, joint enterprise, and shared repertoire). Within each section, I illustrate the concepts using examples from Dejan and Angela's reflections on their team-teaching experiences.

### **Participation and reification.**

I was particularly interested in the ways Dejan and Angela made sense of their experiences as they engaged in a team-teaching collaboration. Because understanding sense-making is the focus of this study, it is important to consider where such sense-making (or meaning) is located. Wenger (1998) proposed that meaning is located in a process he calls "negotiation of meaning" (p. 54), which is characterized by a duality between participation and reification. By "negotiation of meaning," Wenger intended that "meaning exists neither in us, nor in the world, but in the dynamic relation of living in the world" (p. 54). In this section, I describe the two dual components, participation and reification, through which meaning is achieved.

### ***Participation.***

Wenger's (1998) use of the term "participation" is in line with the usual understanding of this term. He explained, "Participation refers to a process of taking part

and also to the relations with others that reflect this process. It suggests both action and connection” (p. 55). Important in his conceptualization of participation is the idea that participation is always situated within social communities. Even if a person is participating in a practice alone, that participation is mediated by and within a broader social community.

Also, if an individual is a participant in a community, that participation does not end when the individual is outside the contextual setting that most aptly characterizes the community’s practice. For instance, Angela is a participant in the mathematics education community even when she joins a group of friends for dinner on the weekend. In this sense, participation and engagement are different concepts. Although Angela may not engage in the typical practices of the mathematics education community when she dines with her friends, her status as a participant of the community does not cease to exist during dinner. In fact, it is not unlikely that her “identity of participation” (Wenger, 1998, p. 56) as a MTE contributes to her interpretation of the conversations that ensue over dinner. Important here is the notion that participation in a community of practice contributes to one’s meaning-making, both within and outside the boundaries of the practice.

***Reification.***

Participation alone is not sufficient to produce meaning. As Wenger (1998) explained, reification is also necessary for an individual to experience meaning. Wenger defined reification as “the process of giving form to our experience by producing objects that congeal this experience into ‘thingness’”(p. 58). Arguing the centrality of reification to a community’s practice, Wenger wrote, “Any community of practice produces

abstractions, tools, symbols, stories, terms, and concepts that reify something of that practice in a congealed form” (p. 59). Reification associates meaning to particular objects or concepts within a community that contribute to the community’s mutual understandings.

The same object or concept may have distinct reifications across different communities. An example from my observation field notes during the instructor’s first planning session illustrates this idea:

Dejan and Angela are working on the syllabus for the Geometry course. They are not creating a new syllabus but instead are revising the syllabus from last semester [Spring 2010]. As they review the previous syllabus, they come to the paragraph on page two under the heading “Instructional Design.” One of the statements in the syllabus says, “There are about 600 exercises in the book and it is our intention to make this course problem-oriented.” Dejan thinks the sentence should be removed from the syllabus, but Angela thinks the sentence is important and should remain. When they discuss this sentence, Dejan is concerned with the first part (i.e., determining the number of exercises in the new book being used this semester). Angela is not as concerned with the number of exercises but more so with the idea that students would be expected to engage in a problem-oriented instructional design. (S. Bleiler, Instructor planning session field notes, 08/21/10)

Having experience as a doctoral student studying mathematics education, I understood the term “problem-oriented” as reified with particular meaning in the mathematics education community. The term “problem-oriented” typically carries with it the image of a type of learning in which students engage in problems characteristic of the

discipline, receive minimal direct instruction related to procedures for solution, reflect collaboratively with classmates about potential strategies, and construct an understanding of the mathematics derived from their problem-solving approaches (Hmelo-Silver, 2004). Dejan's perception that this sentence was not important to the section of the syllabus designated as "Instructional Design" suggests his reification of the term did not carry such implied meanings.

***Duality of participation and reification.***

It is the complementary interaction between the dual processes of participation and reification that leads to meaning, as is elaborated by Wenger (1998):

Participation and reification cannot be considered in isolation: they come as a pair. They form a unity in their duality. Given one, it is a useful heuristic to wonder where the other is. To understand one, it is necessary to understand the other. To enable one, it is necessary to enable the other. They come about through each other, but they cannot replace each other. It is through their various combinations that they give rise to a variety of experiences of meaning. (p. 62)

There are many instances in Chapter 4 that illustrate the complementary nature of participation and reification, and its influence on Dejan and Angela's meaning-making. For example, Dejan reflected on his experiences of participation with technology during the geometry course. He became frustrated with technology because it frequently did not work in the ways he hoped, and restricted his fluidity of presentation. This led Dejan to reify technology as "static" and to reify his crayons (i.e., white board markers) as "dynamic." This example illustrates how Dejan's participation in the practice of using technology and his related reification of the objects involved in his instructional

presentation led to his ultimate feeling of a loss of control of his instruction when employing new technologies.

Likewise, Angela reflected on the different uses of textbooks in the first geometry course (Spring 2010) and the second geometry course (Fall 2010). Through her participation in exchanges with Dejan, she found their discussions about the textbook in the first course, which was familiar to Dejan, often entailed Dejan defending the choice of the text. However, during the second course the text was new to both instructors, so their exchanges about the book were less defensive. In this sense, Angela reified the text in the first course as a symbol of imbalance between the instructors, but reified the text in the second course as a symbol of equilibrium. This interaction between participation and reification led Angela to attribute an importance to mutuality between the instructors in their dealings with the course textbook.

### **The three dimensions of a community of practice.**

Through analysis of Dejan and Angela's reflections during engagement in their community of interest, I hope to show we can gain insight into their identities as members of their respective communities of practice. To achieve this goal, I utilize Wenger's (1998) notion that "practice is the source of coherence of a community" (p. 72). Wenger delineated three essential dimensions of participation in a community of practice: (a) mutual engagement, (b) a joint enterprise, and (c) a shared repertoire. In the remainder of this section, I provide an overview of the three dimensions and provide examples from Dejan and Angela's collaboration to illustrate the concepts.

### *Mutual engagement.*

The first fundamental component of a community of practice is mutual engagement with other participants in the community.<sup>5</sup> Mutual engagement is not a matter of having a title within a particular community, but of meaningful engagement in practices that shape a shared community (Wenger, 1998). In this sense, it was clear Dejan and Angela viewed themselves as deeply engaged in their own communities. Dejan and Angela's regular use of language such as "us," "them," "educators," and "mathematicians," highlighted their perception of identity and mutual engagement as members of their respective communities.

The actual forms of mutual engagement that characterized Dejan and Angela's practice were quite similar across their respective communities. This is not surprising because both communities are shaped by similar institutional structures and by practices characteristic of the broader "academic" constellation. Typical forms of mutual engagement for Dejan and Angela (with members of their respective communities) included participating at academic conferences, discussing teaching and/or curriculum development with colleagues, reading and/or writing academic literature, and engaging in committee work. Although my investigation of Dejan and Angela's case suggested their

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<sup>5</sup> Here, Wenger's (1998) use of "mutual" carries a slightly different meaning than my use when I described the issue of mutuality between Dejan and Angela in Chapter 4. Wenger uses mutual to suggest "people are engaged in actions whose meanings they negotiate with each other" (p. 73). There is no implication that the engagement is equivalent or balanced in any way, but only that members of the community "very directly influence each other's understanding" (p. 75). In my use of mutuality between Dejan and Angela, I mean to imply a sense of reciprocity and balance (or lack thereof) in the instructors' relationship.

forms of *mutual engagement* were similar across communities, the instructors' reflections indicated significant differences across communities with respect to their *joint enterprises* and their *shared repertoires*.

***Joint enterprise.***

The second fundamental component of a community of practice is a joint enterprise. The joint enterprise of a community is constantly negotiated through the mutual engagement of members in the community and is not typically something that can be documented in a goal statement because many of the understandings are implicit. Moreover, having a joint enterprise does not imply all members are in agreement about the enterprise. The key point is that the enterprise is “communally negotiated” (Wenger, 1998, p. 78).

The joint enterprise of a community becomes part of the identity of the members of the community and “creates among participants relations of mutual accountability that become an integral part of the practice” (Wenger, 1998, p. 78). Wenger termed these relations a “regime of mutual accountability” (p. 81), and provided the following examples of elements of a community's practice that are influenced by the regime of mutual accountability:

what matters and what does not, what is important and why it is important, what to do and not to do, what to pay attention to and what to ignore, what to talk about and what to leave unsaid, what to justify and what to take for granted, what to display and what to withhold, when actions and artifacts are good enough and when they need improvement or refinement. (p. 81)

It was evident from Dejan and Angela's reflections that they felt accountable for upholding the principles they perceived as guiding the joint enterprise of their communities. Dejan believed discussions related to the content of mathematics mattered and that questions related to the structure and content of mathematics should not be "brushed over." He reflected on his "scale of values" in which disagreements about pedagogy were not as problematic for him as disagreements about mathematics. Dejan believed educational literature was in need of improvement, seemingly because its style and epistemology differed from that esteemed in his community.

Likewise, Angela made decisions to pay attention to the pedagogical components of instruction during methods courses, and overlooked some of the mathematical misconceptions displayed by PSMTs. Her approach to teaching placed the students, rather than the content, front and center. In her experience as a coach for mathematics teachers, she recognized when it was important to push Dejan to try new pedagogical strategies, and when to hold back so as not to "throw him off," such as when she considered introducing more technology.

Dejan and Angela also made assumptions about the regime of accountability within their partner's community as influential to their partner's corresponding practice. Recall Angela's reflection on Dejan's resistance to participate in the practices of the mathematics education community because it would be perceived by him as "betraying his mathematical person." She believed Dejan's actions were mediated by a strong sense of accountability to his mathematical community. Likewise, Dejan's reflections suggested an understanding of the mathematics education community's regime of accountability. He viewed educators as disinterested in problems related to the

intricacies of mathematical definitions, suggesting, “These are interesting questions which I think mathematicians would like to think about. Let’s put it nicely (laughter). And for educators, that’s irrelevant. It’s not productive use of the time at all.” These examples highlight Dejan and Angela’s understandings of the joint enterprises guiding the practices of their communities.

*Shared repertoire.*

The third fundamental component of a community of practice is a shared repertoire of resources developed through mutual engagement of community members to support the joint enterprise of the community. A shared repertoire within a community includes “routines, words, tools, ways of doing things, stories, gestures, symbols, genres, actions, or concepts that the community has produced or adopted in the course of its existence, and which have become part of its practice” (Wenger, 1998, p. 83). As an example, Dejan described one of the “ways of doing things” in the mathematics community when he explained that mathematicians usually look for a “clever way,” or a short cut, to solve mathematical problems. Similarly, Angela repeatedly spoke of the need to “convince” PSMTs of the pedagogical strategies espoused in teacher preparation programs. The language used in her reflections, such as “we are trying to sell this” seemed to suggest a routine of convincing that she understood as typical of instruction within her broader community of practice.

In summary, within the previous section, I reviewed Wenger’s (1998) theory related to how meaning is located in the interaction between the dual processes of participation and reification. Then, in this section, I illustrated the three dimensions that characterize a community of practice: mutual engagement, joint enterprise, and shared

repertoire. Using these concepts as the theoretical backbone for thinking about communities of practice and meaning-making, I now provide an interpretive look into Dejan and Angela's team-teaching experiences.

### **An Interpretive Look into Dejan and Angela's Experiences**

Lave and Wenger's (1991) conceptualization of learning as "legitimate peripheral participation," positions learners along a spectrum of participation, from "newcomer" to "old-timer" in the community. A newcomer interested in learning within a community of practice must gain access to the three dimensions that characterize that community: mutual engagement, joint enterprise, and shared repertoire (Wenger, 1998). As an old-timer in the community, one must continually participate in its practices and negotiate meanings that arise in order to maintain membership and redefine practices. Within this research, I view Dejan as an old-timer in the mathematics community and Angela as an old-timer in the mathematics education community.

It was clear that as old-timers in their respective communities, Dejan and Angela's perspectives were mediated by their membership in those communities. I provided several examples of this in the sections above, such as Dejan's focus on topics related to the content and structure of mathematics, and his expectation for finding "clever ways" to engage with the problems of his discipline. Similarly, Angela's old-timer status in the mathematics education community was characterized by her concentration on students' learning as the point of departure in teaching, and by her focus on convincing PSMTs of the value of novel pedagogical practices.

What was also clear from their reflections in Chapter 4 was that each of the instructors viewed Dejan as a newcomer to the mathematics education community. His

newcomer status had significant implications for his meaning-making throughout the collaboration, especially as illustrated by the emergent theme, “Encountering the educational community: Navigating unfamiliar terrain.” Although Dejan had previously taught courses for PSMTs, he certainly did not view himself as a full<sup>6</sup> participant in the mathematics education community coming into this collaboration. However, throughout the collaboration, Angela pushed Dejan to better understand the principles and ideals of her community of practice. Her goal was to move Dejan from agreement as appeasement to agreement as acceptance. To do this, she engaged Dejan in legitimate peripheral participation of the mathematics education community’s practice, highlighting elements of the shared repertoire in the community (e.g., employment of instructional technology, facilitation of collaborative group work) and providing justifications for her practice supported by the joint enterprise in the community (e.g., justifying pedagogical strategies based on students’ prior knowledge). We can think of Angela’s pushing of Dejan from appeasement to acceptance as a form of moving Dejan from peripheral to full participation as a member of the mathematics education community.

Being able to engage with an old-timer in the mathematics education community, learn about the joint enterprise, and utilize the elements of the shared repertoire, prompted Dejan to gain an awareness of the guiding principles of the mathematics education community. Recall Dejan’s reflection related to the influence of his participation in the collaboration, “I’m aware of all these issues which previously were

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<sup>6</sup> Participation as “full” in a community of practice does not mean the individual’s participation is “central” or “expert,” but rather that the individual takes on a role that is relevant to the continual reproduction of that community of practice (Wenger, 1998).

just buried.... I have to stop being selfish from that perspective. It's not about me. This teaching process is about the students.” Through engagement in collaboration with Angela, Dejan recognized the importance of one of the major elements Angela understood to be characteristic of the mathematics education community's joint enterprise, that of framing teaching from a student-centered perspective.

Although Dejan's participation in the collaboration led to his increased awareness about many pedagogical issues (e.g., problem selection, caring interaction with students), there were also times throughout the collaboration when Dejan's engagement in the mathematics education community caused him distress and seemed to limit his potential for learning. These occasions were particularly prevalent during the methods course, when Dejan's encounter with the practices of the educational community caused him to perceive a loss of control and autonomy in his instruction.

Wenger (1998) explained that the objects and concepts that constitute a shared repertoire gain meaning in the community through a “history of mutual engagement” (p. 83) and that they are “inherently ambiguous” (p. 83). Dejan certainly experienced the inherent ambiguity of the practices of the mathematics education community. Such practices are not ambiguous to full members of the mathematics education community because full members share a history of meaning they attribute to the repertoire. As explained by Wenger, “when combined with history, ambiguity is not an absence or a lack of meaning” (p. 83).

Dejan often viewed the literature in education as ambiguous. However, he also recognized that his lack of history and engagement restricted his understanding of the literature, as indicated in his reflection,

Like, you feel like everything goes. Any type of statement is okay, is valid, sometimes. But this is ignorance from my side, talking about it. Because I don't have clear criteria about validation of the methodology, of the statements, you see? (Dejan, individual interview #2)

Angela also recognized the issue of ambiguity stemming from deficient shared history when she explained,

And I think part of our challenge with communicating with them [is] they have no context for what we're saying. And they may not have many opportunities to think about, or read the literature.... So when we say it, it's just foreign. There's just no way for them to interpret it. (Angela, individual interview #4)

Even though Dejan had access to the shared repertoire (in this case, a piece of educational literature), he had not taken part in a history of mutual engagement within the community or developed a thorough understanding of its joint enterprise. Therefore, he found it difficult to derive meaning from his reading of educational literature.

Although Dejan's status as a newcomer in the mathematics education community was apparent, less obvious was Angela's participation status in the mathematics community. Angela was certainly not a newcomer. After all, she had spent a great deal of her professional training in social participation within the mathematics community. She earned her undergraduate degree, and the equivalent of a Master's degree, by taking courses and interacting with old-timers (i.e., mathematics professors) in that community. Through her training, she had gained access to all three components of practice that facilitate meaning in the community.

Neither should Angela be considered an old-timer in the mathematics community. For one, she did not engage regularly in practices that characterize mutual engagement in the community, such as attending/presenting mathematics seminars or teaching mathematics content courses. Also, there were instances throughout the collaboration when Angela sought an explanation from Dejan for what was likely Dejan's tacit understanding of the shared repertoire within his own community, suggesting Angela did not have an "old-timer" understanding of that element of the shared repertoire. For example, in the following extract, Angela reflected on a time when she presented a proof in class and Dejan became distressed because her proof departed from what he expected.

The proof [was] clean, worked out, but he says, "Well I typically choose if I'm going to prove something, I'm going to prove it with the theorem. And I said in class, "So are you saying it's more right because you proved it with the theorem versus the corollary?" He says, "No no no. What you did is right, but why not use the main theorem?" I said, "Does it matter whether I use the main theorem, as long as I provided a logical proof?" .... I said, "Do you have to use the big theorem?" He says, "No." I said, "So why is it bothering you that I used [the corollary]?" [He said], "Typically you go with the big one." I said, "Dejan, you are not giving me a reason. Is there a mathematical reason why you have to use the big [theorem]?" [He replied], "Well no, but I just expected you to do this." And I said, "Well you didn't tell me that." (Angela, individual interview #1)

It is probably most appropriate to refer to Angela as a "broker," between the communities of mathematics and mathematics education. Brokering, as defined by Wenger (1998), is characterized as "connections provided by people who can introduce

elements of one practice into another” (p. 105). Dejan’s reflections suggested he viewed Angela as a broker between the mathematics education and mathematics departments at their university,

We [mathematicians in the department] have not paid attention to teaching, unless she [Angela] was actually involved in some sense. I mean, it started a long time ago when she came to the department and said, “Well,” again in this not so direct way, “we need a different type of approach to the education courses, not just the way you have dry, definition, theorem.” (Dejan, individual interview #1)

Angela also viewed herself as a broker, although she never used this term. By introducing the practices and principles of the mathematics education community to Dejan, she hoped to achieve a multifaceted goal of (a) improving Dejan’s pedagogical practice, (b) facilitating Dejan’s understanding of the expectations for PSMTs in the College of Education, and (c) forming a united front with Dejan to send a single, coherent, and meaningful message to PSMTs.

As explained by Wenger (1998), “The job of brokering is complex. It involves processes of translation, coordination, and alignment between perspectives” (p. 109).

This complexity was captured by Angela when she described the synchronization of perspectives that she needed to maintain while providing rationales for her practice,

...when you collaborate with somebody and they are thinking about content coverage then you have to not only negotiate with them, but justify your thinking.... If I were in my own classroom, I would just do it that way because I’m using my professional judgment, because that’s how it ought to be done....

[But here] I needed to provide a rationale that would be palatable to him too.

(Angela, individual interview #2)

Wenger (1998) continued to describe the inherent difficulties of brokering, suggesting that brokering “requires an ability to manage carefully the coexistence of membership and nonmembership, yielding enough distance to bring a different perspective, but also enough legitimacy to be listened to” (p. 110). In order to be successful as a broker, Angela believed she needed to prove her mathematical abilities to Dejan. Although she had a sufficiently different perspective from Dejan, and therefore would be able to contribute something new to his practice, she perceived that Dejan had reservations about her level of legitimacy as a member of the mathematics community.

Angela also struggled throughout the collaboration because she felt she was not able to articulate the tacit understandings and rationales supporting the practices of her community, what Wenger (1998) would refer to as the “regime of mutual accountability.” By the end of the collaboration, Angela accepted the idea that she could not explicate all tacit understandings because these understandings came from years of participation in her community, and characterized the “professionalization” of the community. Her theory is supported by Wenger (1998) who explained,

Becoming good at something involves developing specialized sensitivities, an aesthetic sense, and refined perceptions that are brought to bear on making judgments about the qualities of a product or an action. That these become shared in a community of practice is what allows participants to negotiate the appropriateness of what they do. (p. 81)

As I observed Angela throughout the semester, and spoke with her about her desire to be able to communicate a more explicit understanding of her community, I found myself questioning the expectations she had for herself with respect to providing rationales for her practice. Whereas Angela frequently perceived she was unable to sufficiently reveal the rationales supporting her practice, I thought she was quite successful at explicating aspects of practice in the mathematics education community. The following exchange between Angela and myself during her second individual interview reveals our differing perspectives in relation to this issue:

S: I hope that I can become like you are, like being able to provide arguments for *everything*.

Angela: See, it's funny, because I'm sitting here thinking that I didn't do enough of it.

S: Yeah, no, for everything that comes up you can spit out an argument. I'm like, "Oh my gosh." It amazes me.

Angela: ... It's funny that you say that because I [was] sitting there like, "I didn't do that well enough." Maybe there are other things I wish I could say but I don't, so I give the best argument. But I'm thinking there is a whole lot more I should be able to articulate but I don't know how.

S: I was really interested when I was reviewing your first interview and you were talking about how you thought all of this was coming from your gut. Well when I hear you speaking, it doesn't sound like that.... A lot of what you say is in the literature, you're just framing it sort of. (Exchange between Angela and S. Bleiler, individual interview #2)

Angela and I had very different interpretations of her success in explication of the practices of the mathematics education community. In thinking about these differences with respect to Wenger's theory, I was able to make greater sense of Angela's experience. As explained by Wenger (1998),

The regime of accountability becomes an integral part of the practice. As a result, it may not be something that anyone can articulate very readily, because it is not primarily by being reified that it pervades a community. Even when the enterprise is reified into a statement, the practice evolves into a negotiated interpretation of that statement. (p. 81)

Therefore, I believe it is likely that Angela's frustration did not stem solely, or even primarily, from her inability to explicate her practice, but rather from the fact that reifying her practice into objective statements did little more to contribute to Dejan's understanding. Angela's reifications made sense to me, but I had a history with and understanding of the literature and practices in the mathematics education community. Because Dejan did not have a history of participation in the community, and therefore did not have a solid grasp of the community's joint enterprise and shared repertoire, Angela's reifications did not carry the same "negotiated" meanings for Dejan as they did for Angela or me, leading her to feel as if she was not adequately explicating her practice.

One of the reasons Angela took her role as a broker so seriously was because she believed that if she could influence an old-timer in the mathematics community (i.e., Dejan) to communicate with other old-timers in the community (i.e., other mathematicians in the department) about the needs of PSMTs, those old-timers may be

more inclined to take the information seriously and consider making changes. Recall Angela's reflection,

I think if he has, as a mathematician, a better understanding of what we need our students to do as teachers, he can then, not be an advocate for, but he can, you know, share that [information]. He can be a mathematician talking to other mathematicians about the College of Ed students' needs. Because I think sometimes when it comes from us, it's like, "Sure of course, what else would she say?" But to hear it from another mathematician, the potential for that. (Angela, individual interview #3)

Angela believed that if she, as an outsider of the mathematics community, could influence the understandings and practices of an old-timer in the community, there would be a potentiality for a ripple effect throughout the community. Angela's perspective is supported by Wenger (1998) in the following description of community generation:

the inclusion of new members can...create a ripple of new opportunities for mutual engagement; these new relationships can awaken new interests that translate into a renegotiation of the enterprise; and the process can produce a whole generation of new elements in the repertoire. Because of this combination of an open process (the negotiation of meaning) and a tight system of interrelations, a small perturbation somewhere can rapidly have repercussions throughout the system. (p. 97)

In Dejan and Angela's case, Dejan has since taken on the role of "liaison" between the mathematics and mathematics education departments at their university. Angela's brokering throughout their team-teaching collaboration allowed Dejan access to

the mutual engagement, joint enterprise, and shared repertoire of the mathematics education community, and therefore facilitated his ability to take on a newfound role as broker between the two communities.

Throughout our interviews, both Dejan and Angela repeatedly referred to mutuality as a key issue influencing their collaborative experience. Although they used different language when speaking about this concept (e.g., Angela referred to “give and take” and Dejan referred to “symmetry”), both instructors perceived the reciprocity of their interactions as a meaningful component of their experiences.

Using the terminology of the situated learning perspective and Wenger’s theory of communities of practice, we can think about the instructors’ interactions within both courses (i.e., Geometry and Teaching Senior High School Mathematics) as instances of “boundary crossing.” During the mathematics content course, Angela crossed the boundaries of her typical practice and entered a context characterized by the practices of the mathematics community. During the methods course, Dejan crossed the boundaries of his typical practice and entered a context characterized by the practices of the mathematics education community. Such boundary crossing, akin to brokering, is complex and can lead to varied outcomes. As explained by Wenger (1998), “By creating a tension between experience and competence, crossing boundaries is a process by which learning is potentially enhanced, and potentially impaired” (p. 140). We saw examples of both enhanced and impaired learning during Dejan and Angela’s boundary crossing.

One of the main issues perceived by Angela as a constraint in their collaboration was the lack of “give and take” between the instructors during the methods course. As I discussed above, Dejan did not have a history of participation in the community, and

therefore had little understanding of the joint enterprise and shared repertoire of the community as he initially crossed boundaries. Therefore, at first glance, the situated learning theory would suggest that Dejan's access to participation in the community (e.g., as a co-instructor of the methods course) should lead to his increased learning of that community. As Lave and Wenger (1991) explained, "To be able to participate in a legitimately peripheral way entails that newcomers have broad access to arenas of mature practice" (p. 110).

There is no doubt Dejan had broad access to the practice of MTEs as he took on the role as an instructor in the methods course. However, as Lave and Wenger (1991) went on to explain, in order for learning to be successful, newcomers should gain scaffolded access to the practices of the community,

At the same time, productive peripherality requires less demands on time, effort, and responsibility for work than for full participants. A newcomer's tasks are short and simple, the costs of errors are small, the apprentice has little responsibility for the activity as a whole. (p. 110)

This idea of scaffolding was difficult to implement in Dejan and Angela's collaboration because the terms of the collaboration required Dejan to be a co-instructor of the methods course, which automatically put him in a position of expert, rather than newcomer. Angela recognized this problem, and attempted to use planning sessions as a time to introduce Dejan to the principles and ideas characterizing the methods course. However, without a history of mutual engagement in the community, Dejan could not reasonably be expected to experience those ideas with a similar level of meaning as Angela had developed through her years of "negotiated" meaning-making.

Although Angela tried to explicate the practices of the mathematics education community, it did not often result in Dejan's increased self-efficacy as an instructor in the methods course. Wenger (1998) provided a hypothesis for how mutuality between individuals involved in boundary crossing can act as a source of increased learning,

It is useless to try to excise all ambiguity; it is more productive to look for social arrangements that put history and ambiguity to work. The real problem of communication and design then is to situate ambiguity in the context of a history of mutual engagement that is rich enough to yield an opportunity for negotiation. (p. 84)

According to Dejan and Angela, the context that yielded a greater opportunity for negotiation was the geometry course. Recall Angela's reflection on the equilibrium she perceived between the instructors in the geometry course,

We laughed a whole lot more in the geometry collaboration. We did. And I'm not saying we didn't enjoy ourselves now.... I think part of it, with the geometry, is [there was] more give and take between the two of us.... We both had buy-in to the course. We both had our views about the course. We both can contribute to the course. So we talked about it, disagreed about it. (Angela, individual interview #4)

Likewise, during our final group interview, Dejan and Angela exchanged their perceptions related to the differences between the geometry course and the methods course. This extract demonstrates how even when they disagreed during Geometry, they viewed it as a productive disagreement because both instructors could contribute their perspectives to the discussion.

Dejan: But the previous semester [in Geometry], I mean, yes, we disagreed, but that was kind of, from my perspective, a joyful disagreement.

Angela: It was engaging because you had give and take.

Dejan: Yes it was. Pretty much like two kids, because I felt like, “Okay, I’m on top of this so let me see what she [Angela] can come up with. And then I would go home and [share with my family], “You know what she said? You know what she did today?” This semester [in the methods course], no way, no games, no play. I was just kind of, “Oh my gosh, today,” and, “Okay, you are definitely in charge of that.” And on the other side, I was thankful that you were in charge.

(Dejan and Angela, group interview #2)

Both instructors had a history of participation and an understanding of many of the reifications that hold meaning within the mathematics community. Being introduced to elements of the mathematics education community within the context of the geometry course was perceived by Dejan as particularly effective for his professional growth. Dejan felt he was able to experiment with some of the strategies “brought” to the course by Angela, and at the same time maintain allegiance to the regime of accountability within his community. He was able to talk about or model novel pedagogies when deemed appropriate, but was also able to maintain a focus on the coverage of mathematical content, which he perceived as critical for upholding the regime of mutual accountability within his community.

This was not the case within the methods course. Recall how Dejan voiced concern about the way topics were addressed in the methods course,

... sometimes I feel like I wish my questions were answered readily. Like...what is the pedagogical value of this example specifically? If it's kind of combinatorial? In how many ways can you do this and this and this? Rather, some of what happened so far I see only as an instrument for students to socialize, to make friends, conversation, collaborate.... (Dejan, individual interview #3)

Dejan perceived a lack of focus on the content and structure of mathematics within his and Angela's collaboration. In particular, within the methods course, he sought mathematically-supported rationales for the proposed pedagogical strategies. However, what he found was that many of the rationales provided to PSMTs (and to himself) during the methods course stemmed from a joint enterprise focused on facilitating collaboration and discussion among students. It was in such situations that it became clear that the primary driving forces of what Dejan and Angela perceived as their community's regime of mutual accountability were in contrast.

In this section, I presented my interpretation of the ways Dejan and Angela made sense of their team-teaching experiences, using the situated learning theory (Lave & Wenger, 1991; Wenger, 1998) as my interpretive lens. In line with the tenets of IPA, my goal in venturing "outside" the data in this way was to provide insight into the instructors' experiences using a theoretical lens that broadens our understanding of the individual context in which this case is situated. I now turn to the related implications for practice that stem from the presentation of emergent themes in Chapter 4, the associated interpretation of Dejan and Angela's experiences in this chapter, and the findings from my literature review in Chapter 2.

## **Implications for Practice**

One of the most pervasive findings from this research was that Dejan and Angela perceived their participation in the team-teaching collaboration as influential to their professional development as teacher educators. This finding is aligned with the extant literature related to team-teaching in higher education, which has demonstrated team-teaching leads to an increased level of reflection when compared to teaching by oneself (Albrecht, 2003; Crow & Smith, 2005; Lester & Evans, 2009; Patterson et al., 2008). Dejan and Angela increased their level of reflection on their own practices as well as on the practices they perceived as characteristic of their communities. This was most evident in the depiction of Dejan's theme, "Pedagogical transition: Reflecting on my teaching practice," and Angela's theme, "Articulating tacit disciplinary knowledge: Collaboration as a catalyst for reflection on practice."

Viewing learning under the situated perspective, as broader than a formal teacher/student or mentor/mentee relationship, opens up the realm of possibilities for how we think about the professional development of future and current faculty involved in mathematics education. As Wenger (1998) explained, "our perspectives on learning matter: what we think about learning influences where we recognize learning" (p. 9). In viewing learning as that which occurs through participation in practices of a community, we can more easily recognize and explain the professional learning that occurs through social participation in team-teaching.

Team-teaching seemed to be particularly powerful as a mode of professional development for Dejan, a mathematician who had little formal education related to pedagogy or teacher preparation. As Dejan explained to me during our first individual

interview, the primary means by which he learned to teach was through imitation of his own professors. We saw through his reflections that team-teaching led Dejan to assess the quality of his pedagogical approach, and to attend in a more central way to the needs of the PSMTs as learners. Similarly, Nardi et al. (2005) and Nardi (2008) demonstrated how mathematicians increased their “pedagogical awareness” as a result of reflective discussions (in the form of interviews) with a MTE related to student work samples and important issues in mathematics education.

Mathematics departments across the United States are under increasing accountability pressures to attend to teaching quality in university-level mathematics courses (Madison, 2006; NRC, 2003; Nardi et al., 2005; Steen, 2006) as well as to recognize and attend to the unique needs of PSMTs (Beckmann, 2011; CBMS, 2001, 2012). However, it is not uncommon for mathematicians to progress throughout their graduate education with little focus on pedagogy, teacher preparation, or the current context of school mathematics, much like Dejan (Darling-Hammond et al., 2005; Nardi et al., 2005). Collaboration with MTEs through team-teaching should be recognized as a valuable source of professional development that can lead to mathematicians’ increased awareness of pedagogy and the needs of PSMTs.

In the current context of school mathematics, 45 of 50 states in the United States have adopted the Common Core State Standards (CCSSI, 2010) to guide the mathematics curriculum at the elementary and secondary level. These standards could serve as a valuable (and common) point of discussion for mathematicians and MTEs across the United States. As shown in this case study, collaboration through team-teaching has the

potential to foster in-depth discussions between mathematicians and MTEs about important issues related to teacher education and the context of school mathematics.

Although Angela's primary goals throughout the collaboration were related to coaching Dejan, she too perceived team-teaching as influential for her professional development. For one, Angela's collaboration with Dejan provoked her to reconsider the expectations she had for university level mathematics courses, and to recognize some of the barriers to inquiry-based learning faced by mathematicians in that context. A similar realization was experienced by the MTEs in the team-teaching collaboration depicted by Thompson et al. (in press). In order for collaboration between mathematicians and MTEs to be effective, both groups need to have realistic expectations and understandings of the structural restraints of their communities. In this sense, team-teaching can serve as a potential window through which members of each community can gain an insider perspective on the structure and context of the other community.

In addition to broadening her awareness of structural restraints in mathematics courses, Angela's participation in the collaboration led her to reflect to a greater extent on her own practices and the practices of her community. Through team-teaching, Angela was forced to explicate her practices in a way supported by the joint enterprise of her community, but that would also be accepted by Dejan, an outsider of the community. In this process, Angela discovered that many of the practices characteristic of the mathematics education community are tacitly understood. She believed the community had shared goals, but that these were "accidental almost," and that they were not based on explicitly documented principles.

In a recent lecture by Deborah Ball at the 16<sup>th</sup> Annual Conference of the Association of Mathematics Teacher Educators (entitled “(How) Can Mathematics Teaching Be Taught?”), Ball provided a compelling argument to a room full of MTEs that they, as a community, do not share a common professional language (also see Ball & Foranзи, 2011). Angela’s reflections suggested that she experienced this problem firsthand as she attempted to explicate her practice,

...as a community it made me realize [that] we [mathematics educators] don’t articulate those assumptions in terms of what those expectations are in a clear manner, in terms of shared community.... For example, a lot ... of the courses we [teach] are individually developed. [Is] there a common sense of goals that we share across the community? We do, but I think it’s accidental almost, rather than purposeful. Do you know what I mean?... So, for some reason, working with him [Dejan] last semester made me realize, there [are] a lot of assumptions in what we do that we don’t make explicit. (Angela, individual interview #1)

In her lecture, and in a related online seminar series (Ball & Foranзи, 2011), Ball argued that although all MTEs are concerned with preparing teachers for practice, certain impediments restrict the community’s ability to work “collectively” and “cumulatively” toward that goal. These include the community’s “tendency to describe instructional competence in large global terms,” the notion that there is “no consensus about a set of specific instructional practices that are essential for beginners to be able to carry out,” and the “impoverished vocabulary for describing, teaching, and assessing teaching” (Ball & Forzani, 2011, p. 12). Consequently, Ball recommended that developing a shared language among MTEs needs to become a priority in order for members of the

mathematics education community to more effectively build on each others' understandings. This research demonstrates the importance of developing a shared language within the mathematics education community as a means of facilitating communication and collaboration with those outside the community as well.

I used the situated learning theory to highlight the importance of participation and reification as dual processes contributing to Dejan and Angela's meaning-making throughout the collaboration. The context of the geometry course seemed to be particularly well suited to support the negotiation of these two processes because both instructors had a shared history of engagement in the mathematics community, and therefore had at least a peripheral understanding of the joint enterprise and the shared repertoire within that community.

For those interested in pursuing team-teaching, or other forms of collaboration across the mathematics and mathematics education communities, it may be prudent to situate the collaborative efforts in a context in which collaborators share a history of engagement (Wenger, 1998). As demonstrated in this study, mutuality in the form of reciprocity and balance were key elements that facilitated the instructors' collaboration, and were most aptly facilitated in a context where both instructors shared a history of mutual engagement. Because MTEs typically have experience as members of both communities, it may ease collaborative efforts to begin within a context that is more familiar to mathematicians, such as a mathematics content course. However, this is not to suggest that team-teaching, or other forms of collaboration, within a mathematics education context should be avoided. What is most important is that collaborators are

aware of and plan for the challenges that could arise if “productive peripherality” (Lave & Wenger, 1991, p. 110) or access to mutuality is neglected within either context.

Angela’s status as an old-timer in the mathematics education community and a (peripheral) participant in the mathematics community made possible her role as a broker between the two. Brokers, who are necessarily members of both communities, are in a position to provide access to the mutual engagement, joint enterprise, and shared repertoire of one community to members of the other community. In order to facilitate communication and collaboration between the mathematics and mathematics education communities, we need more people who can serve as brokers. All of the anecdotal reports of team-teaching collaborations between mathematicians and MTEs I reviewed in Chapter 2 were perceived by the instructors as beneficial for their own development and for the development of their students, and likewise, all of these collaborations were facilitated by someone who took the initiative to act as a broker between the communities (Heaton & Lewis, 2011; Grassl & Mingus, 2007; Sultan & Artzt, 2005; Thompson et al., in press). Wenger (1998) suggested certain people may be better suited to take on the challenges of brokering,

Although we all do some brokering, my experience is that certain individuals seem to thrive on being brokers: they love to create connections and engage in “import-export,” and so would rather stay at the boundaries of many practices than move to the core of any one practice. (p. 109)

Members of both communities should make recruitment of such brokers a priority. In the same way as it has been recommended that mathematicians should look for and recruit successful undergraduate mathematics majors to enter the teaching

profession (CBMS, 2001; Common Ground Conference Report, 2006), it is also critical for mathematicians to recognize the potential for brokering in graduate students studying mathematics who may have an inherent interest in education. Such students should be encouraged to seek programs that help them gain access to the mathematics education community.

A parallel recommendation should be made to members of the mathematics education community. It is generally the case that doctoral students studying mathematics education have engaged in some level of participation with old-timers in the mathematics community, though that level of participation varies greatly across and between programs (Reys, Glasgow, Teuscher, & Nevels, 2007). For those students who have less background experience participating as members of the mathematics community, MTEs should encourage them to find opportunities to engage in mutual participation with members of the mathematics community. Some possible ways this can be accomplished is by earning additional graduate credit in mathematics, collaborating on research projects with doctoral students or faculty in the mathematics community, or team-teaching in mathematics content courses with old-timers (e.g., doctoral students or faculty) in the community. For those students who have significant experience participating in the mathematics community, they should be encouraged to maintain contact with old-timers, and to continue to participate peripherally in the mathematics community.

Another key finding from this research was the pervasiveness of the “regime of mutual accountability” as a force within Dejan and Angela’s collaboration. Wenger (1998) explained that,

A one-on-one conversation between two members of two communities involves only the boundary relation between them. The advantage of such private conversations is that interlocutors are by themselves and can therefore be candid about their own practices in an effort to advance the boundary relation. (p. 112)

So why did the “regime of mutual accountability” seem to have such an ubiquitous influence in Dejan and Angela’s collaboration? Although at first glance Dejan and Angela’s collaboration appears to fit Wenger’s criterion, as a one-on-one interaction between the two instructors, the research procedures transpiring in the background likely had an influence on the dynamics of their collaboration. In particular, as a researcher I regularly documented the interactions between Dejan and Angela, whether during planning sessions, class sessions, or instructor interviews. In addition, members of the KnoTSS research team also documented the collaboration through interviews and transcriptions of audio recordings from instructor planning sessions. Therefore, the “candidness” Wenger theorized would evolve from one-on-one interactions was not realistic in this setting.

In fact, at the end of his first individual interview, Dejan revealed how he perceived my participation as influential to his perception of the collaboration, “You change the equation. Me and Angela, we had last semester [on our own]. And suddenly, with your arrival, everything is kind of more official” (Dejan, individual interview #1). The KnoTSS team collected data (audio recordings and phone interviews) from the inception of the instructors’ collaboration. Therefore, what seemed to be most influential in Dejan’s perception of the research being “more official” was my presence and observation within planning sessions and class sessions. It is possible that for

collaborations in which instructors' perceptions and actions are not under constant observation, they may be able to let down their guard in relation to the regime of mutual accountability in their community, more readily facilitating the crossing of community boundaries.

Although this research, and the anecdotal accounts reviewed in Chapter 2 (Heaton & Lewis, 2011; Grassl & Mingus, 2007; Sultan & Artzt, 2005; Thompson et al., in press), suggest team-teaching between mathematicians and MTEs is an effective means of opening communication between the two groups, such collaborations are not realistic in terms of large-scale implementation across teacher preparation programs. As described previously, Dejan and Angela's collaboration was supported by an NSF-funded grant, and therefore one of the instructors was "bought out" of a course each semester. Without such grant support, departments would likely find team-teaching to be a financial hardship. Therefore, it is important to think about other avenues for collaboration and communication between the groups, and to think about how the findings from this study could inform such collaborations.

One possible starting point is related to what Star and Griesemer (1989) referred to as "boundary objects," which they defined as "objects which both inhabit several intersecting social worlds...and satisfy the informational requirements of each of them" (p. 393). Boundary objects are valuable as common sources of communication across communities and have as their purpose the bolstering of coherence across communities. Examples of such boundary objects that have fostered communication between the mathematics and mathematics education communities are the *Mathematical Education of Teachers* reports (CBMS, 2001, 2012), and the reports stemming from the "Common

Ground” conferences (Ball et al., 2005; Common Ground Conference Report, 2006). Not only were these documents crafted through collaboration among mathematicians and MTEs, but the intended readership for these documents was purposefully specified for members of both communities.

Because the purpose of boundary objects is to develop a shared repertoire and provide insight into the joint enterprise of both communities, the production and dissemination of boundary objects should become a priority for members of both the mathematics and mathematics education community as a means of developing shared meanings. This recommendation is supported by Nardi (2008) who illustrated how the mathematicians in her study also struggled to read and interpret educational literature because of its unfamiliar jargon and epistemology. Nardi argued that the lack of shared venues for publication in the mathematics and mathematics education communities hinders communication and interaction between their members.

Boundary objects can serve as valuable means of communicating and coordinating across communities; however, such objects are necessarily reified with particular meanings by each individual who interacts with them. If the joint enterprise of two communities is sufficiently different, as Dejan and Angela perceived within their communities, then meanings attributed to boundary objects may also be sufficiently different to hinder productive communication (e.g., recall Dejan and Angela’s differing reifications of the term “problem-oriented”). For this reason, it is important to combine both reification and participation to facilitate meaning-making when crossing boundaries. In fact, Wenger (1998) suggested,

...it is often a good idea to have artifacts and people travel together.

Accompanied artifacts stand a better chance of bridging practices. A document can give a less partial view of a topic, and person can help interpret the document and negotiate its relevance. (pp. 111-112)

We saw an example of this in Dejan and Angela's collaboration, when Angela attempted to translate meanings to Dejan during planning sessions as he was "reading and reacting" (Angela, individual interview #3) to the methods course textbook and other types of educational literature. In her final individual interview, Angela reflected on alternative approaches she had considered for helping Dejan (and mathematicians in general) better understand the educational community.

Angela: I'm like, "Would you give a reading list?" And if you did that, they [mathematicians] may not be interested because there is nothing there to help them understand the reading. As Dejan says, "It's just a lot of words." You know? (laughter)... Because I've thought a lot about...having a methods course for mathematicians, but I don't think that would be authentic. Even if you have a group of mathematicians, and you try to teach them the methods, I don't think that will work.

S: And how come?

Angela: Because I think that part of Dejan's insightfulness came from the reactions of the students. I think they would reinforce each other.... He's seeing what their needs are, how they're interacting.... He sees why they're responding one way or the other... the things that they raised pushed him to think further. (Angela, individual interview #4)

Although Angela considered alternative approaches such as providing a reading list, or developing a methods course for mathematicians, she recognized the importance of participation in the actual practices of the community (e.g., interaction with students in the methods course) as a key contributing factor to Dejan's learning. In this sense, when mathematicians and MTEs are considering possibilities for collaboration, it is important to ensure a context in which both participation and reification are key components of the experience. There are several possibilities for collaboration that make use of participation and reification, and that may be more feasible than team-teaching on a large scale.

One possibility would be for MTEs to open up their classrooms for observation by mathematicians, or vice versa. An empathetic stance between the communities may be fostered if mathematicians and MTEs can gain a better understanding of the goals and contextual factors driving practice in courses within the "other" community (e.g., Angela's awareness of the contextual restraints of university-level mathematics courses, or Dejan's awareness of the unique mathematical needs of PSMTs). Actively reflecting on course sessions, in a format similar to lesson study (Kamen et al., 2011), could open discourse between the two communities in a way that both mathematicians and MTEs can make valuable contributions. Although lesson study has primarily been utilized at the K-12 level, Kamen et al. (2011) demonstrated the potential of lesson study as a source of professional development for faculty involved in mathematics teacher education.

We could think of this lesson-study type collaboration as "opening of a periphery" (Wenger, 1998, p. 117). Such boundary crossing is particularly well-suited for providing a venue for participation and reification in cases where individuals are "not

on a trajectory to become full members” (p. 117). Members of both communities can learn about the other through observation and discussion, but not feel responsibility for taking on the role of an old-timer in the community. Moreover, observation in courses could provide an access point for more central participation in the community at a later time, as suggested by Angela when she proposed mathematicians may benefit from “sitting in” a methods course *before* serving as a co-instructor.

As another example, mathematicians and MTEs might begin a “book-club” type seminar at their institution wherein all members read a piece of literature of interest to both groups and discuss (a) their interpretations of the main messages/information contained in the literature, and (b) how they could use the information to inform their practice as teacher educators. The brokers within such a community of interest could help clarify differing perspectives and negotiated meanings across communities. Such discussions related to topics of concern in teacher education, or other topics of common interest, have been perceived by mathematicians and MTEs in several other studies as valuable for informing instruction and leading to increased pedagogical awareness of the mathematicians involved (Nardi et al., 2005; Nardi, 2008).

One possible research program that could be useful as a resource to prompt discussions between mathematicians and MTEs in relation to the needs of prospective teachers is the collection of articles written by Deborah Ball and her colleagues related to mathematical knowledge for teaching (e.g., Ball, 2003; Ball & Bass, 2000; Ball et al., 2001; Ball et al., 2008). These research articles highlight the unique mathematical knowledge necessary for teaching, and therefore should be of concern to both mathematicians and MTEs.

Ball et al. (2008) distinguished two types of *content* knowledge necessary for teaching mathematics: (a) common content knowledge (CCK), which is the mathematical content knowledge common to all people well-versed in mathematics, and (b) specialized content knowledge (SCK), which is the mathematical content knowledge unique to the practice of teaching. The distinction between the two categories of content knowledge is an important understanding for faculty who teach courses for prospective teachers. Bass (2005) likened the SCK needed for teaching to a form of “applied” mathematics, much like that offered in courses such as Engineering Calculus or Mathematical Biology. Mathematicians and MTEs could benefit from discussing the specific examples provided in the educational literature that have highlighted the applied mathematics knowledge needed for teaching.

Ball et al. (2008) also distinguished between two types of *pedagogical content* knowledge for teaching mathematics: (a) knowledge of content and students (KCS), which is knowledge about common conceptions and misconceptions students hold about mathematics and how they learn mathematical concepts, and (b) knowledge of content and teaching (KCT), which is knowledge about the sequencing, representation, and presentation of mathematics that is most effective for enhancing student learning. I believe it is also important for mathematicians and MTEs to read about and reflect on the differences between these two categories of pedagogical content knowledge. In observing and documenting Dejan and Angela’s collaboration, I found that during their discussions related to pedagogy the instructors tended to focus on different aspects of pedagogical content knowledge. Dejan’s primary focus was centered on KCT, while Angela’s primary focus was centered on KCS. That is, even when both instructors were

engaged in discussion about “pedagogy,” their reifications of that concept tended to take on different meanings. If members of both communities have a language through which they can speak about these differences in perspectives during collaborative encounters, communication may be better facilitated.

In summary, this research demonstrates the potential of team-teaching as a valuable source of faculty professional development. Organizations such as CBMS (2001; 2012) and NCTM (2000) have argued the importance of mathematicians increased participation and awareness of issues in teacher education. In this study, Dejan and Angela worked together toward this goal, and Dejan obtained a greater understanding of the mathematics education community and the learning needs of PSMTs. However, this case study also demonstrated some of the challenges to collaboration, such as when Dejan and Angela perceived themselves as lacking in mutuality or in a shared history of participation. Those interested in fostering collaboration between members of these two groups can learn from this study through an increased awareness of the complexities involved in boundary crossing, the value of “brokers” in the collaborative process, the importance of both participation and reification as components of collaborative experiences, and the significance of mutuality as a driving force in collaborative relationships. In the next section, I continue to build on the findings from this study, and from the extant literature, to propose suggestions for future research.

### **Suggestions for Future Research**

In this interpretative phenomenological case study, I investigated one case of a team-teaching teaching collaboration between a mathematician and a MTE. My goal was to understand the ways Dejan and Angela made sense of their team-teaching experiences

within their specific context of a mathematics content and mathematics methods course for PSMTs. In this section, I present suggestions for future research that build on the findings from this IPA analysis and discuss possible considerations for those interested in researching similar phenomena.

As I argued in Chapter 1 and Chapter 2, the majority of extant literature related to collaborative efforts between mathematicians and MTEs has focused on the resultant products of collaboration, and has given little attention to the process of collaboration. In this study, I presented an in-depth look into the process of collaboration in one particular team-teaching arrangement between a mathematician and a MTE. Replication of this study in other collaborative contexts could build on the findings presented here and extend the field's understanding of the collaborative process.

I encourage those who plan on researching collaboration between mathematicians and MTEs, whether in the form of team-teaching (e.g., Heaton & Lewis, 2011; Grassl & Mingus, 2007; Sultan & Artzt, 2005; Thompson et al., in press), national “common ground” meetings (Ball et al., 2005; Common Ground Conference Report, 2006), building of innovative programs/courses in teacher preparation (e.g., Eaton & Carbone, 2008; Kehle et al., 2005; Williams, 2005), or some other form of collaboration, to envisage the possibilities and opportunities for learning about the process of collaboration within such arrangements, and to not attend solely to the products that result from them. Interpretative phenomenological analysis (Smith et al., 2009) is a methodological approach that can aid researchers in exploring the meanings collaborators attribute to their experiences in any of the aforementioned collaborative formats. Furthermore, I believe the language and theoretical tenets of the situated learning theory (Lave &

Wenger, 1991; Wenger, 1998) can serve as a means for researchers to build on this inquiry and conceptualize the commonalities and differences across collaborative contexts.

I discussed in Chapter 1 that this team-teaching collaboration was one of four between mathematicians and MTEs at institutions across the United States (supported by the NSF-funded KnoTSS grant). I believe a natural extension of this work would be to investigate the phenomenological experiences of instructors across the four teaching teams. In the analysis of Dejan and Angela's case, I used the situated learning theory to highlight certain aspects of Dejan and Angela's unique experiences that could provide insight into the larger phenomenon of collaboration between mathematicians and MTEs. For example, Dejan and Angela's reflections demonstrated (a) the importance of the dual process of participation and reification to facilitate learning and meaning between instructors, (b) the ways in which a lack of shared history can hinder communication between collaborators, and (c) the complexities of brokering and crossing boundaries between these communities. A cross-case analysis that employs the same interpretive lens could provide a more comprehensive understanding of some of the dynamics of collaboration between members of the mathematics and mathematics education community across various team-teaching contexts.

In addition, with respect to the initial research questions guiding the study, a cross-case analysis could provide a more general understanding of (a) the ways mathematicians and MTEs make sense of their similarities and differences in relation to their perceptions of teaching and learning, (b) the ways mathematicians and MTEs make sense of their roles within teaching teams, (c) what mathematicians and MTEs perceive

as the affordances of collaboration, and (d) what mathematicians and MTEs perceive as the constraints of collaboration. For example, was the coach/student relationship between MTEs/mathematicians prevalent across the other collaborations? Did mutuality play a large role in the other collaborations? If so, in what ways did this manifest? In what ways did mathematicians and MTEs attribute similar or different meanings to reified objects in their communities?

In this study, Dejan and Angela were members of departments that were separated both physically and institutionally. I believe it would be informative in future research to investigate similar collaborations within contexts where mathematicians and MTEs are members of the same department (i.e., institutional homogeneity) and work in the same location (i.e., physical homogeneity). In such situations, many of the products of reification (e.g., departmental norms, classroom space) would be shared by members of both communities. Therefore, an analysis of collaborators' experience within such a setting has potential to reveal the ways mathematicians and MTEs attribute similar or different reifications to shared objects or concepts within their department.

In addition to using the situated learning theory as an interpretive lens for analysis, researchers should consider other possible frameworks through which they may gain further insight into the collaborative process. For example, I explained in the "Implications for Practice" section that I noticed a pattern in Dejan and Angela's attention to varying forms of pedagogical content knowledge (KCS and KCT) in their discussions. Rebecca McGraw (personal communication, June 27, 2011) suggested using the MKT categories (i.e., CCK, SCK, KCT, and KCS) outlined by Ball et al. (2008) as a framework for analysis of data related to team-teaching partnerships. Such an analysis

could provide insight into (a) the primary focus of mathematicians and MTEs with respect to mathematical knowledge for teaching, (b) the areas of teacher knowledge that may be neglected within teacher preparation programs, and (c) the ways in which collaboration between mathematicians and MTEs engenders a focus on specific types of MKT.

The authors of the CBMS (2001) document argued partnerships between mathematicians and MTEs are critical to ensure that important areas of mathematical knowledge for teaching, such as SCK, do not go “unaddressed” in the teacher education curriculum,

Some aspects of mathematical knowledge for teaching...may seem to mathematicians to fall into the domain of methods courses in education.

However, education faculty generally see [some of ] these issues to be more appropriately addressed in mathematics courses, and so such issues often remain unaddressed in teacher preparation. This state of affairs is one of many reasons why efforts to improve the mathematical education of teachers require a partnership between faculty in mathematics and mathematics education (p. 4)

Implicit in the CBMS (2001) argument is the notion that collaborations between mathematicians and MTEs will naturally lead to a more integrated curriculum for PSMTs. I believe the field needs to problematize this assumption, and investigate the circumstances that either promote or hinder such integration within teacher preparation programs. Therefore, future research should investigate instructors’ mathematics content courses and mathematics methods courses before, during, and after collaborative partnerships in order to determine the interactions and processes within collaborative

efforts that do or do not lead to opportunities for PSMTs to integrate their knowledge of mathematics and pedagogy.

In Dejan and Angela's case, the primary focus of their collaboration (as articulated in their interviews) was centered on Dejan's professional development and his increased awareness of the needs of PSMTs. It seems likely that building a shared understanding of the needs of PSMTs between collaborating mathematicians and MTEs would be a necessary precursor to developing integrated curricular experiences for PSMTs. Future investigations should attend to how and when integration of content and pedagogy is facilitated in collaborative relationships. In such investigations, ethnographic field observations, such as the field notes I took within class sessions and instructor planning sessions, may serve as a more valuable source of primary data than reflective interviews. In the interviews, I found that Dejan and Angela provided more general accounts of their experiences as a whole, whereas the data from my field observations provided more specific accounts of daily practice and instructor decision-making.

Moreover, researchers should examine the perceptions of instructors in relation to where (e.g., in mathematics methods courses or mathematics content courses) they believe elements of MKT such as SCK (Ball et al., 2008), or "decompressed" mathematical knowledge (Adler, 2005; Ball & Bass, 2003), should occur within the teacher preparation program. As Adler (2005) suggested, if neither of the groups sees the teaching of decompressed mathematics as a goal in their courses, then this type of knowledge may go uncovered and PSMTs may miss out on important understandings to inform their practice.

Dejan and Angela's reflections on their experiences suggested that a focus on SCK was not the main priority for either of the instructors (in his or her own classes) before this team-teaching collaboration. Dejan was particularly concerned with coverage of CCK in his mathematics courses, and was surprised by the extent to which Angela was willing to sacrifice content coverage in order to slow down and "unpack" (Ball & Bass, 2003) the mathematics in the geometry course. The following quotation illustrates his perspective in this regard,

The other thing I learned [from our collaboration in Geometry] is I shouldn't be pressed with the amount of material. I was actually, not amazed, but I would say, "Gee, she is so brave." She would say, "So what? We didn't cover this, so what?" I would say, "Wow." I always think that some kind of government bureaucrat [will come] and say, "Look, on the syllabus it is written. You have to cover this and this and this and this and you covered only two things, so why are we paying you? Why are the students paying?" (laughter) (Dejan, individual interview #2)

Similarly, we saw in Angela's reflections how her usual approach to instruction in methods courses focused on pedagogy, sometimes at the expense of attending to PSMTs' mathematical knowledge and misconceptions. Dejan's engagement in this course led her to rethink this practice, and to acknowledge the benefit of having Dejan in the class to point to some of the mathematical needs of PSMTs. Future research investigating the collaborative process should attend to the ways in which mathematicians and MTEs' joint work facilitates, or hinders, a focus on the different elements of mathematical knowledge for teaching.

Finally, it was clear through Dejan and Angela's repeated use of language such as "us", "them", "mathematicians", and "mathematics educators" that they each perceived they were members of distinct professional communities. Although the instructors' reflections indicated a strong awareness of the differences that characterized the distinction between "mathematicians" and "MTEs," it would be important in future inquires to investigate the pervasiveness of this "community separateness" within other contextual settings. If we can determine the contexts in which greater commonalities are perceived between people from these two communities, we may be able to gain greater insight into building contexts that support collaboration and a feeling of common ground between the two groups.

### **Delimitations**

Because the purpose of my research was to understand the lived experiences of Dejan and Angela within a collaborative context, I restricted my attention primarily to those two individuals and their meaning-making in regards to the collaborative process. Therefore, although important to the progress and advancement of the literature within teacher education, it was beyond the scope of this study to analyze the impact of team-teaching as it relates to student learning, or to investigate the products of Dejan and Angela's collaboration (e.g., curricular materials, grading rubrics).

Moreover, in any in-depth qualitative study of this nature, issues of personality will be prevalent throughout the narratives. Again, because the purpose of my study was to better understand Angela and Dejan's experiences as they actively reflected on those experiences, a classification or categorization of their personalities was not an aim of this

research. However, I acknowledge that personality has a substantial influence on the dynamics of any such collaboration.

### **Limitations**

Dejan and Angela team-taught together in a Geometry course for PSMTs (Spring, 2010) prior to the two semesters in which I served as a researcher of their collaboration. I did not observe or interview Dejan and Angela during that semester, so I was not able to document their collaboration from its inception. Therefore, as I collected and analyzed the data, I took into consideration possible meanings the instructors' had developed from the previous semester's collaboration, and asked for clarification and elaboration on their past experiences when necessary.

Another limitation of the proposed study is there was only one researcher (me) throughout the majority of the data collection process within Dejan and Angela's collaboration. In order to control for this limitation, I (a) conducted two "participant validations" (Smith et al., 2009, p. 54) with Dejan and Angela to ensure I accurately portrayed their perceptions, (2) kept a researcher reflective journal to reflect on my assumptions and biases throughout the analysis cycle, and to keep a record of any decisions I made so that an audit trail could be conducted, and (3) collected several sources of data to triangulate my findings and developing understandings of the instructors' experiences.

### **Conclusion**

In this interpretative phenomenological case study, I have provided an in-depth account of the experiences of a mathematician (Dejan) and a MTE (Angela) as they engaged in a team-teaching collaboration within a mathematics content course

(Geometry) and a mathematics methods course (Teaching Senior High School Mathematics). The themes that emerged from my analysis illustrated (a) how crossing community boundaries led to Dejan and Angela's increased awareness of their practice, as demonstrated in Angela's theme, "Articulating tacit disciplinary knowledge: Collaboration as a catalyst for reflection on practice," and Dejan's theme, "Pedagogical transition: Reflecting on my teaching practice," (b) the roles of coach and student taken on by Angela and Dejan throughout the collaboration in an effort to increase Dejan's awareness of the needs of PSMTs, as demonstrated in Angela's theme, "Pushing Dejan: From appeasement to acceptance," and Dejan's theme, "Encountering the educational community: Navigating unfamiliar terrain," and (c) the influence of mutuality as a driving force in the instructors' collaborative experiences, as demonstrated in Angela's theme, "'Give and take': Mutuality as a critical force in our co-teaching relationship," and Dejan's theme, "'This collaboration is not symmetric': Disproportionate exchange of intellectual capital."

I employed the situated learning theory as an interpretive lens to describe and explain the instructors' meaning-making throughout their collaboration. From this interpretive analysis, I demonstrated (a) the importance of the dual processes of participation and reification to facilitate learning and meaning between instructors, (b) the ways in which a lack of shared history can hinder communication between collaborators, (c) the influence of a community's "regime of mutual accountability" on collaborators' decision making and interactions, and (d) the value and complexities of brokering and crossing boundaries.

It is my hope that through reading this research, members of both the mathematics and mathematics education community are able to transfer some of the lessons learned from Dejan and Angela's experiences in a meaningful way to their own practices. So often within the literature related to the mathematics and mathematics education community, discussions are centered on the lack of trust or disrespect among the communities (CBMS, 2001; Dörfler, 2003; Heaton & Lewis, 2011; Ferrini-Mundy & Findell, 2001; Wu, 2006). Although Dejan and Angela were at times skeptical of the practices of their partner, and perceived a reciprocal skepticism from their partner, the larger message from this case study should be one of mutual learning and professional development. Through engagement in their community of interest, Dejan and Angela were able to increase awareness of their own practices and the practices characteristic of their respective communities of practice.

Dejan was open to change in his classroom and the collaboration led to his increased reflection on his pedagogical practices and a renewed vision for his instruction. He also felt strongly that other members of the mathematics community may benefit from an increased attention to pedagogical issues. Recall Dejan's reflection, "And I would say that it is not that mathematicians don't *want* the other way, they don't *know* the other way." Those who are in a position to serve as a broker between the communities, as was Angela, should take the opportunity to collaborate with mathematicians, many of whom, like Dejan, may be happy to have the opportunity to reflect on their own practice and on the needs of prospective teachers.

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## **Appendix: Interview Protocols**

### **Interview Protocol 1**

Educational background:

1. Tell me about your educational/professional background
  - a. Locations
  - b. Subjects of interest
  - c. Pre-college education
  - d. Undergraduate education
  - e. Graduate education
  - f. Employment outside academia
  - g. Employment within academia

Philosophies on the teaching and learning of mathematics:

1. In what ways do you think your own educational background influences the way you look at teaching mathematics today?
2. Can you give me an overview of your philosophy of teaching?
3. What are the procedures you typically use to evaluate students in the undergraduate courses you teach (i.e., mathematics education courses for Angela and mathematics courses for Dejan)?
4. Do you think these procedures would change significantly if you were teaching a course in your team member's discipline (i.e., mathematics courses for Angela and mathematics education courses for Dejan)?

Understanding of team member's discipline:

1. What prior understanding do you have about the general ideology (i.e., goals, expectations, actions) of your team member's field of study?
2. Please describe the key learning objectives and theoretical grounding for a course in your team member's field of study.

Goals and expectations for the collaboration:

1. What are three major goals you have for the students in the Geometry course this semester?
2. What are three major goals you have for yourself in the Geometry course this semester?
3. What do you expect might be possible areas of agreement between you and your team member during the team-teaching collaboration in Geometry?
4. What do you expect might be possible areas of disagreement between you and your team member during the team-teaching collaboration in Geometry?

### **Interview Protocol 2 (with Angela)**

1. How would you describe your role in the collaboration this semester?

- a. Do you think Dejan viewed your role in the same way?
  - b. What do you think Dejan’s role was in the collaboration?
2. What did you learn from participating in this collaboration? What do you believe Dejan learned?
3. What was the most frustrating aspect of the collaboration for you this semester?
4. What was the most rewarding aspect of the collaboration for you this semester?
5. In our first interview, you mentioned the following goals you have for the students in the geometry course:
  - a. Students should understand the importance of communicating clearly about the subject matter.
  - b. Students learn “how to learn” rather than just teaching the details of geometry content.

Looking back on the semester, how successful do you believe you and Dejan were at achieving these goals? What do you believe contributed to the success or lack of success?

6. In our first interview, you also stated that in the previous semester’s collaboration, you sometimes felt that the information you provide to Dejan was based on “gut” because there is not a well-developed research base to inform all of your pedagogical decisions. Have you felt the same way this semester?
7. One of the goals you and Dejan stated in your planning meetings at the beginning of the semester was for a more collaborative model for your co-teaching. For example, you had hoped to grade together and plan together. Do you believe that you did work more collaboratively this semester than in the previous semester? Why or why not?

### **Interview Protocol 2 (with Dejan)**

1. How would you describe your role in the collaboration this semester?
  - a. Do you think Angela viewed your role in the same way?
  - b. How would you describe Angela’s role in the collaboration?
2. What did you learn from participating in this collaboration? What do you believe Angela learned?
3. What was the most frustrating aspect of the collaboration for you this semester?
4. What was the most rewarding aspect of the collaboration for you this semester?
5. There have been several instances throughout the semester when you have referred to “what other mathematicians” might think about a certain decision you make or mode of instruction you use. Can you talk a little bit about your experiences with other mathematicians and how you believe this might influence the way you think about teaching and learning?
6. One of the goals you and Angela stated in your planning meetings at the beginning of the semester was for a more collaborative model for your co-teaching. For example, you had hoped to grade together and plan together. Do you believe that you did work more collaboratively this semester than in the previous semester? Why or why not?

### **Interview Protocol 3**

Goals and expectations for the collaboration:

1. How do you think your collaboration will be different as a result of it being situated within an education/methods course rather than a content course?
2. How do you envision your potential role in the team-teaching collaboration this semester (in particular as compared to your role last semester in the geometry course)?
3. Are there specific goals you have for the students in the High School Methods course this semester? If so, what are they?
4. Are there specific goals you have for yourself this semester? If so, what are they?
5. What do you expect will be some of the benefits/advantages of team-teaching in the High School Methods course?
6. What do you expect will be some of the challenges of team-teaching in the High School Methods course?

### **Interview Protocol 4 (with Angela)**

1. How would you describe your role in the collaboration this semester?
  - a. Do you think Dejan viewed your role in the same way?
  - b. What do you think Dejan's role was in the collaboration?
2. In our interview at the beginning of this semester and then again at the group interview last week, you expressed that you were pleasantly surprised at how Dejan found a place/way to contribute significantly to the methods course. Are there specific instances of this that stick out to you?
3. What did you learn from participating in this collaboration? What do you believe Dejan learned?
4. What was the most frustrating aspect of the collaboration for you this semester?
5. What was the most rewarding aspect of the collaboration for you this semester?
6. How important do you think it is to have a mathematician contributing to a methods course?
  - a. Would you recommend to faculty in other institutions that mathematicians partake in a methods course? [If Angela responds that she thinks it is beneficial in terms of Dejan's (or other mathematicians') personal professional development, then ask her if she would recommend it solely for the purpose of having a deeper mathematical perspective/expertise to add to the course? (i.e., not for professional development of mathematicians but for the professional development of students)].
7. There have been several instances throughout the semester when Dejan mentioned that he did not really feel invested in the course (as much as he did in the geometry course). Why do you think this is? Can you think of anything that might have helped him feel more invested in the methods course?
8. If you could re-do the collaboration in only one of the semesters, which would it be? Why?

#### **Interview Protocol 4 (with Dejan)**

1. How would you describe your role in the collaboration this semester?
  - a. Do you think Angela viewed your role in the same way?
  - b. How would you describe Angela's role in the collaboration?
2. What did you learn from participating in this collaboration? What do you believe Angela learned?
3. What was the most frustrating aspect of the collaboration for you this semester?
4. What was the most rewarding aspect of the collaboration for you this semester?
5. There have been several instances throughout the semester when you have mentioned that you have not felt invested in the course (as much as you did in the geometry course). Why do you think this is? Can you think of anything that might have helped you feel more invested in the course?
6. One of the reoccurring events during the semester was when Angela would point out, either good or bad, some of the pedagogical decisions/strategies/actions that you used during your part of the lesson. How did you feel about this?
7. Throughout the semester, you expressed how you would like to better understand what educators mean by learning things "in depth" or "conceptually"- do you think you have a better idea of that after this collaboration? Can you think of any specific experiences that helped you to understand what educators are looking for?

#### **Interview Protocol (Group interview- Fall 2010)**

In this interview, I will ask a question which each of you will probably answer differently. I envision the interview progressing as one of your usual conversations about teaching, but I might interject as we go along.

1. If you were both at a conference and two people interested in beginning a team-teaching collaboration approached you, what advice would you give them about participating in such a collaboration?
2. Do you believe that the collaboration was successful? If so, in what ways? If not, why not?
3. We collected initial student feedback and I sent you the typed responses in mid-October. What were your initial reactions to those student comments? Did the comments change the way either of you approached the collaboration?
4. What was the biggest difference between the collaboration this semester compared to last Spring?
5. If you were to teach this geometry course together again next fall, what changes would you make? What would you keep the same?

#### **Interview Protocol (Group interview- Spring 2011)**

In this interview, I will ask a question which each of you will probably answer differently. I envision the interview progressing as one of your usual conversations about teaching, but I might interject as we go along.

1. Last week, I sent you comments from the students in the methods course. What were your initial reactions to their comments? Were there any surprises? Any points of concern?
2. Do you believe that the collaboration during the methods course was successful? If so, in what ways? If not, why not?
3. If you were both at a conference and two people interested in beginning a team-teaching collaboration in a methods course approached you, what advice would you give them about participating in such a collaboration?
4. What did you perceive as some of the biggest differences between the collaboration this semester in the methods course compared to last semester in the geometry course?
5. If you were to teach this methods course together again next spring, what changes would you make? What would you keep the same? (If instructors focus on the way they would change the structure of the course rather than their collaborative partnership, probe into this topic area.)
6. As an observer in the course, one of the key issues that I noticed was the friction between a focus on content and a focus on pedagogy. You often had to make decisions about when to cover a mathematical topic area in more depth, and when to cut the mathematical discussion short to make time for a broader pedagogical discussion. Can you each talk a little bit about this? Probes: For instance, did you feel a friction between content and pedagogy? How did you deal with this? To Dejan: Did you find it challenging to use mathematics as a vehicle for illustrating pedagogy? To Angela: How did you feel about Dejan going deeper into the mathematics (and using class time) when traditionally the mathematics is only used as a means to illustrate the pedagogy?