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Collaboration among Mathematicians and Mathematics Educators: Working Together to Educate Preservice Teachers

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Collaboration among Mathematicians and Mathematics Educators: Working Together to Educate
Preservice Teachers

by

Amanda R. Mohn

A dissertation submitted in partial fulfillment of the requirements for the degree of Doctor of Philosophy in Curriculum and Instruction with a concentration in Mathematics Education Department of Teaching and Learning College of Education University of South Florida

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DEDICATION

This dissertation is dedicated to Jackson and Emilia. I hope someday you both have the opportunity to pursue your goals, and the determination to see them through. “I love you more than anything in the whole wide world.”
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Thank you to “Melina,” “Tom,” and “Doug,” for your willingness to participate in my study and the time you dedicated to do so.

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ABSTRACT

Collaboration among higher education professors who are responsible for the education of preservice teachers is one potential solution to the problem of poor teacher preparation. Specifically, collaboration among mathematics educators and mathematicians can enhance preservice teacher preparation because it provides opportunities for preservice teachers to develop pedagogical content knowledge. However, collaborative efforts are challenging, and collaborators often face obstacles and tensions arise among the collaborative group members. Learning about ways the collaborators approach their collaborative efforts, the issues and tensions that arise, the hindering and supporting factors that affect the collaboration, and the potential outcomes of collaborative efforts provides information beneficial to higher education instructors looking to collaborate in teacher education programs.

An exploratory descriptive case study was employed to answer the following research questions:

1. What approaches do a team comprised of a mathematics educator and two mathematicians use to facilitate their collaborative co-planning efforts as they prepare for and teach concurrent mathematics methods and mathematics courses for preservice middle grades mathematics teachers?
2. What factors support or hinder the collaboration?
3. In what ways does the collaboration affect the mathematics educator’s and mathematicians’ course planning and teaching?
A mathematics educator and two mathematicians co-planned, and concurrently taught, courses for preservice middle grades mathematics teachers enrolled in a middle school mathematics teacher education program. Data collected from observations of planning meetings, observations of classes taught by the participants, and from interviews were analyzed through thematic analysis.

At the onset of the collaboration, the collaborators assumed roles that initiated the collaboration, with the mathematics educator emerging as the leader and setting the schedule and meeting agendas. However, the hierarchical roles they established ultimately led to a power imbalance, the major hindering factor of the collaboration. Other hindering factors include administrative business, lack of authority, and undefined goals. The instructors in the collaborative group formed relationships and bonded over similar challenges with the preservice teachers. The connections among the collaborators facilitated the collaboration. As a result of the collaboration, each of the instructors made planning and teaching changes in their courses. The mathematicians employed instructional strategies consistent with best practices in education, such as group work, which they had not utilized in other courses. The mathematics educator made direct connections with content the preservice teachers in her course were learning in their mathematics courses taught by her collaborators.
CHAPTER 1:
INTRODUCTION

Statement of the Problem

Many preservice mathematics teachers are not adequately prepared to teach (Martin & Gobstein, 2015; National Academy of Education Committee on Teacher Education, 2007). University-based teacher preparation programs are often criticized for this lack of readiness, citing low standards and weak programs (Levine, 2010, 2011; Schmidt, 2012). To address this criticism, there is currently an emphasis on improving mathematics teacher preparation programs in the United States (Cochran-Smith & Power, 2010; National Academy of Education, 2009; National Research Council, 2010).

A necessary aspect of any mathematics teacher preparation program is the development of pedagogical content knowledge (PCK), which mathematics teachers need to possess in order to effectively help their K-12 students learn mathematics (Shulman, 1986; Ball, Lubienski, & Mewborn, 2001; CBMS 2001, 2012). The possession of PCK differentiates a mathematics teacher from a mathematician (Cochran et al., 1991). When teachers possess PCK, they are able to present content in a way that creates meaningful learning experiences for their students (Schmidt, 2012). Preservice teachers need to engage in activities in their classes and experiences throughout their teacher preparation program to help them develop PCK (Lloyd, 2013). One possible way for preservice teachers to develop this unique, integrated form of knowledge results from collaboration among mathematicians and mathematics educators (Cochran et al., 1991).
The call for collaboration among mathematicians and mathematics educators is not new, as Cochran et al. (1991) suggested over 20 years ago that “cooperation between subject area faculty and pedagogy faculty, and substantial and innovative course development and revision” (p. 15) would be imperative for preservice teachers to adequately develop PCK. Yet, there is a lack of extant literature that documents attempts at faculty collaboration. There is, however, evidence of collaborative efforts recently taking place in higher education institutions across the country (e.g., see Bleiler, 2014; Eddy & Mitchell, 2012; Hart & Mars, 2009; Lele & Norgaard, 2005; Vanasupa et al., 2012).

At many post-secondary institution offering education programs, preservice mathematics teachers are educated by both mathematics teacher educators and mathematicians. The collaboration of mathematics teacher educators and mathematicians has been recommended to improve mathematics teacher preparation (CBMS 2001, 2012). A partnership might benefit both parties. Mathematics educators may inform mathematicians about the mathematical knowledge preservice teachers need based on mathematics education research and state standards and may provide “valuable insights and information about what takes place in school classrooms” (CBMS, 2012, p. 9). Mathematicians may inform mathematics educators of developments in the field of mathematics that may impact school mathematics. Exchanging this important information may assist each party in determining what and how they will teach preservice teachers. Preservice teachers will also benefit as they will have opportunities to develop both the content knowledge and pedagogical knowledge necessary for effective teaching (CBMS, 2001, 2012). To date, there is scarce research focusing on the successful collaborative processes among mathematics education professors and mathematics professors. Research is needed to examine the collaborative processes between mathematics educators and mathematicians to help the
mathematics and education communities understand factors that contribute to successful partnerships.

Collaboration among higher education faculty has potential to be invigorating and all-encompassing for those involved (Eddy & Mitchell, 2012). It may increase productivity and possibly lead to more successful programs (Eddy & Mitchell, 2012; Konecki et al., 2012). However, collaboration is not a simple undertaking. Successful collaborative efforts take time, hard work, and commitment, and often collaborative team members must overcome challenges and obstacles. Collaborative work among professors may be difficult due to issues and tensions that arise such as inherent differences among group members’ beliefs, values, epistemologies, expertise, and teaching styles, power imbalances, and lack of resources (Eddy & Mitchell, 2012; Konecki et al., 2012; Lele & Norgaard, 2005; Stoll et al., 2006; Vanasupa et al., 2012).

Mathematics educators and mathematicians often have different views of learning and teaching, which may make collaborative efforts between them challenging (Bleiler, 2014). In order for collaborative efforts to succeed, members of the collaborative group must be committed to the shared, co-created goals, the collaborative process, and each other (DuFour, 2004; Eddy & Mitchell, 2012; Konecki et al., 2012; Vanasupa et al., 2012).

Participation in a successful collaboration should enhance teacher knowledge, making collaboration a form of professional development for educators and potentially inciting instructor change (Bolam et al., 2005; Fennema et al., 1996; Henderson et al., 2011). This instructor change may be the catalyst necessary to enhance mathematics teacher preparation programs.

Because collaboration is increasingly encouraged for preservice teacher education, more studies are needed to explore the processes through which collaboration occurs and what makes
collaborative efforts successful. Specifically, studies should look at collaborative efforts associated with teacher preparation programs.

Much of the extant research on collaboration was conducted from the perspective of researchers as collaborators. The studies are autobiographical narrative case studies based on personal experiences (see Konecki et al., 2012; Lele & Norgaard, 2005; Vanasupa et al., 2012). However, there is little research in which a third party researcher observes and analyzes the collaborative process. Research from this perspective may provide an unbiased account of the collaboration, possibly detailing characteristics of success, supporting or hindering factors, or obstacles that may be overlooked by a participating member of a collaborative group.

There is also little research that examines interdisciplinary learning communities at the higher education level, specifically studies focused on how mathematics teacher educators and mathematicians collaborate. There is a lack of research related to the engagement of mathematics teacher educators and mathematicians in communities of practice or learning communities. More inquiries in this area might provide an opportunity to examine how faculty learning communities may enhance students’ achievement in mathematics.

However, the results of extant research are promising. In a study that examined the team teaching experiences of a mathematics educator and a mathematician, professors worked together to plan and coteach courses for preservice secondary mathematics teachers (Bleiler, 2012). The researcher found the professors “perceived their participation in the team-teaching collaboration as influential to their professional development as teacher educators” (p. 212). She also determined participating in the collaboration increased professors’ awareness of their own practices and of the needs of preservice mathematics teachers. More studies of this nature may
provide insight into what makes collaborations among mathematicians and mathematics educators successful.

It has been suggested in calls for the transformation of preservice mathematics teacher education programs that mathematics educators and mathematicians work collaboratively to develop courses and teach preservice teachers. Mathematics education professors and mathematics professors must work together towards a unified program that encompasses the content, methods, and best practices in every course. Those who participate in such collaborative efforts may be informed by research that identified supporting and hindering factors and characteristics and may utilize this information to support the success of the endeavors in which they engage.

**Purpose**

Utilizing a descriptive case study approach, I explored the collaborative efforts of a mathematics educator and two mathematicians as they co-planned, and concurrently taught, courses for preservice middle grades mathematics teachers enrolled in a middle school mathematics teacher education program. I described the process of the collaboration, detailing the challenges and supporting factors, and described the noticeable changes in the participants’ planning and teaching that resulted from the collaboration.

**Context**

The collaborative effort in this inquiry is part of a larger, grant-funded effort to develop, implement, and refine a middle school mathematics teacher education program at a large university in the southeastern United States (Ellerbrock et al., 2016). As part of this project,
teams of faculty have collaborated to design courses that meet the program goals, which include preparing highly effective middle school mathematics teachers who are qualified to teach rigorous content standards to a diverse student population.

The middle school teacher education program was collaboratively developed by faculty in the College of Education, the College of Arts and Sciences, and the College of Engineering, in partnership with mathematics personnel from the partnering public school district. The first cohort of students in the program began in Fall 2013.

**Research Questions**

The following questions guided my inquiry:

4. What approaches do a team comprised of a mathematics educator and two mathematicians use to facilitate their collaborative co-planning efforts as they prepare for and teach concurrent mathematics methods and mathematics courses for preservice middle grades mathematics teachers?

5. What factors support or hinder the collaboration?

6. In what ways does the collaboration affect the mathematics educator’s and mathematicians’ course planning and teaching?

**Methods**

To answer the questions above, I observed a team consisting of a mathematics educator and two mathematicians as they co-planned and concurrently taught courses in the middle grades teacher preparation program. I observed and took detailed field notes during collaboration sessions and classes taught by each participant. I interviewed each participant, collecting data
about their participation in the collaboration and the possible ways the collaborative efforts affected their planning and teaching.

**Significance**

This study provides insights about collaborations in higher education, contributing specifically to the sparse information on collaboration among mathematics education and mathematics faculty. The inquiry has potential to contribute to theory and practice of successful and productive collaborations. It will inform both the education field and the mathematics field about the complexities of collaboration and provide details regarding the factors that support and hinder collaborative efforts between these two groups. It will potentially provide information about the benefit of faculty collaboration in course planning and teaching, and specifically how it benefits the preparation of preservice mathematics teachers.

**Limitations and Delimitations**

There are limitations associated with the data collection methods I used in my research, namely interviews and observations. One limitation with interview data is the truthfulness of the participants’ responses (Yin, 1994). The participants in the study are current faculty members at the university. At the time of data collection and analysis, each participant was working on the middle grades teacher preparation program that is the context for this inquiry. They may not have wanted to disclose information that might have potentially jeopardized their position or anonymity. Their responses may also have been limited due to inaccuracies because of misremembered information or memory distortion, as some of the interview questions posed were about events that occurred during previous semesters. In addition, the data collected is
limited due to the questions asked. Salient data may have been missed if I failed to pose appropriate follow up questions.

A limitation of observation data collection is the possibility the events happen differently because of the researcher’s presence (Yin, 1994). For all participants, my presence in their classroom and in their meetings might have impacted their normal behavior. For the mathematics faculty, having an observer in the classroom from the education department might have influenced their behavior. Additionally, my presence may have also affected the behavior of the students in the class, which in turn would affect the teachers’ instructional decisions.

There are two limitations related to my role in the study. There are hermeneutic considerations for my role as researcher. The data are subject to my analysis and my interpretations, which are affected by my values and life experiences (Crotty, 1998). Another consideration is my role in the collaborative group and my relationship to the participants. I have developed relationships with each of the participants due to my involvement in the middle grades teacher preparation program. During the observations of the collaborative group, I assumed the role of “participant observer” (Gold, 1958). Often, during collaborative meetings and classroom observations, my role as observer was informal, and I would participate in discussions related to the course planning or content. My participation in the group was also recorded in the field notes. This participation did not influence the data as my role did not affect the collaborative process, the presence of hindering or supporting factors, or the potential for instructor change. I approached interviews with the participants formally; I scheduled interviews with each the participants and wrote guiding questions to focus the conversations.
CHAPTER 2:
REVIEW OF THE LITERATURE

Collaboration among higher education faculty across the departments responsible for educating preservice teachers is one possible approach to improve teacher preparation (Cochran et al., 1991; CBMS, 2001, 2012; Levine, 2010). When faculty work together in a collaborative setting with the purpose of increasing their knowledge and enhancing student learning, they form a learning community (Bolam et al., 2005; Stoll, 2010; Stoll & Louis, 2007). As a form of professional development, learning communities have the potential to enact change in teachers (Bolam et al., 2005; Henderson et al., 2011), which might lead to a strengthened program for mathematics preservice teachers.

Literature Search

To inform the study design, I wanted insights from research conducted to examine faculty collaborations. First, I searched the library database of education journals for articles related to faculty collaborations. My initial search terms were “collaboration,” “higher education,” and “mathematics education.” The results were limited so I expanded the search criteria by removing the “mathematics education” term. This permitted me to draw from literature on collaboration in all disciplines. However I focused on studies of collaborative efforts among mathematics educators and mathematicians whenever possible. I read abstracts to determine the relevance of the articles. I included any articles that discussed higher education faculty collaborations. In addition, other relevant sources were found by examining the reference lists of relevant articles.
Much of the literature on collaboration involved learning communities, so I also searched for “learning communities” and “higher education.” The literature on learning communities in higher education in general was also limited, therefore I also included studies on learning communities at the elementary and secondary level. Although the schooling level was different, such literature provided insights that assisted in defining, characterizing, and explaining the concept, as well as provided descriptions of the supporting and hindering factors found at that level which may also be relevant in higher education.

While reviewing the literature on collaborations, I was intrigued by the possibility raised by researchers that collaborative efforts, when undertaken as professional development, might lead to changes in instructor pedagogical practices. Because of this, I then searched for articles using the terms “collaborations,” “professional development,” “teacher change,” and “higher education.” I found an abundance of research related to teacher change but my focus is on how teachers change as a result of professional development. Thus, I included research studies in which teachers participated in professional development in the form of collaborative efforts and/or learning communities. As I read through and analyzed this literature, I became more interested in the potential of faculty collaborations to impact preservice mathematics teacher education. Thus, finally, I searched for articles about the education of preservice mathematics teachers, specifically looking at articles with a focus on pedagogical content knowledge for preservice mathematics education teachers.

**Organization**

I begin the discussion of the literature with results about the advantages and benefits of collaborative work. Then I discuss the challenges associated with engaging in collaborative
efforts. Following that, I summarize findings from studies of successful collaborations. Next, I describe four types of learning communities to provide information about learning communities, including their purpose, how they are formed, and what factors contribute to their success. This is followed by an overview of the available literature on learning communities in higher education.

In the next section, I discuss faculty collaboration in relation to the preparation of preservice mathematics teachers. This section includes an overview of the typical structure of preservice mathematics teacher preparation, with a specific focus on the importance of pedagogical content knowledge. Then, I discuss how collaborative efforts may lead to instructor change. I conclude the literature review by summarizing the literature and discussing implications for collaborative efforts to enhance mathematics teacher preparation.

Collaboration

“The challenge of the modern university is to...help to create a better, more integral and inclusive world” (Corrigan, 2012, p. 70). Part of this inclusivity requires professors from different departments, particularly the social sciences and natural sciences, to work together to create integrated, collaborative relationships (Corrigan, 2012). This section provides what researchers found to be the benefits of collaborative work. This is followed by a discussion of the issues and challenges that may arise during collaborative efforts. Then, I continue the discussion by highlighting the characteristics that have facilitated successful collaborations.

Benefits of collaboration. Research has identified a number of benefits to both the individuals who work together in a collaborative group and the institutions where they work. It has been suggested that collaborative relationships among collegiate faculty may ease their work
demand and enliven them in their approach to teaching and research (Eddy & Mitchell, 2012). Not only may collaboration invigorate faculty, but collaborative work has been found to decrease the sense of isolation often felt among faculty (Beers & Davidson, 2009). Working collaboratively with colleagues opens possibilities for faculty to experience an “intellectual stimulation” that occurs when collaborative team members have opportunities to listen openly to the beliefs and pedagogical ideas from faculty members in other disciplines and explain their own perspectives and rationales for the pedagogical decisions (Beers & Davidson, 2009, p. 534). Additionally, working collaboratively may provide support for instructors who are implementing new content or instruction methods in their courses (Martin & Dismuke, 2015). Collaborative work may potentially lead to increased productivity, increased knowledge, and more diverse thinking among faculty. It may also provide an outlet for “idea generation” and encourage “reflective practice”, benefiting all aspects of faculty work (Eddy & Mitchell, 2012, p. 294).

For institutions, Corrigan (2012) suggests collaboration has the potential to end the division among different departments in higher education institutions and create opportunities for new programs, courses, etc. Researchers have found the collaborative development of programs promotes shared ownership of those programs, leading to more stakeholders who are concerned for and interested in the success of the programs, potentially engendering more successful programs in the institution (Konecki et al., 2012).

**Issues and tensions associated with collaboration.** Although the advantages of collaborative work are many, the collaborative process may be difficult; issues and tensions may arise and other factors may inhibit the collaboration (Eddy & Mitchell, 2012; Lele & Norgaard, 2005; Martin & Dismuke, 2015; Mellin & Winton, 2003; Stoll & Louis, 2007; Vanasupa et al., 2012).
Problems the collaborative group encounters might be due to the group members, the group structure, or outside influences or resources.

The major potential barriers to interdisciplinary collaboration are often due to the differences among group members (Eddy & Mitchell, 2012; Lele & Norgaard, 2005; Vanasupa et al., 2012). Lele & Norgaard (2005) suggest these differences are found in the individual group members’ values, theoretical positions, explanatory models, underlying assumptions, and epistemologies. An individuals’ orientation to change, typically based on their backgrounds, biographies, beliefs, skills, priorities, and lives, as well as their teaching style might hinder collaborative group development (Stoll et al., 2006). There are also differences in the cultures of the different disciplines taught by individual group members and societal and cultural expectations for those individuals that might cause tension in the group (Lele & Norgaard, 2005; Vanasupa et al., 2012). Additionally, Eddy and Mitchell (2012) suggest differences in collaborative members’ positions, expertise, and individual power may create tensions among the group.

There is potential for difficulties in collaborations if collaborative group members’ individual goals and objectives are not in line with the group vision, or if a member is not actively participating or contributing (Eddy & Mitchell, 2012). If members do not feel commitment or loyalty to or respect for, or cannot identify with other members, collaborative efforts might be hindered (Stoll et al., 2006).

Furthermore, racial and ethnic diversity of the collaborative group members might also hinder collaboration (Bryk et al., 1999). There is potential for tensions among group members if the group does not establish a system for discussing possible issues and differences (Eddy & Mitchell, 2012). When differences are “unexamined”, when the group is not willing or able to
address the differences and resolve them together, or openly discuss disagreements, collaboration may fail (Eddy & Mitchell, 2012; Vanasupa, et al., 2012). Additionally, it is possible that differences in the way terms are understood and defined among group members from different academic departments may cause issues among collaborators (Lele & Norgaard, 2005).

The structure of the group might be a potential source of problems. Eddy and Mitchell (2012) suggest power imbalances among collaborative team members, due to rank or longevity, may cause issues. Additionally, Lele and Norgaard (2005) posit one group member assuming a leadership role may cause tensions because it may cause other members to perceive they no longer have a say in the decisions of the collaborative group or to feel conflicted between their own values and goals and what they believe is required. Motivation may also cause problems in a collaborative group (Daly, 2009; Lele & Norgaard, 2005). When group members are motivated extrinsically rather than intrinsically, they do not value the outcomes as if they were their own.

Konecki et al (2012) found lack of resources, such as time and money, is also a challenge to the collaborative process. Similarly, Martin and Dismuke (2015) found scheduling time to hold collaborative meetings was challenging. Mellin and Winton (2003) found lack of time coupled with collaborators’ other responsibilities were major barriers to collaborations. Additionally, designing a program in a way that promotes sustainability is a hindrance (Konecki et al., 2012). Hart and Mars (2009) found collaborating with people from other departments may cause feelings of detachment from one’s own academic community. Also, although collaborative work, specifically collaborative efforts across different departments, is sometimes necessary for research funding and large projects, it is often undervalued in terms of tenure and promotions (Hart & Mars, 2009).
Successful collaborations. Research on collaborative work has helped researchers to identify characteristics of collaborative efforts that succeed. In this section I give an overview of those characteristics then share research studies involving collaborative efforts.

Members of the collaborative group must be committed to the group and the goals and dedicated to the collaborative process (Konecki et al., 2012; Vanasupa et al., 2012). Collaborative group members must have a shared vision and shared goals (Vanasupa et al., 2012). These goals, along with the form and structure of the collaboration, should be co-created so each member is personally invested in the success of the work (Vanasupa et al., 2012). When each member is personally invested, they share ownership of the collaborative work, leading to a commitment to its success, respect for each other, and equal engagement in the work (Konecki et al., 2012). Additionally, when the collaborators are interested in and excited about the collaborative efforts, the collaboration is more likely to be sustained (Mellin & Winton, 2003).

Group members must build relationships with one another. These relationships have potential to engender the trust necessary for success (Eddy & Mitchell, 2012). The group should schedule and attend regular meetings and respect that meeting time, because the time spent together contributes to trust among group members. Open communication and shared understanding contribute to trust among the group. Also, “working together over time creates a sense of shared purpose and sense of worth in working together” (p. 293). Thus, with regular meetings, norms become established such that members feel comfortable to discuss differences and disagreements openly, and critique one another as necessary. Eventually the time spent together may cause each member to question their own underlying assumptions. It is suggested that this critical reflection is necessary for sustaining the collaborative group (Eddy & Mitchell, 2012). In order to facilitate the tensions that might arise with critiques, members need to directly
and explicitly examine their mental models and their intent to work together before the project begins and be willing to acknowledge what they do not know (Vanasupa et al., 2012). Collaborations have the potential to be most effective when the group members are able to learn from each other (Fullan, 2005).

After an exhaustive review of the literature, Stoll and Louis (2007), determined five principles of engagement that facilitate collaborative communities. The first principle is deep respect. Every person involved must be viewed as a “valued participant… someone with ideas and thoughts to share and with an important role to play” (p. 32). The second principle is collective responsibility. All members of the collaborative group must take responsibility for the outcomes. The third principle is appreciation of diversity. Differences should be seen as core values and celebrated because diversity “serves as the spark for new learning, growth, and development” (p. 33). The fourth principle is problem-solving orientation. Members of the collaborative group must be flexible and open to uncertainty, experimentation, and change. Also, they must be willing to question their practice and its effects on others. The fifth principle is positive role modeling. Every member of the collaborative group is both a teacher and a learner. This may help the development of “distributed leadership, where individuals from all stakeholder groups seek out opportunities both to learn and to lead” (p. 34).

In a narrative case study of interdisciplinary higher education faculty who attempted to work together and ultimately failed, the researchers, who were also the members of the collaborative group, were eventually able to come together to identify reasons for their unsuccessful collaboration (Vanuspa et al., 2012). In this study, faculty from the engineering, architecture, history, and graphic design departments worked together to assign their students a transdisciplinary, integrated class project. The members of the collaborative group found the
majority of their problems were due to their “very different beliefs about teaching, learning, the nature of knowledge, the methods of gaining understanding, interactions with students, and management of the project” (p. 178). After the failure to collaborate, the collaborative group acknowledged if they had explicitly stated and examined their assumptions about the collaborative work and project, then they may have avoided the conflicts they faced while working together and their students faced when completing the assignment. In order to effectively collaborate in these circumstances, the group members needed to be open about their goals and ideas for the collaborative work. Open and honest communication might have allayed the difficulties the group faced.

Another issue the collaborative group encountered was one member of the collaborative team emerged as a “leader” while the others followed her lead (Vanuspa et al., 2012). However, the researchers came to realize that “a true collaboration requires individuals to relate as equal co-creators with shared goals” whereas they were functioning as “contracted agents who are serving someone else’s goals” (p. 178). In order to avoid potential conflicts, the researchers assert that more focus should be placed on researching the process of collaboration. They also provide the following recommendations for successful transdisciplinary work:

- Each member of the collaborative group should possess an ability or habit of self-reflection about their own learning, epistemological views, and mental models, so the members are open to learning together throughout the collaborative process.

- A shared purpose and expected outcomes for students and faculty should be established together and these shared aspirations should be revisited recursively to determine whether or not decisions align with them.
The collaborative group should create the form and structure, including roles and responsibilities, after establishing the purpose. Avoid hierarchical structures.

Make decisions regarding processes and physical elements of the collaboration after the intent and form have been determined. Be sure the processes and other elements are aligned with the shared goals.

The group should self-monitor their progress and growth throughout the process and work with conflict. Members should embrace conflict, knowing there are differences in hidden assumptions and mental models, and use the conflict to explore each other’s views.

In a case study describing the collaborative process of designing and implementing a STEM (science, technology, engineering, mathematics) teacher education program, researchers found certain techniques and strategies responsible for successful collaborations (Konecki et al., 2012). At Grand Valley State University (GVSU), a higher education institution in Michigan, a clinically based teacher education program was collaboratively created and implemented. The project was funded by the W. K. Kellogg Foundation's Woodrow Wilson Michigan Teaching Fellowship Program and made possible by the efforts of various stakeholders. The collaboration began with the president, provost, and deans of the GVSU Colleges of Education, Liberal Arts, and Engineering and Computing, respectively, and eventually included other faculty from those colleges as well as administrators and educators from local school districts.

Analyzing the process through which the team worked to develop the program, the researchers identified important elements related to the group’s operation that contributed to the success of the collaboration and the resulting program. The researchers found the following characteristics necessary for success: a democratic process for decision making; an equal voice
for all stakeholders; agreement among stakeholders on program goals and structure; and group
discussion of ideas and revisions, as well as agreement on all aspects of the program
development (Konecki et al., 2012). In this study, the collaborative team had a shared, mutually
developed purpose and framework. They agreed upon their overall goals and desired results.
They had clearly defined tasks. After the program was implemented, the collaboration continued,
as “regular review, revision, and refinement are essential parts of program development” (p.
536). Workshops and monthly meetings were held to keep communication open, keep everyone
informed, and foster collaborative problem solving. Each of these aspects contributed to the
success of the collaboration.

Research shows collaborations, if organized and structured appropriately, may be highly
successful, and the benefits outweigh the obstacles. Collaborative groups may be organized
informally, with members joining because of shared interest (Lele & Norgaard, 2005) or to work
on transdisciplinarity (Vanasupa et al., 2012), or they may be organized formally, such as those
involved forming a learning community, as described below.

**Collaborative communities**

Collaborative efforts often occur through participation in a learning communities, such as
professional learning communities, faculty learning communities, thinking communities, or
networks. Participation in a collaborative learning community has been found to help educators
improve their practice and increase their and their students’ knowledge (Cox, 2004; Eddy &
Mitchell, 2012; Stoll, 2010; Stoll et al., 2006). Although each of the learning communities have
some features in common, there are differences worth noting. In the sections that follow, I
describe each type of learning communities and discuss research studies involving these
communities, focusing on the contributing and hindering factors to their success. Because the context for many studies conducted to examine collaborations occur within the context of K-12 education, I share results from those studies to provide insights about the potential of collaborative work in higher education.

There is general agreement in the education field that a learning community “broadly refers to an inclusive and mutually supportive group of people with a collaborative, reflective, and growth-oriented approach toward investigating and learning more about their practice in order to improve students’ learning” (Stoll, 2010, p. 151). Professional learning and community are two distinct concepts that are merged in the formation of a collaborative learning community (Mullen, 2009). These communities share main goals of increasing educator knowledge and enhancing student learning (Bolam et al., 2005).

A collaborative community may be categorized by the members of the community and/or how the community functions. In this section I discuss four different types of collaborative communities: professional learning communities, faculty learning communities, thinking communities, and networks. I give a brief overview of each type, including a definition, purpose, and characteristics of each, and discuss studies that have these types of collaborative communities at their focus.

**Professional learning communities.** There is no precise definition of professional learning community (PLC). However, a PLC typically involves “a group of teachers sharing and critically interrogating their practice in an ongoing, reflective, collaborative, inclusive, learning-oriented, growth promoting way” (Stoll & Louis, 2007, p. 2). Stoll and Louis (2007) define a PLC as:
an inclusive group of people, motivated by a shared learning vision, who support and work with each other, finding ways, inside and outside their immediate community, to enquire on their practice and together learn new and better approaches that will enhance all pupils’ learning” (Stoll & Louis, 2007, p. 5-6).

The main purpose of a PLC is to enhance student learning (Stoll et al., 2006; Stoll & Louis, 2007). Collaboration in the form of PLCs may help teachers enhance student learning because by “tackling problems of practice together, teachers come closer to solving them” (Wong, 2010, p. 623). PLCs have other important goals, such as increasing teacher knowledge, but all other goals should also lead to the overall purpose of student learning. PLCs also increase teachers’ morale and practice (Stoll, 2010). Another important goal of a PLC is continuous learning and growth, not the simple implementation of one specific change or improvement initiative, but the constant pursuit of increased success through learning (Stoll et al., 2006).

Members of a PLC should share a common passion and desire to learn how to enhance their own teaching and understanding and knowledge of their discipline (Pegg & Panizzon, 2011). They must have time to form connections and build relationships with one another. This is a complex task, as it requires “personal commitment, engagement, and a degree of negotiation by those involved in the relationship” (p. 151).

Although the term “professional learning community” has been employed to “describe every imaginable combination of individuals with an interest in education” (DuFour, 2004, p. 1), it is not a comprehensive term for any collaboration. Thus, a PLC has specific identifiable characteristics, even if every PLC will not appear exactly the same. DuFour outlines three core principles of PLCs. First, PLCs must ensure students learn. The focus of education must shift from teaching to learning. Second, PLCs must be formed in a culture of collaboration;
collaborative work must be viewed as valuable and necessary rather than expected or required.

Educators in a PLC must work together, in a systematic fashion, to achieve their collective focus of learning for all through analyzing and improving their practice. Third, PLCs must focus on results, which determine the effectiveness of a PLC. PLC members participate in an “ongoing process of identifying the current level of student achievement, establishing a goal to improve the current level, working together to achieve that goal, and providing periodic evidence of progress” (p. 6).

After an exhaustive literature review and a large-scale study of PLCs in schools in England, Bolam et al. (2005) found eight characteristics should be evidenced in a PLC. They are: shared values and vision; collective responsibility for pupil learning; collaboration focused on learning; individual and collective professional learning; reflective professional enquiry; openness, networks, and partnerships; inclusive memberships; and mutual trust, respect, and support. After studying PLCs in a middle school, Liebermann (2009) found the following characteristics necessary in a learning community: a shared mission for all students to learn, a collaborative culture, and engagement in continual improvement, which supports the findings from Bolam et al. (2005).

Huffman (2003) analyzed existing data from a five-year study of PLCs conducted by Southwest Educational Developmental Laboratory in Texas. In the study, principals and teacher leaders from 18 schools with PLCs were interviewed about their involvement in PLCs. Huffman found shared vision is the most important characteristic in a successful PLC, and the shared vision should be based on collective values and will form the foundation for informed leadership, staff commitment, student success, and sustained growth.
In their study of PLCs, Bryk et al. (1999) sought to determine if “a climate of experimentation and innovation is more common in schools organized as professional communities” (p. 760). The researchers used data from a survey previously administered to 5,690 teachers in 248 public elementary schools in Chicago in spring of 1994. The survey contained items regarding “teachers’ views of the school environment, classroom learning, parental involvement, governance, and the professional work life of teachers” (p. 760). The researchers focused on seven components of PLCs in their data analysis: reflective dialogue; deprivatized practice; staff collegiality/collaboration; focus on student learning; collective responsibility for school operations and improvement; teacher socialization; and professional community composite.

The researchers found PLCs can thrive in all types of schools (Bryk, Camburn, & Louis, 1999). Professional community can occur in many diverse educational settings and teachers from a wide variety of schools give positive reports about professional community. Moreover, the researchers found characteristics of the school such as race and ethnicity, socioeconomic factors, and even academic background were not strong predictors of a school’s professional community. However, Bryk et al. (1999) found there are certain factors which help support the development, implementation, and sustainability of the collaborations. The researchers determined there are three core practices in which adults in successful PLCs engage. First, teachers must participate in reflective dialogue together regarding instructional practices and student learning. Second, they must work towards a deprivatization of practice. Teachers must observe one another’s practice and work together to solve problems. Third, teachers must be willing to collaborate with their peers and engage in shared work.
In a case study of a PLC comprised of mathematics and science secondary teachers, Nelson (2009) found interdisciplinary work may cause issues when teachers from different perspectives work together in a learning community. The participants had different understandings of formative assessment, student engagement, hands-on learning, among others. They also had different “beliefs about the importance of various teaching strategies and educational initiatives” (p. 567). The community embraced a “culture of niceness,” inhibiting their “willingness or abilities to question each other’s stated beliefs” (p. 567-568). They did not challenge their beliefs or understandings, and thus, the community struggled to build shared knowledge and optimize collective learning.

In a study of PLCs in Shanghai, China, Wong (2009) found collaboration flourished when teachers looked for ways to increase student achievement in a test-driven school wide reform. She found having a shared goal helped to “adhere teachers together” and share “practices of their teaching” (Wong, 2009, p. 634). Wong also found the PLC, which was comprised of secondary mathematics teachers, succeeded in part due to an outside expert who was brought in to facilitate meetings. Specifically, she found the members of the PLC “tended to follow rather than challenge tasks and ideas delivered by experts” (p. 635) suggesting there may be a tendency for mathematicians to comply with those who they see as the “expert” in the situation.

The studies involving PLCs mentioned above provide much information about the critical characteristics necessary for a successful PLC. PLCs should be inclusively developed to pursue a shared goal of student learning. Members should have shared visions and values, be committed to the group and goal, be willing to engage in collaborative work in which they are collectively responsible, be open to building relationships based on mutual respect and trust, and reflect on the process. PLCs are often found in primary and secondary schools yet the findings show that
the successful PLCs often have the same characteristics and structure that makes all collaborations successful. Thus, the research on PLCs might be applicable to collaborations in other educational settings, such as higher education.

**Faculty learning communities.** A learning community formed in a higher education institution is often referred to as a faculty learning community (FLC). Researchers at Miami University instituted a Faculty Learning Community, defined as:

a cross-disciplinary faculty and staff group of six to fifteen members who engage in an active, collaborative, yearlong program with a curriculum about enhancing teaching and learning and with frequent seminars and activities that provide learning, development, the scholarship of teaching, and community building. (Cox, 2004, p. 8).

An FLC can be topic-based or cohort-based. Self-reported data analyzed from surveys completed by 50 past FLC members at Miami University showed evidence of increased student learning as a result of faculty participation in the FLC.

Community in an FLC is of utmost importance. Cox (2004) found ten qualities necessary for community in FLCs: safety and trust; openness; respect; responsiveness; collaboration; relevance to participants’ lives, careers, etc.; challenge and high expectations; enjoyment; esprit de corps (feelings of loyalty, enthusiasm, and devotion); and empowerment.

Faculty across science, technology, engineering, and mathematics (STEM) disciplines at Howard University participated in the faculty learning community project, based on the Miami University FLC structure (Smith et al., 2008). The diverse group of participants engaged in the “scholarship of teaching and learning by learning about teaching, reflecting on their practice, and demonstrating competence or knowledge of effective teaching” (Smith et al., 2008, p. 203). The researchers evaluated the FLC activities, which included interdisciplinary seminars, linked
courses, teaching experiments, and biweekly meetings, and analyzed self-reported survey data and found FLCs are an effective way to enhance teaching and learning in STEM subjects. However, the members of the FLCs did face some challenges. Obstacles to success included a lack of incentive for faculty to participate and complicated institutional procedures (Smith et al., 2008). Sustainability was also a challenge because it took time to see effects on student learning. Almost half of the participants had withdrawn from the FLC before the researcher had an opportunity to examine links to student learning outcomes. Perhaps, if the participants had been able to see the effect of the FLC on student achievement, they may have had more incentive to remain part of the FLC.

**Thinking communities.** Another type of learning communities in higher education is a thinking community. A thinking community is a “reflective group intentionally developed by faculty members and often nurtured by faculty developers to create a synergy for knowledge creation” (Eddy & Mitchell, 2012, p. 284). Although thinking communities and FLCs share a common goal of faculty learning, thinking communities differ from FLCs in that they are less formal and are not typically organized around a particular faculty group or topic. The focus of a thinking community is the collaborative process, not an outcome or product, although products may be an additional result of the collaborative and reflective process. Shared research interests form the foundation of the thinking community, and those interests are developed and supported in the community’s reflective and collaborative environment.

Participation in a thinking community involves “creating a framework within which all members can contribute, establishing a location in which joint work occurs – both in a physical sense by meeting together and in an intellectual sense”, which encourages the collaborative team to mutually determine expectations and build trust in one another (Eddy & Mitchell, 2012, p.
Thinking communities evolve from FLCs or other collaborations when the collaborative team enters into a “reflective process that includes changes in the way group members think or perceive what they know” (p. 290). The members of a thinking community focus on learning and expanding their knowledge. Thinking communities must have regularly scheduled meeting time for group members to communicate and interact in order to develop (Eddy & Mitchell, 2012).

**Networks.** Learning communities in higher education may also function similar to a networked learning community (NLC). Learning in a NLC occurs when individuals from different schools in a network engage together “in purposeful and sustained developmental activity… using their own know-how and co-constructing knowledge together” (Stoll & Louis, 2007, p. 48). In doing so, they learn from and with one another while also learning about their own learning. One of the main tenants of the NLC framework is adult learning through mutual commitment and co-leadership.

Researchers studied 137 networks comprised of members from 1500 schools in England’s National College for School Leadership Networked Learning Communities program from 2002-2006 (Stoll & Louis, 2007). Through their analysis of data, researchers determined five network learning activities that enhance professional learning: joint work groups, collective planning, mutual problem-solving teams, collaborative enquiry groups, and shared professional development activities. They also found the main goal of NLCs is improving teacher knowledge and best practices with the intent of increasing student achievement and “networks foster effective collaborative professional learning” (Stoll & Louis, 2007, p. 55).

**Summary.** Overall, research shows participation in collaborative learning communities improves teacher efficacy, increases teacher knowledge, and empowers teachers. To achieve...
these results, learning communities must be developed with a shared vision and goals and have commitment of its members.

Although the research described above may be used to define, create, and implement learning communities in higher education, there is a lack of research regarding the development and success of learning communities in higher education. There is also little literature on collaborative efforts among or learning communities comprised of members of an education department and specific content faculty, particularly mathematicians and mathematics educators. This research is necessary for the preparation of preservice teachers because these two groups are responsible for their education.

Collaboration as an Approach to Preservice Mathematics Teacher Preparation

Preservice mathematics teachers are expected to develop mathematical knowledge for teaching, pedagogical knowledge, and pedagogical content knowledge (PCK) in order to effectively teach mathematics (Ball et al., 2001; Shulman, 1986). PCK is the ability to use “the understandings of subject matter concepts, learning processes, and strategies for teaching the specific content of a discipline in a way that enables students to construct their own knowledge effectively in a given context” (Cochran et al., 1991, p. 11). It is the content knowledge that is exclusive to teaching, the knowledge needed in order to teach specific content to others that bridges the ideas of knowing content and teaching content (Shulman, 1986). PCK is the knowledge that allows teachers to take their own knowledge they have gained through their own interpretations of content and transform it so they can help others understand it.

In order to develop PCK, understanding of both content knowledge and pedagogical knowledge is necessary. Preservice teachers enrolled in education programs in many higher
education institutions often take courses in different college departments to develop their pedagogical knowledge and content knowledge. For example, secondary education mathematics preservice teachers may take methods and pedagogy courses in the College of Education and their mathematics content courses in the College of Arts and Sciences. Unfortunately, these courses are often disjointed and preservice teachers have few opportunities to make connections needed to develop PCK (CBMS, 2001).

Ball, Thames, and Phelps (2008) examined data from a database of records documenting one year of teaching in a third grade classroom, previously collected with grant funding from the National Science Foundation. The researchers investigated PCK and how teachers need to know the content they are teaching. Specifically, the researchers were guided by two questions. First, researchers wanted to know the recurrent tasks and problems of teaching mathematics and what teachers do as they teach mathematics. Second, they wanted to know what mathematical knowledge, skills, and sensibilities are required to manage these tasks. The researchers also relied on their own personal experiences and previous research as data.

The researchers found the knowledge needed for teaching mathematics consisted of more than just mathematics content (Ball et al., 2008). Mathematics teachers need to be able to analyze student errors, evaluate student solution strategies, explain rationale for algorithms and procedures, choose appropriate tasks and problems, and ask appropriate mathematical questions. Additionally, many of these tasks must be done “in the moment” when responding to students in the classroom setting.

Although these tasks are mathematical in nature, knowing the mathematics alone is not enough. The researchers found teachers need to know and understand more and different mathematics than what they are teaching (Ball et al., 2008). According to Ball et al., PCK can be
divided into two separate types of knowledge, knowledge of content and students and knowledge of content and teaching. Similarly, not only do teachers need common content knowledge, or mathematical knowledge that would be used in settings other than teaching, such as calculating an answer or following a procedure, but they also need specialized content knowledge, or mathematical knowledge and skills that are unique to teaching, such as being able to explain rules and methods and be able to choose examples to demonstrate specific concepts.

Preservice teachers need a preparation program that can help them acquire the unique pedagogical content knowledge, a program which helps them acquire mathematical knowledge they must know and be able to use “inside the work of teaching” (Ball et al., 2008, p. 404). However, the mathematics content courses taken by preservice teachers tend to be irrelevant to teaching (Ball et al., 2008). Also, mathematics content taught in methods courses is often decontextualized in the sense that the content is not applicable to preservice teachers’ experiences in the classroom (Enzor, 2001). The mathematics content they are learning cannot be integrated with their knowledge of methods of teaching or pedagogy. Preservice teachers need a preparation program that helps them transfer knowledge of pedagogy and content successfully in the classroom (Lloyd, 2013). Collaborative efforts between faculty in education departments and mathematics departments have the potential to prepare preservice teachers in a way that enhances their learning of PCK and more effectively prepares them for teaching (Cochran et al., 1991; CBMS, 2001, 2012).

In a qualitative study of the effectiveness a teacher preparation program, Lloyd (2013) observed 16 first year mathematics teachers after they completed their teacher preparation program to determine how well the ideals and methods they learned in the program transferred to their teaching in the classroom. The teacher preparation program focused on student-centered
classrooms and conceptual learning through critical thinking, reasoning, high levels of abstraction, and problem solving and advocated the use of hands-on, deductive, inductive, and discovery-learning activities, real world connections, prior knowledge, relevant problems, scaffolding, and connections to broad mathematical ideas.

Through observations of the teachers in their classrooms, the researcher found 71% of all observations were practices taught in the teacher preparation program (Lloyd, 2013). Although sometimes teachers designed teacher-centered classrooms, promoted memorizing facts and procedural understanding over conceptual understanding, and emphasized correct answers and grades over making sure their students understood the content, overall, the teacher preparation program was effective (Lloyd, 2013).

The teachers in the study were able to transfer the practices learned in their teacher preparation program because they were exposed to connected pedagogical content knowledge in their preparation program. Their courses were not taught as disjoint entities and preservice teachers were able to experience learning mathematics and methods through the practices espoused by the program (Lloyd, 2013).

Traditionally, mathematics teaching focuses on facts and procedural understanding whereas mathematics educators stress the importance of teaching “big ideas” and conceptual understanding (Reeder, Cassel, Reynolds, & Fleener, 2006). Based on the results of her study, Lloyd (2013) suggests teacher preparation programs be designed consistent with the ways the program suggests mathematics be taught and preservice teachers be taught “using examples that connect to prior experiences, the real world, and to other pedagogical concepts” (p. 114).

Preservice teacher preparation programs must be designed such that preservice mathematics teachers are taught in the same manner they expect to teach their future students.
Essentially, to maximize retention and transfer, teacher educators must teach “using authentic learning strategies that facilitate conceptual understanding of pedagogical practices” (Lloyd, 2013, p. 114). As educators of preservice teachers, mathematicians may also want to teach preservice mathematics teachers by employing these concepts. Often, mathematicians teach through lecture, yet “there is much more to effective teaching than standing in the front of the room giving information to students” (The National Academy of Education Committee on Teacher Education, 2007, p. 113).

At a private university in Boston, a mathematics educator and a mathematician formed a learning community to enhance elementary preservice teachers education as it relates to mathematics concepts and how to teach them (Beers & Davidson, 2009). They attended weekly planning meetings, taught their respective mathematics content and mathematics methods course for preservice elementary teachers, and co-taught an integrative seminar including both mathematics concepts and the methods for teaching those topics to elementary students. The collaboration proved beneficial for both parties. The mathematician learned about elementary mathematics standards, what and how topics are typically taught in an elementary classroom, and the tests that preservice teachers are required to pass for certification. The mathematics educator learned about the topics covered in the mathematics content course for preservice teachers and how those topics are taught in an advanced setting as compared to elementary mathematics. Additionally, she increased her knowledge of mathematical models and better appreciates the need for elementary teachers to understand the mathematics at a deeper level in order to effectively communicate it to elementary students.

**Summary.** Teachers need to have PCK in order to be effective (Ball et al., 2008; Shulman, 1986). In order to develop PCK, prospective teachers need to be able to make
connections between the pedagogical knowledge and the content knowledge they are learning in their teacher preparation program (Ball et al., 2008; CBMS, 2001). They also need to be able to make a connection between the content and pedagogical knowledge and their experiences in the classroom (Enzor, 2001; Lloyd, 2013). Collaboration between the mathematics educators and mathematicians might result in preservice teachers having these crucial experiences (Cochran et al., 1991; CBMS, 2001; 2012). In the following section, I discuss how collaboration, as a form of professional development, may encourage change in educators of preservice mathematics teachers.

Instructor Change as a Result of Collaboration

Researchers and educators have called for the need to change the way mathematics, among other subjects, is taught in higher education communities, focusing particularly on changing from teacher-centered instruction to student-centered learning (Henderson et al., 2011). In their exhaustive literature review, Henderson et al. looked at changes in instructors’ teaching in undergraduate STEM (science, technology, engineering, and mathematics) courses and found the changes often result from the instructor’s participation in professional development.

Instructor change and professional development. Meaningful professional development, lasting for at least a full semester, has the potential to enhance teacher knowledge (Bolam et al., 2005; Henderson et al., 2011). Instructor change often is the result of an increase in teachers’ knowledge and the application of that new knowledge in their classrooms. (Fennema et al., 1996). Particularly, “strategies that deliberately focus on conceptual change appear to have high levels of success in creating meaningful conceptual change in faculty that result in changes in practice” (Henderson et al., 2011, p. 973).
Instructor change and learning communities. Participation in learning communities may and should be considered professional development for instructors (Bolam et al., 2005; Hamos et al., 2009). Participation in a collaborative learning community affords instructors the opportunity to form a “professional identity” in which learning from other instructors and education professionals and continuously improving their own practice is imperative (Liebermann, 2009, p. 97).

In her study of a PLC in a middle school mathematics department, Lieberman (2009) documented how prolonged work in a learning community is a form of professional development for teacher involved. The PLC was formed when the seven teachers in the department decided to participate in lesson study. In her study, Liebermann researched the impact of lesson study on the development of PLCs at Lincoln Middle School. Seven teachers in the mathematics department at Lincoln had been involved in lesson study for seven years and were chosen for a case study because of their continual involvement and level of participation. The researcher, who was also the lesson-study leader, collected and analyzed data from audio recordings of lesson study planning meetings and video analysis sessions, interviews with selected teachers, and lesson plans developed during the past five years. The researcher coded data, focusing on what it means to be part of a teacher learning community, how teachers learn from being part of such a community and how participation in lesson study groups facilitates the process of becoming a learning community.

The researcher found the following: the teachers learned to value the collaboration process, not just the outcomes; the teachers learned to plan with student understanding and success as an overarching, long term goal; and the teachers learned to challenge their students to think on their own (Liebermann, 2009). These findings lead Liebermann to conclude
“participating in a learning community allows teachers to develop or confirm a teacher identity that includes meeting the needs of students and learning from other teachers in order to do so” (p. 85) and through interaction “with one another about teaching, [teachers] develop and re-develop their skills, knowledge, beliefs and philosophies of teaching and learning that directly influence how they teach mathematics to students” (p. 96).

Daly (2011) describes a study of faculty learning communities in seven higher education institutions. Each individual faculty learning community was grant-funded, and the instructors volunteered to participate in each learning community. The learning communities were self-directed and autonomous, and the participants met weekly during one semester to “to engage in professional reflection and initiate changes in their courses to improve curriculum and pedagogy” (Daly, 2011, p. 9). Each collaborative group also designed projects to improve the educational environment for diverse students. At the conclusion of the one year project, 40 out of 51 total faculty members participated in an interview about their perceptions of and experiences in the learning community. The researcher found faculty learning and development occurred due to the participation in the learning community (Daly, 2011). As part of the learning community, the group members experienced autonomy, competence, and relatedness, increasing their intrinsic motivation to improve their teaching and learning, and ultimately leading to faculty development and growth, and pedagogical change.

**Successful instructor change.** In order for instructors to embrace change, they must “understand their own practice and the conceptions of teaching that influence it” (Henderson et al., 2011, p. 975-976). When the climate of the classroom changes to one that is student-centered and focused on inquiry and problem solving, the role of the instructor changes as well (Sowder, 2007). In a study of the collaboration between a mathematics teacher educator and a
mathematician, Bleiler (2014) found the mathematician’s attitude toward his students changed as a result of the collaboration. He learned that selecting and posing mathematical problems that align with students’ needs is important for student learning.

Instructor change is not an easy process and barriers include institutional structures not aligned with the change effort and current beliefs of instructors involved in the change effort. Sustained engagement in professional development and support may facilitate instructor change (Henderson et al., 2011). Instructor change is necessary because there have been calls to transform the way preservice mathematics teachers are educated, requiring collaboration and a focus on helping preservice teachers develop the knowledge needed for teaching (CBMS, 2001, 2012).

**Summary and Discussion**

Collaboration among mathematics educators and mathematicians has been encouraged for improvement of mathematics teacher preparation programs (Cochran et al., 1991; CBMS, 2001, 2012). Research has shown that not only is collaboration effective in increasing teacher knowledge and student learning, but it might potentially incite instructor change, which might provide great benefits for teacher education programs. However, successful collaborative efforts take time, hard work, and commitment, and often must overcome challenges and obstacles. In the following section, I summarize the literature review and discuss the implications drawn from the literature.

Collaboration among higher education faculty may be invigorating and all-encompassing for those involved (Eddy & Mitchell, 2012). It may increase productivity and possibly lead to more successful programs (Eddy & Mitchell, 2012; Konecki et al., 2012). However, there are
many challenges and obstacles to collaboration, such as tensions among collaborators due to individual, epistemological, and teaching differences and power imbalances or lack of resources (Eddy & Mitchell, 2012; Konecki et al., 2012; Lele & Norgaard, 2005; Stoll et al., 2006; Vanasupa et al., 2012). In order for collaborative efforts to succeed, members of the collaborative group must be committed to the shared, co-created goals, the collaborative process, and each other (DuFour, 2004; Eddy & Mitchell, 2012; Konecki et al., 2012; Vanasupa et al., 2012).

Collaborative efforts are often seen in the form of learning communities, such as professional learning communities, faculty learning communities, thinking communities, or networks. Participation in a collaborative learning community helps educators improve their practice and increase their knowledge (Cox, 2004; Eddy & Mitchell, 2012; Stoll, 2010; Stoll et al., 2006).

Preservice mathematics teachers are educated by both mathematics educators and mathematicians. Thus, mathematics education faculty and mathematics faculty in higher education institutions must work together to help preservice teachers develop both the content knowledge and pedagogical knowledge necessary for effective teaching (CBMS, 2001, 2012). However, mathematics educators and mathematicians often have different views of learning and teaching, which may make collaborative efforts between them challenging (Bleiler, 2014).

Participation in successful collaboration, in the form of learning communities or other collaborative efforts, should enhance teacher knowledge, making collaboration a form of professional development for educators and potentially inciting instructor change (Bolam et al., 2005; Fennema et al., 1996; Henderson et al., 2011). This instructor change may be the catalyst necessary to enhance mathematics teacher preparation programs.
Because collaboration is increasingly encouraged for preservice teacher education, more studies are needed to examine the processes through which collaboration occurs and what makes collaborative efforts successful. Specifically, studies should look at collaborative efforts associated with teacher preparation program.

Much of the extant research on collaboration was conducted from the perspective of researchers as collaborators. The studies are autobiographical narrative case studies based on personal experiences (see Konecki et al., 2012; Vanasupa et al., 2012). However, there is little research in which third party researcher observes and analyzes the collaborative process. Research done from this perspective may provide an unbiased account of the collaboration, possibly detailing characteristics of success, supporting or hindering factors, or obstacles that may be overlooked by a participating member of a collaborative group.

There is also little research that examines interdisciplinary learning communities at the higher education level, specifically studies focused on how mathematics teacher educators and mathematicians collaborate. There is a lack of research related to the engagement of mathematics teacher educators and mathematicians in learning communities. More research in this area might provide an opportunity to examine how faculty learning communities may enhance students’ achievement in mathematics.

However, the results of extant research are promising. In a study that examined the team teaching experiences of a mathematics educator and a mathematician, professors worked together to plan and coteach courses for preservice secondary mathematics teachers (Bleiler, 2012). The researcher found the professors “perceived their participation in the team-teaching collaboration as influential to their professional development as teacher educators” (p. 212). She also determined participating in the collaboration increased professors’ awareness of their own
practices and of the needs of preservice mathematics teachers. More studies of this nature may provide insight into what makes collaborations among mathematicians and mathematics educators successful.

It has been suggested in calls for the transformation of preservice mathematics teacher education programs that mathematics educators and mathematicians work collaboratively to develop courses and teach preservice teachers. Mathematics education professors and mathematics professors must work together towards a unified program that encompasses the content, methods, and best practices in every course. Those who participate in such collaborative efforts may be informed by research that identified supporting and hindering factors and characteristics and may utilize this information to support the success of the endeavors in which they engage.
CHAPTER 3:

METHOD

I explored the experiences of three professors, one mathematics educator and two mathematicians, as they worked together to plan and teach concurrent mathematics education and mathematics courses for preservice middle level mathematics education teachers. I used existing data from observations conducted as part of a large scale evaluation effort and interviewed participants in an attempt to answer the following research questions:

1. What approaches do a team comprised of a mathematics educator and two mathematicians use to facilitate their collaborative co-planning efforts as they prepare for and teach concurrent mathematics methods and mathematics courses for preservice middle grades mathematics teachers?

2. What factors support or hinder the collaboration?

3. In what ways does the collaboration affect the mathematics educator’s and mathematicians’ course planning and teaching?

Context of the Study

The collaborative effort under investigation was part of a larger, grant-funded effort to develop, implement, and refine a middle school mathematics teacher education program at a large university in the southeastern United States. As part of this project, teams of faculty have collaborated to design courses that meet the program goals, including preparing highly effective
middle school mathematics teachers who are qualified to teach rigorous content standards to a diverse student population.

The program has been collaboratively developed by faculty in the College of Education, the College of Arts and Sciences, and the College of Engineering, in partnership with mathematics personnel from a large county-wide public school district. Over the course of three years (2012 – 2014), the faculty from the mathematics department and the mathematics education department worked together to develop and subsequently teach the courses for the middle grades mathematics education preservice teachers. The involvement of faculty is vital to the success of the program; commitment, shared responsibility, and contributions from all collaborators are essential aspects needed to support the effective implementation and sustainability of the program (Ellerbrock et al., 2016). These faculty members, who were likely to be impacted by the program, provided input on integral decisions.

As part of the program, preservice teachers take mathematics content courses and mathematics methods courses. The content courses are designed to give preservice teachers advanced experiences with topics they will be responsible for teaching. These experiences will help them develop the specialized knowledge needed for teaching. The pedagogy courses are designed for preservice teachers to examine topics related to curriculum, instruction, assessment, and other education issues, such as technology and equity, with a focus on inquiry based teaching and lesson and unit planning, while addressing the needs of the adolescent learner (Ellerbrock et al., 2016).

To ensure the courses are implemented as envisioned, the instructors for the content and methods courses met during the summer prior to start of the program to co-plan. During the semester they taught the co-requisite courses, the instructors met to discuss issues and
experiences with preservice teachers, and adjust and refine plans as necessary (Ellerbrock et al., 2016). Graduate students observed the planning meetings and individual courses and recorded detailed field notes. Instructors also met with the graduate students for both pre- and post-conferences to discuss their plans for each class and their views on whether they taught and covered topics as they had intended.

The collaboration examined in this study occurred during the spring semester of the first year of implementation with the first cohort of preservice teachers who began in Fall 2013 and graduated in May 2015. I was the graduate student assigned to observe the two mathematics content courses the students matriculated that semester as well as the collaborative meetings among the mathematicians and the mathematics educator.

Conceptual Framework

The conceptual framework (see Figure 1) identifies the main concepts examined in this study and explains the relationship between and among them (Miles and Huberman, 1994). The concepts examined in the study are the collaborative process, the hindering and supporting factors, and instructor change.

![Figure 1. Graphical representation of framework.](image)

**Hindering Factors**
- unresolved differences
- power imbalances
- lack of participation

**Supporting Factors**
- commitment
- respect
- shared goals
- responsibility
- ownership

**Collaboration Process**

**Instructor Change**
Extant research has identified key factors that support and hinder collaborative efforts. How the supporting and hindering factors are addressed as part of the collaborative process has been found to affect the success of the collaboration. Supporting factors include commitment and dedication of collaborative group members; shared vision, goals, ownership, and responsibility; and respect for and trust of group members (DuFour, 2004; Eddy & Mitchell, 2012; Konecki et al., 2012; Stoll & Louis, 2007; Vanasupa et al., 2012). These factors provide evidence of a successful collaboration as they indicate members’ commitment to the process, willingness to work together towards success, and an openness to learn from one another.

Hindering factors are unresolved differences among group members’ values, theoretical positions or assumptions, disciplinary cultures, expertise, or career positions; unaligned vision or goals; unwillingness to change; lack of respect for other group members; lack of participation by one or more group members; power imbalances; and lack of time (Bryk et al., 1999; Eddy & Mitchell, 2012; Konecki et al., 2012; Lele & Norgaard, 2005; Vanasupa et al., 2012). These factors indicate the possible failure of a collaboration as they have the potential to cause problems with communication and demonstrate members’ unwillingness to resolve differences and arguments in order to work towards a common goal.

Participation in a collaborative effort may provide mathematicians the guidance, assistance, and scaffolding necessary for a change in the way they teach preservice teachers. The instructional practices of mathematician are typically characterized as teacher-centered, focused on facts and procedures, whereas the goal for instruction, from a mathematics education perspective, is to be student-centered (Lloyd, 2013; Reeder, Cassel, Reynolds, & Fleener, 2006). Evidence exists that suggests mathematicians involved in collaborations with mathematics teacher educators have become more student-centered (Bleiler, 2014; Henderson et al., 2011;
Reeder et al., 2006). Additionally, instructor change is a possible result of collaborative efforts (Henderson et al., 2011).

**Descriptive Case Study**

I employed a descriptive case study approach for this research to provide a rich description of events in the real-life context where they occur (Baxter & Jack, 2008; Merriam, 2009). Specifically, I described the collaborative processes and experiences of three faculty members, one mathematics educator and two mathematicians, as they worked together to plan and teach concurrent courses for preservice middle grades mathematics education teachers. A descriptive case study is the best method to answer the research questions guiding my inquiry, as it allowed me to learn in depth about the roles played by each individual involved in the collaboration as well as the interactions between them. As recommended, I “systematically gather[ed] enough information about a particular person, social setting, event, or group to permit [me] to effectively understand how the subject operates or functions” (Berg, 2009, p. 317). This allowed me “to retain the holistic and meaningful characteristics of real-life events” (Yin, 1994, p. 3). In addition, it ensures the information collected was rich, detailed, and in-depth (Berg, 2009) so the presented case has sufficient information to build understanding.

**Participants.** The participants in the inquiry were two mathematicians (Tom and Doug) and one mathematics educator (Melina) who collaborated on the development of the mathematics content and mathematics methods courses in the program described earlier. This was the first time they collaborated with each other, although two of the participants had prior collaborative experiences.

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1 Pseudonyms used for confidentiality of participants
Tom. Tom earned his bachelor’s degree in mathematics with an emphasis in secondary mathematics education at a university in the southeast European country where he was born. For two years, he taught at a high school for mathematically advanced students who planned to pursue a post-secondary mathematics degree. He earned his Ph.D. in mathematics in the United States. He has worked in department of mathematics and statistics for 22 years, first as an instructor for 18 years and now as an assistant professor. He has prior experience teaching courses designed for undergraduate preservice teachers. Tom has participated in a collaborative effort with the college of education in the past, in which he worked with a different mathematics educator to co-plan and co-teach a mathematics content course and a mathematics methods course for preservice secondary education teachers (see Bleiler, 2014).

Doug. Doug earned his bachelor’s degree in mathematics and physics, his master’s degree in applied mathematics, and his Ph.D. in applied mathematics in the United States. He has taught at the post-secondary level for a total of 24 years, in his current position as a professor in the department of mathematics and statistics for the last 19 years. He has not taught undergraduate mathematics courses designed specifically for preservice mathematics teachers prior to teaching the course in this program. He has had no formal education or training in teaching.

Melina. Melina began her undergraduate program in the southern European country where she grew up, but completed the program and earned her bachelor’s of science degree in mathematics in the United States. She earned her master’s degree in secondary mathematics education and her Ph.D. in curriculum and instruction with an emphasis in mathematics education in the United States. She taught middle school and high school mathematics for two
years and has taught mathematics education at the post-secondary level in her current position in the college of education for nine years.

**Data Collection**

In the following section, I begin with a description of the tools used for data collection. Then I discuss the data collection methods.

**Instrumentation.** In this section, I describe the tools employed in this study during class observations and interviews.

**Observation tool.** I recorded field notes using an observation protocol (see Appendix A) as I observed classes taught by each instructor. The protocol includes sections to record the general topic(s) covered in each class and how much time is spent on each. Then, for each topic the protocol includes a section for the observer to record observations about the instructor’s teaching method, including how the topic was taught, the materials used by the instructor and students, and the purpose for the teaching activity/method (e.g. introduce new concepts, review, etc.).

**Interview Protocol.** I developed an interview protocol to collect information about: participants’ (1) teaching background and education, as well as their expectations and anticipations for the collaborative work to occur throughout the rest of the semester; (2) ideas and thoughts about the progression of the collaborative work they are doing and what is occurring in their classroom; (3) their overall experiences co-planning, focusing specifically on challenges and supporting and hindering factors and; (4) any teaching changes they have made due to the participation in the collaboration or the middle grades education program. The semi-structured interview questionnaires used in the interviews are provided in Appendix B.
**Data sources.** To address my research questions, I used existing data collected while I worked as a graduate assistant as part of the evaluation of the middle grades education project. The specific data used in this study are three semesters of observations of planning meetings among the participants, one semester of class observations (Geometry Connections, Algebra Connections, and Mathematics Methods 2), and interviews.

**Observations.** I was a participant observer while the team engaged in co-planning courses for the preservice teachers in the middle grades mathematics program before, during, and after the semester in which they taught concurrent courses offered during the same semester. I observed both planning meetings and classes taught by the collaborators to collect contextual data from the events viewed in “real time” (Yin, 1994).

**Planning meetings.** I participated in and wrote detailed field notes during 17 planning meetings that occurred throughout three semesters: Summer 2013, Spring 2014, and Summer 2014. There were six meetings in Summer 2013, each of which was attended by all three participants. Six meetings were held in Spring 2014, four of which were attended by all three participants. Each mathematician missed one meeting. During Summer 2014, one meeting was attended by all three participants. For the remaining meetings, the mathematics educator met with one mathematician at a time, for a total of four other meetings.

**Classes.** I attended and took detailed field notes during each class taught by each participant for the middle grades teacher education program. I took field notes during the observations and used these notes to complete an observation form developed for the evaluation of the middle grades teacher education program, which can be found in Appendix A. Each participant taught two 75 minute classes per week, all of which I attended, with the exception of
test days, for a total of 77 classes. This includes 25 math education classes taught by Melina, 26
math classes taught by Tom, and 26 math classes taught by Doug.

**Interviews.** I conducted three semi-structured interviews with each participant. Each
participant was asked the same questions for the first interview. The questions for subsequent
interviews were determined based on the participants’ responses to the first interview and from
observation notes, thus each participant has different interview questions for the second and third
interviews.

**Researcher’s journal.** I kept a journal during the data collection phase to note my own
thoughts as I collected information. I often noted my perceptions of the meetings, interviews,
and classes. During observations, I noted my thoughts about the communication processes
occurring among the three professors. For example, during a meeting in the Summer of 2013, in
the journal, I wrote, “Melina is leader of the group – Tom and Doug seem to work/behave as if
she is the one with the information and they are taking their lead from her.” Journals written
during class observations often noted whether things discussed in the meetings were being
observed in the classroom. Journaling while conducting interviews helped me to refine follow up
questions. As a result, my journal served as an additional source of data for the study.

**Data Organization**

I audio-recorded and transcribed each interview. After the initial transcription, I read the
transcripts while listening to the audio-recordings to ascertain the extent to which they were
accurate. Field notes from class observations and planning meetings were typed and organized
according to date.
Data Analysis

Before beginning an analysis of the data, I read and reread the interview transcripts and field notes several times in order to develop a complete understanding and in depth knowledge of the data. I used ATLAS.ti, a qualitative data analysis tool, to code the data.

Thematic analysis of meeting observations and interviews. I analyzed the observation and interview data using thematic analysis as described by Braun & Clarke (2006), summarized below in Table 1.

Table 1. Thematic Analysis Guidelines

<table>
<thead>
<tr>
<th>Phase</th>
<th>Description of the process</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Familiarizing yourself with your data:</td>
<td>Transcribing data (if necessary), reading and re-reading the data, noting down initial ideas</td>
</tr>
<tr>
<td>2. Generating initial codes:</td>
<td>Coding interesting features of the data in a systematic fashion across the entire data set, collating data relevant to each code.</td>
</tr>
<tr>
<td>3. Searching for themes:</td>
<td>Collating codes into potential themes, gathering all data relevant to each potential theme.</td>
</tr>
<tr>
<td>4. Reviewing themes:</td>
<td>Checking of the themes work in relation to the coded extracts (Level 1) and the entire data set (Level 2), generating a thematic “map” of the analysis.</td>
</tr>
<tr>
<td>5. Defining and naming themes:</td>
<td>Ongoing analysis to refine the specifics of each theme, and the overall story the analysis tells, generating clear definitions and names for each theme.</td>
</tr>
<tr>
<td>6. Producing the report</td>
<td>The final opportunity for analysis. Selection of vivid, compelling extract examples, final analysis of selected extracts, relating back of the analysis to the research question and literature, producing a scholarly report of the analysis.</td>
</tr>
</tbody>
</table>

Braun and Clarke (2006, p. 87)

First, I read and reread the data and made notes and memos to gain an understanding about the data. These memos typically indicated whether I thought the segments of the data were relevant to research question one, two, or three. There was often data that were classified into more than
one category. Then I coded the data, as described below. I went through several iterations of this step to ensure consistency in my coding. Next, I combined codes into themes that address each of the research questions.

The thematic analysis was data-driven. I determined *A Priori* codes based on evidence found in the review of the extant literature. However, I did not restrict coding solely to the *A Priori* codes. Additional codes emerged as I analyzed the data. For example, Cox (2004) identified factors necessary for successful learning communities: safety and trust; openness; respect; responsiveness; collaboration; relevance to participants’ lives, careers, etc.; challenge and high expectations; enjoyment; esprit de corps (feelings of loyalty, enthusiasm, and devotion); and empowerment. Although using these factors as *A Priori* codes were applicable to some of the data, it was clear that more, and different, codes were needed as I analyzed the interview data. I generated additional codes based on the content of the transcripts and my knowledge of the research and other literature that identified other relevant factors that engender and impede success in collaborative efforts. For example, as I analyzed the data, it became clear there were power imbalances among the group members. Because of that, the code “power imbalance” was introduced to accurately capture this phenomena. After all of the data were coded, themes were determined by grouping similar codes.

**Analysis of class observations.** I utilized the method developed by Fennema et al. (1996) to analyze the data from mathematics class observations as one way of determining if the mathematicians’ teaching or planning had undergone changes due to their participation in the collaborative efforts. In order to identify teacher change, Fennema et al. (1996) developed a system of categorizing teachers according to four levels of mathematics teaching. At Level 1, teachers teach procedures and are often guided by a textbook. At Level 2, teaching is similar to
Level 1, but teachers incorporate some rich problems, often learned through professional development. At Level 3, teachers allow students to engage in solving problems not found in the typical textbook and sharing their solutions. At Level 4, teachers make instructional decisions based on students’ problem solving capabilities, strategies, and communication. One of the goals of the mathematics courses in the middle grades teacher education program is students will develop the specialized knowledge needed for teaching, such as explaining, justifying, representing, using content specific language, posing questions, and the like. The professors will need to be able to engage students in mathematical problem solving (levels 3 and 4) to accomplish this goal.

I coded each class session taught by each of the mathematicians according to one of the four levels. I coded the class based on the highest level of teaching reached on that particular day. Thus, if at any time during the class period, the instructor taught at level 4, that session was coded as level 4. In addition, I coded data from field notes taken during planning meetings and interview data from each participant to determine other planning or teaching changes, and whether the changes were related to participation in the collaborative efforts.

**Credibility Measures and Quality Indicators**

Credibility measures to ensure the research is trustworthy are necessary for all qualitative studies (Brantlinger et al., 2005). I analyzed data from multiple sources, namely observations of classes and planning meetings and interviews with each participant, to triangulate the data, by comparing evidence from different individuals and methods of data collection (Creswell, 2002) and to check for data consistency (Yin, 1994). Specifically, I compared interview data for each participant for consistency across interviews. I also compared interview data to field notes taken...
during planning meetings and class observations. Additionally, I employed member checks in which I provided the study participants with the transcribed interviews and my interpretations of data to confirm I had not misrepresented their statements, thoughts, or feelings. After presenting the three collaborators with this information, two of them assented. One participant did not respond. Finally, thick, detailed descriptions were generated to provide explanations and transparency about how I drew conclusions and determined implications. Thick descriptions create verisimilitude, providing the reader with the feeling that they could have experienced the events being described (Cresswell & Miller, 2000).

Additionally, this study adheres to the following quality indicators (Brantlinger et al., 2005). I chose the participants because of their voluntary participation in a collaborative effort to develop and teach courses for middle grades education mathematics preservice teachers. They had already committed to work together to plan and subsequently teach courses for the middle grades education program. The questions used during the semi-structured interviews were purposeful and asked in relation to the specific research questions. I recorded interviews using a sound recorder program on my laptop and subsequently transcribed them. To ensure confidentiality I used pseudonyms in reporting information about the participants and their responses were reported accurately and honestly. Using thematic analysis, I organized and coded the data systematically to answer my research questions using the approaches described in (Braun & Clarke, 2006). (See Table 1). Each step is clearly explained to provide transparency.
CHAPTER 4:
FINDINGS

In this chapter, I present the discoveries from a descriptive case study of the collaborative efforts of a mathematics educator and two mathematicians, as they worked together to plan and co-currently teach courses for a new middle grades mathematics teacher education program. The following research questions guided my inquiry:

4. What approaches do a team comprised of a mathematics educator and two mathematicians use to facilitate their collaborative co-planning efforts as they prepare for and teach concurrent mathematics methods and mathematics courses for preservice middle grades mathematics teachers?

5. What factors support or hinder the collaboration?

6. In what ways does the collaboration affect the mathematics educator’s and mathematicians’ course planning and teaching?

I determined the findings through thematic data analysis of the following data sources: three individual interviews with each of the participants and observations of planning meetings and classes taught by the participants. The findings are organized by themes that emerged as I analyzed the data. The themes are displayed in table 2 below.

Throughout the chapter, I quote the participants to support the themes. I selected all quotes from planning meetings (P) or interviews (I) and noted each with corresponding dates in citations following the quote. In the selected quotations, I altered certain words or phrases for clarification (e.g. “gonna” to “going to”) and irrelevant or unnecessary words and phrases were
deleted as indicated by “…”. Text inserted in square brackets ([ ]) is provided for clarification or further explanation when needed. Citations from field notes taken during observations of planning meetings are denoted as “personal observation” with corresponding dates.

Table 2. Themes derived from data analysis

<table>
<thead>
<tr>
<th>Theme</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Theme 1</td>
<td>Roles are established and embraced but ultimately lead to an unequal share of power.</td>
</tr>
<tr>
<td>Theme 2</td>
<td>Administrative business, lack of authority, and undefined goals cause issues for the collaborative group.</td>
</tr>
<tr>
<td>Theme 3</td>
<td>Camaraderie brings the collaborative group together and facilitates the collaboration.</td>
</tr>
<tr>
<td>Theme 4</td>
<td>Participants make teaching and planning changes as a result of the collaboration.</td>
</tr>
</tbody>
</table>

Below, I provide background information about the project as it relates to the findings discussed in the chapter. I also provide general information about the middle grades mathematics education program and course requirements so as to provide context for the findings as written.

I then present the findings, structured as follows. First, I provide detailed descriptions of the collaborative meetings that occurred throughout the study. Then, I discuss the roles the participants established as they worked together and how those roles ultimately hindered the collaboration. Then, I address other factors that hindered or facilitated the collaborative effort. Finally, I discuss how the collaborative efforts influenced changes in instruction and planning.

Background. As part of the middle grades teacher preparation program, faculty from the mathematics department and the mathematics education department worked together to develop and subsequently teach courses for the middle grades mathematics education preservice teachers. During the planning phase of the program, faculty from both the college of education and the
college of arts and sciences developed the syllabi for the courses and created tasks to be used in those courses.

To ensure the courses were implemented as envisioned, the instructors for the content and methods courses met to co-plan throughout the implementation phase. Meetings began during the summer prior to the start of the program (Summer 2013), with an overarching goal of developing specific details for class sessions and course tasks and activities, which had been previously outlined during the program development phase of the project (Ellerbrock et al., 2016). During the semester they taught the co-requisite courses (Spring 2014), the instructors met with the goal of discussing issues and experiences with preservice teachers, and adjusting and refining plans as necessary. During the subsequent summer (Summer 2014), the goal of the collaborative meetings was for instructors to review reports and data provided by graduate students, with the intention of improving and revising the course to align more closely with the program goals.

An important goal of the middle grades mathematics education program was for students to make connections between their methods and content courses. Ideally, collaboration among the instructors of those courses would allow opportunities for the instructors to discuss potential connections. Additionally, developing and implementing mathematical tasks that engage students in mathematical content and the standards for mathematical practice (SMPs) (CCSSO & NGA Center, 2010) was a major part of the development of the courses in the middle grades program.

The courses taught by the three instructors included course assessments called critical tasks or “Chalk and Wire” tasks. Chalk and Wire is the learning assessment tool utilized by the university where the participants are employed. Instructors upload tasks for students to complete.
These tasks from various courses make up an e-portfolio of the students’ work throughout their time at the university. These tasks are termed “critical” because students must earn a passing grade on the assessment in order to pass the course. For the middle grades mathematics teacher education program, the assessments were components of both the education and mathematics courses. These assessments are typically implemented in education courses, thus the instructors in the education department are familiar with the tool. However, these assessments are not typically implemented in courses outside of the education department, and as a result, the mathematicians were not familiar with the need to include them as part of their courses.

**Collaborative Meetings**

The participants in this study partook in 17 collaborative meetings throughout three semesters: Summer 2013, Spring 2014, and Summer 2014. Below, I provide a summary of the nature of the meetings that occurred during each of those semesters.

**Summer 2013.** The participants met six times over the course of four weeks in the Summer of 2013. During these meetings, the collaborative group spent significant time discussing the Common Core Standards for Mathematical Practice (SMPs) (CCSSO & NGA Center, 2010). The purpose of these discussions was to make sure the mathematicians understood the intent of the SMPs so they would be able to design tasks and other assignments that afforded students opportunities to engage in the SMPs. The assumption was if students engaged in SMPs in the content courses, they could discuss the tasks in their methods courses, forming connections between the content and the methods. The collaborators focused on creating, designing, and modifying mathematical tasks addressing content taught in the mathematics courses and incorporated the SMPs. Through this process, the participants
discussed the SMPs and how students would actively engage in them while completing identified tasks.

The collaborative team members also spent time discussing the assessment of different competencies and skills students needed to acquire in the courses. They completed a matrix detailing how specific standards would be assessed. They also discussed the use, as well as the benefits and disadvantages, of different assessments such as tests, quizzes, homework assignments, class activities and tasks, class discussion, and journals.

Spring 2014. The participants met six times over the course of three months in the Spring of 2014. During this semester, the participants also taught their respective courses. In the meetings, they talked often about classroom occurrences. Each collaborator thought similarly about the students’ weak mathematical knowledge and lack of professionalism. Students were often late to class, not prepared for class, and turned in work late, or not at all. They all thought they were constantly making changes to their planned courses and syllabi because students were not at the academic or mathematical level they had expected. This posed a challenge for the collaborators and they struggled to make the connections between the courses they had originally hoped to make.

The collaborators also spent significant time developing course assessments, which were not previously discussed or addressed during the summer meetings prior to the start of the courses. At that time, none of the participants were aware that the mathematicians had to assign a specific assessment task as part of an overall programmatic assessment effort. Thus, creating the assessment tasks and corresponding rubrics occupied much of the planning time during the Spring 2014 meetings. This resulted in a decrease in the amount of time the group had to co-plan and discuss possible connections among the courses. The collaborators were frustrated by this
change in focus as they had hoped to spend more time talking about the content of their courses, making connections among the courses, and learning from one another. Doug mentioned this lack of time specifically in his interview, saying, “the coordination part… I think we just didn’t have time” (personal communication (I), April 30, 2014).

All of the participants shared how they were frustrated by not having the opportunities to make connections between the mathematics content and methods courses and discuss their courses in depth. Doug, one of the mathematicians, noted the bulk of the meetings were spent talking about their students or other trivial topics, not related to the courses and program. Doug said, “usually when we meet we just kind of yakkity yak yak and, which I don’t mind but… it hasn’t really accomplished very much” (personal communication (I), June 11, 2014). He believed the superficial talk about students and courses became the topics of discussion because it was hard to plan for meetings because they had to make changes constantly in their courses. He continued, “it gets back to having a concrete idea of what you’re meeting about. I just don’t think we did last spring…. We said, ‘let’s meet’… we’d all touch base, and [say] ‘this [course] isn’t going like I thought it would be’” (personal communication (I), June 11, 2014).

Tom, the other mathematician, also believed the main topics of discussion at the meetings involved simple and straightforward talk of their respective courses, whereas he would have preferred in depth discussions of the topics being taught and the methods used to teach them. He stated:

The collaboration is, I’m on this side, you’re on that side, I’ll tell you something about geometry and maybe I’ll hear something about algebra or pedagogy and that’s about it. I mean, there is no… I want my concepts of geometry or, I would say, how this material
should be delivered or what is appropriate way of presenting this material, I want that to be challenged (personal communication (I), April 30, 2014).

Melina agreed with the opinions of the mathematicians. She thought the meetings lacked focus, and were ultimately unproductive, because of how differently their courses were playing out than originally planned. She said, “just like me, I don’t think [Tom and Doug] felt like the meetings we had in the spring were really productive (personal communication (I), July 23, 2014).

The group spent time during meetings helping one another when possible or as necessary. Incorporating technology is an important facet of the program and a goal for the each of the classes taught by the collaborators. During one meeting, while the group was discussing technology, Doug mentioned he had been reading about algebra tiles but was unable to fully comprehend how they worked. Melina projected virtual algebra tiles and explained what they are and how they are used to teach. Each of the participants had an opportunity to think about them and how they might be used.

**Summer 2014.** In Summer 2014, the collaborators met five times over the course of two weeks. Their goal for the summer 2014 meetings was to set up concrete plans for making connections between the methods course and content courses and for integrating technology into the mathematics content courses. In order to do this, Tom and Doug each chose a strand of the state mathematics standards that corresponded with a topic they had planned to teach in their course. With the help of Melina, each mathematician created a general plan for teaching that topic which included the incorporation of a mathematics-specific instructional technology. Melina then planned to use those strands and technology to plan a lesson for the methods course. For example, Doug chose the following standard: “Analyze and solve pairs of simultaneous linear equations” (Common Core Standards for Mathematics 8.EE.C.8). He planned to teach
this topic in his course. Typically he had students solve the systems of equations using different algebraic methods he presented. Melina and Doug discussed how Doug might incorporate technology while teaching this topic. Melina thought graphing calculators could be used to find intersection points and intercepts and Doug agreed. The discussion moved to how Melina will make a connection with this content in her course. Melina decided she would be able to build on what Doug did in his class by having the students consider how solving equations using manipulatives, specifically algebra tiles and a scale balance, might enhance student learning. She planned to orchestrate a class discussion about the use of multiple representations to solve equations in middle grades using these three different mediums (graphing calculator, algebra tiles, and scale balance) (personal observation, June 25, 2014).

When compared to the meetings the two previous semesters, the planning meetings that occurred in Summer 2014 were different. First, the meetings were held through Skype because Melina was out of the country. Although the participants were able to meet and have discussions online, this was not ideal for all of the participants, as Tom and Doug would have preferred meeting in person. Tom thought that, “[it’s] more difficult to conduct these interviews on Skype or electronically… it just works better when you are in person definitely” (personal communication (I), July 15, 2014). Doug agreed, stating, “if I was in charge, I probably wouldn’t, at least not on a regular basis… have Skype be the mode of communication” (personal communication (I), June 11, 2014).

In addition, these meetings were structured differently than previous meetings. Previously, all three participants were involved in each meeting. All three participants attended the first meeting in Summer 2014. The subsequent meetings were split such that Melina met with either Tom or Doug, with each pair meeting twice. Tom and Doug did not meet without Melina.
This structure was suggested by Melina and accepted by Tom and Doug. Melina made this decision because she believed the meetings would be more productive if she was able to work one on one with each mathematician, as they will be incorporating different technologies, each specific to their respective content, algebra or geometry. She stated, “because technology will be more content specific… I don’t think it’s going to be that productive if [we all met]” (personal communication (I), June 13, 2014). She expressed concern about the need to ensure that each of the mathematicians had the opportunity to think about and discuss their plan for using technology. She worried that if all three of them met together, then the group may unintentionally focus more on one of the courses. Tom agreed that the split was effective for the purpose of the meetings. He prefers shorter meetings, focusing on only one course, and thinks algebra and geometry are distinct subjects that are likely to be taught differently, and thus it made sense to keep the discussions separate. He said, “three people have more opinions about something and then it’s a longer discussion. And of course, algebra and geometry do have separate… issues concerning the approach… for example the visual element in geometry is dominant versus analytic reasoning in algebra” (personal communication (I), July 15, 2014).

During the Summer 2014 meetings, the collaborators decided to support one another while teaching their respective classes. The group discussed how they wanted to, and thought they must, better explain the purpose and importance of each course and articulate this for each other’s courses, and not only the specific course each was teaching. For example, Tom would explain why the content they were learning in geometry connections was important and then Melina could reinforce this by making explicit connections between the geometry content they were learning in Tom’s course and the instructional methods they were learning in her course.
Participants’ expectations. Each of the collaborators entered this collaboration with some general expectations for occurrences, but they also kept an open mind, knowing and accepting the possibility that things could, and likely would, change as time progressed. The collaborators joined the efforts for different reasons and had differing expectations and anticipations for the collaborative meetings.

Tom felt obligated to participate because of his position. At the time, Tom was an instructor in the mathematics department and the liaison between the mathematics and mathematics education departments. As this program required collaboration between those departments, he believed it was his responsibility to take an active role in the implementation of the program. He states, “I felt like, you know, as liaison for the college of education… it was my, kind of, duty, it was most natural for me to get involved” (personal communication (I), April 30, 2014).

Doug became involved with the program because Tom approached him to teach the course. The program needed math instructors who were willing to teach content courses for the newly designed mathematics teacher education program. Doug had no knowledge of the program previously. He says, “I wasn’t actively involved with the [program development]. I was unaware of it…. after the grant had been approved and then they needed instructors for the four math courses and at that point [Tom] approached me” (personal communication (I), April 30, 2014). Doug expected the collaboration to help him plan for the course. He had not taught any courses for preservice teachers prior to this course and he thought the collaboration would provide insight for teaching these students.

Melina expected the collaboration would be an undertaking among three equal partners. She thought each of the collaborators would enter the collaboration with similar perspectives and
would work together to determine what they should be doing for their courses and the students. She says, “a big part was… trying to figure out what we’re supposed to be doing…. I was just thinking that we would all really try to figure this out together” (personal communication (I), May 1, 2014).

**Roles are established and embraced but ultimately lead to an unequal share of power.**

Early on, the collaborators assumed roles they would continue to play as the collaboration progressed over the next few semesters. Melina, the mathematics educator, assumed the role of leader while Doug and Tom, the mathematicians, assumed passive roles. Melina did not enter the collaboration with the intention of taking on the leadership role, she had expected all three collaborative team members would work together, but once the meetings began, she believed she had to take charge, because the mathematicians appeared to have had already decided she was the leader. Once this became apparent to her, she willingly accepted the leadership role. Melina said:

at some point, it became almost clear to me… that [Tom and Doug] were kind of expecting from me to take the initiative for everything and to make the final decision for everything and… to decide how we’re going to [work together], what we’re going to do, how were going to do it, when we’re going to meet… everything. Actually it was, so it was almost like they, they kind of felt like I would have to be in charge… I did take on that role… so it’s not like I resisted it or anything… it just happened (personal communication (I), May 1, 2014).

Although unexpected, this role was easy for her to assume. Melina was “very comfortable” telling Doug and Tom what to do (personal communication (I), June 13, 2014).
However, Melina assuming the role of leader did not always mean she was the authority on what Tom and Doug should do. She was unsure if this was because they did not want to follow her instructions or if they thought she was just giving suggestions. She stated:

there were things that I would tell [Tom and Doug] and either they were interpreting them differently or they just would decide that that’s not what they would want to do and they would just not do it… from the beginning [Tom and Doug] just decided that I would be in charge of everything, but… that did not go with me necessarily being the authority (personal communication (I), May 1, 2014).

Melina’s role as leader, combined with her position in education, where the program was initiated, created an unequal distribution of power in the group. This power imbalance was the major hindering factor, as the group was not a partnership among equals but rather a hierarchy of individuals of which one, the mathematics educator, had more control. This unequal distribution of power caused the mathematicians to perceive they were subservient to the educator, and that the educator was placing demands on them. The educator felt pressure as the sole decision maker and the “boss” of the collaborative team.

Melina perceived that Tom and Doug gave her more power in the group by allowing, and wanting, her to take the lead. She recognized that they allowed her the lead because they were unsure of what they were supposed to do when the courses began. They were unsure of what they would be collaborating on and what the goals were, and looked to her for answers. She stated, “[Tom and Doug] were both like, ‘we don’t know what we’re doing, you tell us’” (personal communication (I), June 13, 2014). Tom and Doug agreed. Their lack of knowledge about the program and their acceptance of their passive roles, placed the power in Melina’s hands. Doug stated, “I guess I’m looking to Melina to tell us if she thinks were going off track…
I think [she has] maybe a better handle on what the [program is] all about than I do” (personal communication (I), April 30, 2014).

However, Melina was often unsure of this herself and therefore felt pressured by this power imbalance. She took on the majority of the responsibility for the collaboration and was in charge of organizing meetings, determining what will be on the meeting agendas, and conducting the meetings, while Doug and Tom waited for her to tell them the plans for the meetings and what they needed to do. She said:

it was hard for me… it was almost like I had to be in charge of… everything… what goals to set, what we’re going to do, how we’re going to do it, how we’re going to organize our meetings, what we’re going to talk about… [Tom and Doug] just waited for me. Um, they just made sure that they were there (personal communication (I), May 1, 2014).

Melina would have preferred that Doug and Tom take initiative. She believed this would have created a balance among them and more equality throughout the collaboration. Also, she believed if Tom and Doug were acting on things they wanted to do, rather than on what they were told they had to do, it is possible they would have been more invested and engaged. She said:

I feel like it would be better if… it was a little more of a balance because… they would take the initiative for certain things and it would become more of their own rather than something that I’m thinking of doing and wanting to do… if that were the case then they would be more proactive (personal communication (I), May 1, 2014).

Yet, Melina did not give Tom and Doug an opportunity to take initiative after she had taken on the leadership position. When she talked about possibly trying to change the dynamic of the
group as the summer 2014 meetings commenced, she did not think it was feasible to create a more equal partnership due to lack of time and the agenda she had set forth. She had a goal for her course for the following semester. She wanted her students to have experiences with specific mathematics content in their math courses so she would be able to build on that foundation with pedagogy and methods for middle grades students in her course. She said, “because I have that goal and because I want to get that done in a short period of time, trying to change the dynamics, I can’t do it, I can’t see how it would happen in like two weeks that we’re going to be working intensively together” (personal communication (I), May 1, 2014).

Tom and Doug saw themselves as outsiders in the college of education, thus they assumed that Melina, an insider in the college of education, had more information about the goals and intent of the middle grades teacher education program, and was better able to interpret that information. They expected her to tell them what to do, and were complacent in their passive roles. Tom perceived his position in the collaboration was to learn about what the college of education wanted him to do as a mathematician educating preservice teachers and then do it. He stated, “I see myself as someone who is providing service or delivering what educators want” (personal communication (I), April 30, 2014). He attended meetings, expecting to be told what to do. He likened himself and Doug to students in a classroom, stating, “[Doug and I] position ourselves... in a back row desk” (personal communication (I), June 16, 2014). Doug thought his role in the collaboration was a passive one, attending meetings to be told whether or not he is following the objectives of the grant and program. He said his role is not to follow or lead; “it’s just try to make sure that I’m not just going off and doing something that’s not relevant to the intent of the [middle grades teacher preparation program]” (personal communication (I), April 30, 2014).
Tom and Doug waited for Melina’s lead during meetings. If they arrived at the meeting before Melina did, they did not begin the meeting without her, even if she had suggested they do so. Tom talked about his passivity in his interview, saying, “I was passive in the sense that I’m waiting from what the educators want and then I would just deliver whatever they want” (personal communication (I), April 30, 2014).

Tom, however, did believe the roles of the collaborators were unequal. He believed the mathematicians often talked during the collaborative meetings about the content of their courses but the mathematics educator did not share hers. He thought the educators benefitted more from this asymmetry than the mathematicians. The educator was able to take the content he spoke of and apply it to topics she was teaching in her class. Tom did not have the opportunity to do so. He did not learn of the content taught in the methods course and was unable to take that knowledge and apply it to his own course. He said:

most of the time, I felt like the educator will go like ‘oh this is a very nice… subject you have in the, in geometry class and I’m going to use that to illustrate this or that in my methods class.’ Uh, I wonder, I mean, did it work the other way around? Usually… in collaborations you would like, you know, being on an equal footing and exchange ideas (personal communication (I), April 30, 2014).

Tom and Doug believed Melina’s leadership and power in the collaborative group often allowed her to demand or insist they do something. Tom and Doug talked about what Melina “wants them to do.” However, these demands placed on them were usually program or college of education requirements. Yet, because Melina was the one asking or relaying the requirement, it became something she was demanding of them.
Technology incorporation is an important part of the middle school program and it is often discussed in meetings that occur in each of the three semesters. Time was spent talking about what technology would be beneficial to implement in the courses, and how best to incorporate it. Melina created the agenda for the meetings and when she asked Tom and Doug to come prepared to talk about technology, it was seen as a demand from her, making Melina seem like she was in charge of what Doug and Tom were doing in their classrooms. Doug said, “I know Melina wants us to be doing more [technology]” (personal communication (I), April 30, 2014). Similarly, with the tasks the mathematicians were incorporating into their courses, it was viewed as something Melina was requiring of them, not necessarily a program expectation. Doug stated, “I know Melina was pushing [the tasks] last summer and I just couldn’t, never could get all that worked out” (personal communication (I), April 30, 2014).

Because Melina was part of the design of the middle grades teacher preparation program and is the collaborative team member from the college of education, the mathematicians looked to her to answer their questions and tell them how to implement the program requirements appropriately. At times, the mathematicians were out of their element; as instructors in the college of arts and sciences, they were not familiar with the college of education policies and practices and were teaching courses that had expectations and accreditation requirements to document what students learned that their typical mathematics courses did not (e.g. assessments described above). Melina was able to provide guidance. Melina offered some explanation as to why the power imbalance occurred initially and grew as time went on:

I was part of thinking about it that way [the creation of the program], and putting [the courses and course requirements] together that way… I’m the math ed person that’s telling them, ‘you need to incorporate technology because that’s what the program says’
so then they’re going to wait for me to help them think about how to do it. And I guess because it’s something that they’re not as familiar with and so their comfort level is low and it is something that, uh, will take time and effort and if it’s not something that they really want to do, because they just want to do it… so they’re going to just wait for me to at least point them in some directions (personal communication (I), May 1, 2014).

The following examples present various scenarios where Melina was placed in the position of power because the mathematicians relied on her expertise and knowledge.

**Knowledge of program expectations.** Because the mathematics faculty were unfamiliar with the philosophies undergirding the program and the standards for teaching and learning, Melina led efforts to support their understanding. During co-planning meetings in Summer of 2013, she was placed in the power-position because she had knowledge the others did not have.

During a planning meeting, a conversation about analyzing mathematical errors, one of the various competencies often discussed during the meetings, as described above, occurred. Doug had assumed this competency referred to his analyzing the students’ errors. However, Melina explained that the competencies are skills the students needed to practice and learn; the goal is for the students to be able to analyze mathematical errors. She cautioned Doug not to do the thinking for them, but to allow the students to engage in this activity. Doug replied that he found it “difficult to wrap [his] head around” this expectation (personal observation, June 24, 2013). A similar exchange between Melina and Tom happened a short time later when Tom interpreted the phrase “identify and apply” as “memorize and repeat.” Melina corrected him, telling him it means to “demonstrate.”

Much of the meeting time during summer 2013 was spent on creating critical tasks that engage the students in the SMPs, as described above, for Tom and Doug to use in their classes.
Initially, the mathematicians had no knowledge of the SMPs, whereas Melina had extensive knowledge of them. When Melina began discussing the SMPs, she explained each one and what it would look like for students in the classroom to engage in each. During this time, Melina talked while Tom and Doug listened and took notes.

Melina initiated the work on these tasks by emailing Tom and Doug to inform them of what they should include in the drafts of their tasks. She specified that the tasks should include the following: the activity or problem; solution(s); a description of how it will be used in the classroom, including the purpose, how students will complete the task (e.g. in groups, individually, etc.), and instructional technology or tools to be utilized; and the content standards and SMPs aligned with the task and how instructors will ensure students are engaging in the SMPs.

During the meetings, discussions about these tasks often followed a similar pattern. First, Doug or Tom explained their task. Then, Melina described what parts of the tasks needed to be revised or expanded upon and explained why. During one such discussion, Tom provided each group member with a copy of his task, a problem about paper folding (see Figure 2 below).

Melina told Tom he needed more information in the problem description, that students should be able to read the description and understand the problem without relying on the instructor for clarification. Additionally, although Tom had listed the content standards and SMPs aligned with his task, Melina asked for more information about how the problem specifically addressed the standards and told him to provide a brief description of how the students would engage in each SMP. She also told him he needed to include information about what he would be doing as the students were working on the task. She also suggested he provide more than one possible solution strategy.
Folding $\sqrt{3}$

The Problem

We are given a piece of paper (POP) shaped as a rectangle ABCD and we know that the side AB has unit length. Using only a pencil, find two points on this POP which are $\sqrt{3}$ units apart.

Purpose of the problem

The purpose of this task is twofold. Students will experience some of the geometric transformations (in our case reflections) as natural mathematical abstractions emanating from real life situations (paper folding, mirrors, billiard tables, etc.) and gain better understanding of properties of figures which are preserved under these transformations (distance, angles,...). Secondarily, they will see a real life application of the converse of the Pythagorean Theorem.

Implementation

This task should not take more than 20 minutes of the class time and we expect students to work in groups (three to five students in a group would be ideal setting). The students will get a series of hints designed to lead them towards one possible solution of the problem.

Materials needed for this problem are one rectangular piece of paper (approximately 3 by 8 inches) and a (sharp!) pencil.

Common Core State Standards

We recommend this task after students have been exposed to the properties of rotations, reflections and translations and also after they have seen an explanation (proof?) of the converse of Pythagorean theorem. Therefore this task satisfies the following CCSS Math Content in Geometry: 8.G.A.1; 8.G.A.2 and 8.G.B.7.

The Common Core State Standards for Mathematical Practice

We believe that students engaged in this task will straighten their ability to

1. Make sense of problems and persevere in solving them
2. Reason abstractly and quantitatively
3. Construct viable arguments and critique the reasoning of others, and
4. Model with mathematics

Solution:

If students had no previous experience with paper folding, one can start this task with few hints designed to give students desired direction. The hints should be given as questions each group of students will discuss.
**Hint #1.** Note that we already have points which are one unit apart, namely the points A and B. One can easily create points which are $\frac{1}{2}$ unit apart by folding the POP in such a way that sides BC and AD coincide (A and B getting together as shown below). The crease formed after this folding will determine a point B’ on AB which is $\frac{1}{2}$ unit apart from A (or from B).

**Hint #2.** How can we create a point D’ on the side AD which is one unit apart from A? Of course, this can be accomplished by folding the POP in such a way that the line AB coincides with the line AD. Using the point B as a marker, with pencil we can mark the point D’ on side DA which corresponds to the point B, as shown below.

**Hint #3.** How can we create point C’ on the side CB such that ABC’D’ represents a square?

**Figure 2.** Tom’s paper folding task

Throughout this discussion, Tom was amenable to each of Melina’s requests. Towards the end of the meeting, as Melina remarked again that the task needs more detail throughout, Tom responds
with, “whatever you say I will do, if you are happy, I am happy” (personal observation, June 25, 2013).

In a similar conversation during a planning meeting, the collaborative group talked about why it was necessary to include an explanation of the standards in which students will be engaging in their descriptions of the mathematical tasks. During the discussion, Melina told Tom and Doug they needed to explain how the students will be engaging in the SMPs. This allowed the mathematicians to think through the way the task would be presented and implemented in the classroom, but was also an opportunity for Melina to determine if the mathematicians understood the SMPs from an educational standpoint.

In a subsequent meeting, in his updated task description (see Figure 3 below), Tom explained that students would discuss the solutions, thus engaging in SMP 3: Construct viable arguments and critique the reasoning of others. Melina wanted Tom to expand on this, and describe how he anticipated students discussing the solutions.

Briefly, Tom struggled to respond to Melina and said it would be difficult for him to explain, because a discussion might be him asking questions to three students where one student answers correctly, one student answers incorrectly, and one student does not answer. Melina then explained that did not describe a mathematical discussion, at least from an educational perspective, as a true mathematical discussion would contain a back and forth dialogue about the mathematics, not be limited to basic question and answer.

As the discussion of the SMPs continued, Melina asked Tom and Doug to again explain how they will be sure the students are engaging in the SMPs listed in their tasks. At this point, Doug asked Melina if she was purposely being argumentative when she asked about the SMPs in the tasks or if she really was unsure of how the students would engage in them. Melina explained
that she was not asking Doug and Tom to prove themselves, but wanted the three of them to think through the scenario together.

The Common Core State Standards for Mathematical Practice

We believe that students engaged in this task will straighten their ability to

1. Make sense of problems and persevere in solving them

   The task will demonstrate that even though we may not have a measuring device or technology at hand when needed, ordinary everyday materials (paper, piece of string, stick…) may be used in such a way that by following the properties of abstract mathematical objects (for example the notion that angle bisectors determine the line of reflection for a given angle) we will obtain a reasonable approximation of some desired lengths.

2. Reason abstractly and quantitatively.

   We see this task as a nice interplay between some abstract mathematical notions (irrational number, reflection, distance, point, segment, line…) and their practical realization on a piece of paper. For example, the act of folding a piece of paper may represent a reflection, which by itself, is an abstract mathematical object.

3. Construct viable arguments and critique the reasoning of others

   We expect that during their group work, students to be engaged in discussion and they will be asked to justify why particular folding will produce desired outcome.

4. Model with mathematics.

   Knowing that the length of the diagonal of a unit square is $\sqrt{2}$ or being reminded that $(\sqrt{2})^2 + 1^2 = (\sqrt{3})^2$ and look for a folding that will produce a right triangle with legs of length $\sqrt{2}$ and 1, is something students will demonstrate because they know (the converse of the ) Pythagorean theorem.

Figure 3. Tom’s updated SMP section of the paper folding task

Knowledge of critical assessment requirement. In spring 2014, much of the meeting time became devoted to developing critical assessments required for students to pass the course,
as described previously. Creating these assessments took priority because students needed to complete them by the end of the semester. Melina’s knowledge of the Chalk and Wire Assessment Tool further solidified her role as leader because she had to explain the how to use the tool and help Tom and Doug create acceptable tasks and rubrics. Additionally, when Doug and Tom questioned the necessity of these assessments, Melina had to explain their importance in the education department.

**Leading the connection making.** Throughout the semester, the collaborators continued working on tasks to be used in their classes. Tom and Doug were responsible for implementing the task in their classes; Melina was responsible for discussing the teaching methods and pedagogical aspects of the task in her class. For example, in one of Tom’s geometry classes, the students completed a task in which they were able to visualize a proof of the Pythagorean Theorem by cutting and pasting to show equal areas. Melina then facilitated a lesson planning activity in her class where students adapted that task and used it to teach the Pythagorean Theorem to middle grades students. She followed the activity with a guided discussion about how the task can be used to introduce Pythagorean Theorem to a middle grade mathematics class. As all three of the collaborative group members worked on making connections between the content and the pedagogy, Melina continued to lead the group through the process. She formed the plans for the task, advised how it should be taught in the mathematics classes, and determined how she would make the connection in her own class.

**Determining meeting schedules and agendas.** By summer 2014, Melina had committed to the leadership role and determined prior that meetings will occur over the course of two weeks. She decided they would meet as a group once and then subsequently she would meet with Tom twice and Doug twice. Neither Doug nor Tom outwardly opposed Melina’s choice to
conducted the meetings this way. However, while discussing this during an interview, Doug said, “I personally think it’s helpful for me to know what Tom’s doing…. But if Melina wants to do it that way, I don’t object” (personal communication (I), June 11, 2014). Because Melina was out of the country, these meetings took place online, using Skype. She had a pre-determined plan for what she wanted to accomplish during these meetings in order to facilitate the teaching of her class and the connections she would make between the mathematics content courses and her own course. Tom and Doug also continued their complacency in the non-leadership roles. As the first meeting began, Tom mentioned he planned to wait “for Melina’s lead, as usual” (personal communication (P), June 17, 2014).

In the first meeting, Melina shared her plan for subsequent meetings. She discussed how she planned to make the connections between the mathematics content and mathematics methods courses and what she would need from Doug and Tom in order to accomplish her plan. She also asked each mathematician if they had anything they would like to cover or discuss during the summer meetings. She embraced her position of power at this point in order to make the connections that are a necessary and important part of the program. In the subsequent meetings, Melina guided the discussion, but each participant was active and contributed to the discussion and planning. Yet, Melina was still the “leader” in each pairing, keeping the discussion on task and guiding the mathematician through the work.

**Leading technology incorporation efforts.** During the individual meeting with Tom, he and Melina spent time talking about incorporating Geogebra to teach constructions. Tom explained how he typically teaches constructions using paper and pencil but said he would be willing to try the technology. While they discussed these options, Tom expressed how he felt as though he was waiting for Melina’s approval; he was waiting for her to say whether he should
use Geogebra or teach with paper and pencil. When Melina gave her opinion, Tom responded by saying he believed educators “are in command of the content of the course and how it is experienced [by the students]” (personal observation, June 24, 2014).

Melina liked her power in the group because it gave her the ability to plan things in ways that were most beneficial for her class. She was able to make connections between her class and the math classes in the way she wants. However, she had to keep her power in check so she did not end up doing all the planning for Tom and Doug’s lessons that would coordinate with hers. She knew if she did, then they would not be invested in the plan to make the connections. She said, “I need to make sure that I don’t run the meetings in the sense of me doing the planning for [Doug and Tom]. Although I kind of want to (laughter). But I know that then it’s not going to work” (personal communication (I), June 13, 2014). When asked why she wanted to plan for them she replied:

because, uh, I want to have control of what’s going to happen in their classroom (laughter)…. I mean, that’s what it comes down to because I have an agenda, there’s certain things I want them to do in their classrooms. So I can come up with a plan that they, if they can implement it then those things are going to happen or they’re likely to happen (personal communication (I), June 13, 2014).

Equality in one area. One exception to the defined roles the group had developed was discussion concerning the students in the courses. These conversations covered the mathematical knowledge of the students, their professionalism and work ethic, their attendance and attitudes, and changes that had been made to the instruction and/or syllabi to accommodate the students. During these discussions, everyone participated equally and there was no defined “leader.”
**Leader as mentor.** Melina used her position as leader to take on a mentorship role, helping Tom and Doug understand their part in the education of the preservice teachers. She intended to help Tom and Doug implement the requirements from the middle school mathematics teacher preparation program and was willing to help Tom and Doug plan their course in any way possible, even if they needed help planning a lesson for content that would not affect her own class, stating:

> I’m thinking that if any of them wants… my help thinking about planning a class on something else that’s… above the middle grade content, so this would not necessarily be something that I would make direct connections with my class, I would still… be open to do that or discuss anything (personal communication (I), July 23, 2014).

When discussing her intentions to help Doug with the technology, Melina said she would like to “help [Doug] experience using the technology and think of benefits in incorporating it…and then maybe addressing his concerns…. [then] just giving some suggestions” (personal communication (I), June 13, 2014). The mathematicians recognized Melina’s willingness to help, and appreciated the opportunity to have her support. Doug talked about having her thoughts on implementing group work. Group work was a new instructional strategy for him and he knew Melina would be an expert on this. He said he would definitely want to “seek out the opinions of those who actually know what, know how to [incorporate group work]… effectively” (personal communication (I), April 30, 2014).
Administrative business, lack of authority, and undefined goals cause issues for the collaborative group.

In addition to the unequal share of power, other hindering factors were present that caused issues and challenges for the group as well. As the collaborative group meetings got underway, the members perceived they had to attend to much administrative business rather than focusing on the course content and students. In addition, the group often felt unsure of their goals and that they had an “unknown authority” to follow.

**Administrative business.** As mentioned above, much of the time during the spring 2014 meetings was spent on the development of critical assessments that were a requirement for the mathematics courses.

Doug’s impression of the chalk and wire requirement was that it was an unnecessary, trivial assignment. He acknowledged the differences in perspectives between the college of education and the college of arts and science were likely the reasons why he did not understand the reasoning behind or the need for chalk and wire tasks, stating, “I know there’s a different thinking in math [education], uh, but the only time it kind of impacted me I felt was when we had to do that chalk and wire and I just thought that was kind of… a silly exercise” (personal communication (I), July 15, 2014). Tom agreed and thought the tasks were requirements from administration which caused unnecessary work for him and his students. He called the chalk and wire requirement a “bureaucratic burden that we have to satisfy” (personal communication (I), April 30, 2014) which reduced time which could have been spent on mathematics. He said he is “always amazed on how much… bureaucratic things the students must do, the students from
college of education are required to do... that’s incredible” (personal communication (I), April 30, 2014).

**Undefined goals.** When the group began meeting in summer 2013, as discussed above, Tom and Doug waited for Melina to take the lead, assuming that as the educator on the team, she was more aware of the goals of the collaborative team planning and intent of the meetings. Doug states, “last summer I just went in, I wasn’t sure what we were going to be doing” (personal communication (I), June 11, 2014).

However, Melina believed she was in the same position as Tom and Doug. Because Melina was part of the program design and planning, she did understand the general, overall goals set for co-planning teams. She knew they had to make connections, as well as incorporate tasks and technology, and engage the students in the mathematical practices. However, determining how to do these things was a struggle. Melina reiterated this a few times during our interviews, saying:

> we probably didn’t have a really good understanding of what we were supposed to do, or we did but we didn’t, we didn’t have a good understanding of how we were supposed to do it… in terms of our collaboration. So we knew we wanted to make some links, we wanted to make links between the courses, specifically with using technology, and with mathematical practices, and that was the extent to, we didn’t know how to do it or any of that, and then, so that was the limitation (personal communication (I), July 23, 2014).

None of the three collaborators had a good idea of what their specific goals were; they were unsure of what should be accomplished or discussed in the meetings. This made the initial collaboration efforts difficult for each of the three collaborative team members. What they decided to do in order to make connections among the courses was basic. Melina stated, “what
made [the initial collaboration] difficult was that… we had no clue what we’re going to do, how we’re going to do it. So we were really trying to figure that out. So what we did was like very surface level” (personal communication (I), July 23, 2014).

In addition to these challenges, when the collaboration began, none of the participants had actually taught the courses. The initial collaborative meetings occurred between the planning phase of the program and the implementation phase. The program, courses, and syllabi had been created, but there were no experiences with students yet. Thus, they did not have much to work from, except what they had hoped or anticipated about the students and material. Melina stated, “we were asked to co-plan, the problem… that we were really working off of theory, like what would be” (personal communication (I), May 1, 2014). Tom agreed that the summer 2013 planning was idealistic, and when the courses actually began, it was difficult to maintain the plans for making connections and implementing technology and tasks. He said, “we had some ideas [about] how things will develop… but then in reality very little from what we have actually anticipated in these meetings last year materialized” (personal communication (I), April 30, 2014).

As the collaborative meetings progressed into the spring of 2014, the participants’ perceptions of having undefined goals continued. Doug thought for the most part, the meetings were unorganized and the group did not have a strategy for making connections and working together. When reflecting on the spring meetings, Doug said, “we probably should have been meeting once a week and had a… strategy…. in hindsight, that would have been best…. I was just kind of doing my thing, Tom was doing his thing, Melina was doing her thing” (personal communication (I), April 30, 2014).
Unknown authority. The collaborative group knew they had requirements for their courses as part of the middle school mathematics teacher preparation program. These requirements were determined during the program design phase of the middle grades teacher preparation program. Both Melina and Tom were involved in this phase of the project, however Doug was not. After the courses were created, the instructors were assigned. The instructors were given the previously created syllabi to follow and requirements for incorporating mathematical tasks and instructional technology, and had to assign and grade a chalk and wire assessment. However, each of the participants were unsure of who the authority for those requirements were once the classes began. As discussed previously, Tom and Doug often resorted to Melina as their authority, but did not always respond to her as an authority figure. Melina was unsure of who her authority was in the situation. She said, “I think there was the sense…. that there were these things from this authority that we had to follow and then we were trying to figure out how we’re going to do it” (personal communication (I), May 1, 2014).

Each of the participants felt confusion with the “unknown authority.” Doug talked about what “they” put in the syllabus, referring to an unknown creator of the course. He said, “they had the topics they wanted and that was the topics that were put on that syllabus and those were the topics that I tried to teach” (personal communication (I), July 15, 2014). When discussing the syllabus, Tom often talked about having to teach the content in the syllabus, even though it may not have been his preferred content for a geometry course, usually emphasizing it was something he had to do which was not his own. When talking about the topics in the course, he said, “this is the material which we have [emphasis added] to deliver or I’m even afraid to say the word ‘cover’ [emphasis added] (laughter)” (personal communication (I), April 30, 2014). Tom shared his concern with the syllabus with Melina. He would have preferred to teach concepts in depth
but could not “cover” all the topics in the syllabus if he did this. Melina was unsure how to answer him. She was not sure who she could have taken his concern to, in an attempt to get an answer in accordance with the design of the program. She stated:

[Tom]’s struggling with what is the authority here and what he needs to go by, so does he really have to follow the syllabus in terms of covering the math topics or should he neglect some and go in depth with others thinking that if students go in depth and rethink mathematics in some areas then at some point later they will kind of do the same on their own like to kind of develop that habit of mind. So, and I’m not sure what to tell him because I’m not sure I have the answer for that. I can tell him what I would do but I’m not even sure that would be good so I don’t, I don’t know who would ask, who to ask about that (personal communication (I), May 1, 2014).

The unknown authority made things difficult for the group as they attempted to work their way through their courses, while implementing tasks, technology, and making connections. In order to do these things, they had to make decisions but were not always sure the decisions they made were allowed. The group felt challenged by this dilemma, unsure of how much autonomy they had.

Although there were issues and challenges throughout the collaboration, there were also factors that made the collaboration easy, that supported the collaborative efforts, and that assisted the participants in their work together.

**Camaraderie brings the collaborative group together and facilitates the collaboration.**

Melina, Tom, and Doug were each happy to have the opportunity to collaborate. Overall, they worked well together and their fondness and respect for one another was apparent in
meetings and spoken of during interviews. They developed close relationships throughout the collaboration and supported one another whenever possible.

Overall, the participants were pleased with the collaboration and its results. Tom stated, “I’m happy with how the collaboration developed” (personal communication (I), July 15, 2014). Tom appreciated the opportunity to work with Melina. He did not believe collaboration is always easy, and in fact is often difficult. He was skeptical of becoming involved in the collaboration, but thought Melina was part of the reason this collaboration went well as it was easy to work and have open discussions with her. He said:

I’m happy that I have [Melina] to collaborate… [she] is just a great person… to work with…. By nature, I’m skeptical of many things, but this is an accident. I don’t think that… these things do happen often, but it’s nice when it happens… you have someone who is just… so easy to collaborate with and to share opinions about things” (personal communication (I), July 15, 2014).

During meetings, mainly when discussing the students in the program, the group often perceived they were on the same page, and they were able to take solace in the fact that the other members of the collaborative team were having similar, often times difficult or challenging, experiences with the students. Each of the instructors struggled with students’ lack of mathematical background knowledge, and thought this weak mathematical knowledge often hindered the students from learning the course content and moving forward with concepts. They also dealt with certain students often missing class and not turning in assignments. The three instructors bonded over the connection. Doug stated:

I did like finding out that I wasn’t the only one who just kind of felt the students were not what I was expecting… it was good just to hear Melina’s and Tom’s thoughts about, you
know, what they were experiencing once the classes actually got going (personal communication (I), July 15, 2014).

Tom talked about the opportunity to work with Melina and have her support. He appreciated he could learn about educational perspectives through discussions with her. He said, “I’m lucky to… have access to… her mind. A lot of times it’s very interesting to see how she’s… thinking about certain problems from an educational perspective and that’s extremely valuable to me” (personal communication (I), July 15, 2104). He also talked of the relationship he and Doug have formed, as being in the same building made informal communication between them easier than with Melina. He mentioned how he and Doug talked casually about occurrences in their classes. He said, “I talk to Doug [about] his experience and what he thinks about this or that” (personal communication (I), June 16, 2014). Doug reiterated this sentiment in his interview, saying:

[Tom and I] talk about how the courses are going and how the students are performing.…. If, you know, for no other reason, even if we just meet in the hallway, we talk about it. I mean, it’s not like we set up formal meetings, if he and I run into each other, it’s a topic of discussion (personal communication (I), June 11, 2014).

Melina also talked of the bond the group formed as the collaboration progressed, stating, “we started feeling more comfortable with each other… we established a relationship” (personal communication (I), July 23, 2014).

Although the collaboration had its issues and challenges, it worked because the participants were able to work through those challenges in such a way that they could support and help one another. The collaboration directly caused some changes to the participants’ teaching and planning, as discussed in the following section.
Participants make teaching and planning changes as a result of the collaboration.

To address the third research question, I explored changes that occurred in the participants’ planning or teaching, or both, that were associated with the collaboration. In the following section, I detail the observed changes and describe the participants’ perceptions of and thoughts about the changes they made as the collaboration progressed. For Melina, the mathematics educator, her changes were examined and described in terms of how her planning and teaching differed because of her work with the mathematicians. For Tom and Doug, the mathematicians, their planning and teaching changes were examined and described, both in what was changed relative to teaching a course as part of the middle school teacher preparation program and according to the Fennema levels.

Fennema et al. (1996) identified teacher change, categorizing teachers according to four levels of mathematics teaching. At Level 1, teachers teach procedures and are often guided by a textbook. At Level 2, teaching is similar to Level 1, but teachers incorporate some rich problems, often learned through professional development. At Level 3, teachers allow students to engage in solving problems not found in the typical textbook and sharing their solutions. At Level 4, teachers make instructional decisions based on students’ problem solving capabilities, strategies, and communication. In the following sections, I detail the changes for each participant individually.

Changes in Melina’s planning and teaching. Melina taught the Middle Grades Mathematics Methods II course, which focused on the methods to teach middle grade mathematics, including different pedagogical approaches to teaching mathematics, designing
Melina’s planning and teaching of the course were affected by the collaborative efforts. Melina planned and implemented certain activities for her class based directly on content students were learning in their mathematics courses, allowing her to help the students make explicit connections with those courses. For example, in one of Melina’s classes, students worked in small groups on an activity involving circumference of circles. The students in each group measured the circumference (C) and diameter (d) of the base of different cylindrical objects and recorded those values, then divided C by d. Each group provided their various values for \( \frac{C}{d} \) for each of the items they measured. As a class, they found the average of the values of \( \frac{C}{d} \), a number which, if done correctly, approximates pi. During the class discussion following the activity, Melina attempted to have students make a connection between this activity and what they recently learned about circles and pi in their geometry connections course. The students had been introduced to circles and pi, the ratio of the circumference of the circle to its diameter. This activity afforded the students an opportunity to determine this ratio for themselves in a hands-on manner, and provided them with a task they might eventually use while teaching middle grades. Connections such as these would not be possible without the collaboration of the professors.

Melina believed the collaboration had a direct effect on her planning and the events in her class because she had the opportunity to talk to the math instructors during the collaboration. Through her conversations with the instructors, she gained insight on what the students were learning and doing in their mathematics classes, and with that knowledge she was able to plan her class to include specific mathematical content, and guide her class discussions around middle grades teaching methods for that content. She stated:
I’ll know… what experiences [the students] are having in their math classes, I can build on that in my instruction… I can make direct links with what they’re doing in the math class. Actually what they’re doing in the math class will in some ways determine some discussions were going to have (personal communication (I), June 13, 2014).

When Melina planned for her course, she often tried to make connections with the mathematics courses. Specifically, she wanted the students to have experiences with certain mathematical content in their mathematics courses so she could then talk about the methods used to teach that content on a middle school level. She said she often wondered what she “can do with the math professors so that they do certain things in their courses, where… then it will help things run better in my class” (personal communication (I), May 1, 2014). She wanted the students to learn the content in their mathematics courses so she could then focus solely on the teaching methods, and not spend time on the mathematical content. She said:

once I figure out which lessons the preservice teachers are going to actually teach in the school as part of the lesson plan assignment… if any of those lessons are algebra or geometry related, I want to coordinate with [Tom and Doug] and make sure that they spend… maybe one lesson, even if it’s not part of their… syllabus. So just devote like maybe one lesson to explore the content… I don’t know if that’s feasible but I’ll try it (personal communication (I), June 13, 2014).

**Changes in Doug’s planning and teaching.** Doug taught the Algebra Connections course. He typically taught by handing out pre-typed notes to students, which included definitions, rules, theorems, and problems, both with and without solutions. He would then read through these handouts out loud with the class. The problems he included in his lectures were often procedure based, textbook type problems such as the following: Graph the function $y =$
3 – 2(x + 1)^2 by applying transformations. At times, he incorporated some richer problems for students to work through, however they were also typically procedure based. For example, when Doug taught about different types of functions (e.g. rational, radical, polynomial, etc.), he provided students with a matching exercise where they had to determine which graph illustrated each equation. Students discussed their answers, providing mathematical reasoning to justify their selections.

As the semester progressed, Doug attempted to incorporate different teaching methods in his course as a way for students to stay involved and engaged in the class. In week 4, he first implemented a group work activity. The students were unprepared to do the work, had not looked at the problem prior to class as it was assigned, and were confused by the problems, thus, they struggled to complete the problem in groups. Doug viewed this as a failed attempt and he was frustrated by it, though not deterred. He tried group work again in week 6. This time, the students worked well in groups and Doug was pleased with the class. He planned for and implemented group work problems in weeks 13 and 14 as well.

Often, the group work problems assigned were rich, real world application problems that engaged the students in problem solving and discussion of their solution strategies. These problems were different from the procedural problems included in his lectures, as described above. For example, when learning about mathematical modeling, one problem Doug had students work on is:

XXX Airlines requires that the total dimensions (length + width + height) of a carry-on bag not exceed \( k \) inches, where \( k \) is a specified constant. Assume you have a bag in the shape of a rectangular box that just meets this restriction. That is, \((\text{length} + \text{width} + \text{height}) = k\). Construct a function of two variables that
represents the volume of this box. Suppose the length of the box is twice the width. Write the volume of the box as a polynomial with the width as the independent variable. What are the zeros of this polynomial? Draw a graph of this polynomial that has the correct end behavior and the correct behavior at the zeros. Based on your graph, for what approximate value of the width, in terms of \( k \), does the maximum volume occur?

Students worked on the problems in small groups then shared their solutions with the class. Similarly, in another class, students worked in groups on word problems involving systems of equations. They were given time to struggle with the problems and share their thoughts and solutions. There was some argument among the students about what the equations should look like. Doug did not get involved; he let the students discuss the solutions and they did come to a correct consensus.

In addition to implementing the group work strategy to his teaching of the algebra connections course, Doug also incorporated more student participation. In the beginning of the semester, Doug would solve the example problems for the students and explain the solutions. At times, the solutions were already written in the handouts. In week 8, Doug began giving students the opportunity to solve problems, write their work on the board, and explain their solutions to the class.

Doug changed his instructional methods, incorporating group work and student presentations and explanation of work, due to his involvement in the collaboration and the fact that he was teaching preservice teachers in the course. He mentions his typical teaching is lecture style but he tried to do more than lecture with this class. He thought his efforts enhanced the course and the students appreciated it. He said, “I started off probably lecturing quite a bit and
then I tried to back off on that as the semester progressed, which I think [the students] liked…. I think the course got better as it went on” (personal communication (I), June 11, 2014). When talking about those changes, he says:

[I] turned over some days to the class. I don’t usually do that…. the group work… I know that it’s been around for years and I’ve never actively pursued it. And I did try to, try to do that this semester. So that was new for me (personal communication (I), April 30, 2014).

When Doug taught the algebra connections course using lecture as the main teaching method, he taught at a Fennema level 1 or 2. This comprised the majority of the classes throughout the semester. However, when he incorporated some of the ideas discussed during collaborative meetings, such as group work and student led problem solving, his teaching level typically rose to a 3. Doug began to understand involving the students in what he called “active learning,” would be more beneficial to students, and having a small class presented the opportunity for him to try different instructional strategies. He recognized that he had taken steps to change his teaching style from lecture-based, using procedure-type problems to one with student participation and student led problem solving. Doug stated:

I feel like I’m still working out most of the problems for them but… I don’t pick just the most basic problems to discuss… I’m going to try to get them to be telling me what to do rather than me just doing it, but uh, I’m not there yet, but that’s my goal… You know certainly it was an advantage to have such a small class… A lot easier to do some of that stuff, or at least it is for me (personal communication (I), July 15, 2014).

Although it took some time for Doug to adjust to some of these new techniques, overall he was happy with the outcomes. He said, “one class I liked quite a bit was where the notes were kind of
written but the problems weren’t solved and they just took turns coming up to the board and solving the problems. I thought that went pretty well” (personal communication (I), April 30, 2014).

**Changes in Tom’s course.** Tom taught the Geometry Connections course. He typically provided students with a handout of notes for each class prior to the class meeting. The handout usually consisted of the definitions and theorems related to the topic and problems for students to work out. In class, he would discuss the definitions and theorems and guide students through select problems from the handout.

Tom’s teaching often fluctuates among Fennema’s levels 1, 2, and 3. Tom spent time in nearly every class helping students learn precise definition and theorems. He wanted to be sure students understood what the definitions and theorems meant, and that the students were able to state definitions and theorems precisely. For example, in one class, Tom asked the students to get into three small groups and write the definitions of midpoint of a segment, perpendicular bisector of a segment, and bisector of an angle from memory without using their book. Other classes were focused on proving theorems and solving other geometric problems. For example, students derived the distance formula from the Pythagorean Theorem. Students had previously learned the Pythagorean Theorem and Tom explained the relationship between the Pythagorean Theorem and distance formula. He gave an explanation of what the distance formula does but did not tell the students the formula. Then he gave students two points and asked them to find the distance and explain. Students discussed with each other, then a student put a solution on the board.

Students worked on more challenging problems as well. For example, Tom gave the students some historical background of the golden ratio and then described the golden ratio in
general terms. He handed each student a piece of paper with a segment drawn on it and asked them how they would divide the segment so they have the golden ratio. He told students to find the golden ratio using \( \frac{1}{x} = \frac{x}{(1-x)} \). The students worked individually on this for a few minutes. A student then solved for \( x \). When the students gave both positive and negative values, Tom reminded students that \( x \) represents a distance and the student said the answer would be positive. From here, the students continued to work on determining how to divide the segment.

The collaboration affected Tom’s class planning and teaching methods. When Tom teaches his mathematics courses, he usually teaches solely through lecture. But in the geometry connections course, Tom had students come to the board to write out and explain their solutions to problems. During an interview, he explained he does not do this in his typical mathematics courses, stating, “I didn’t have in the math classroom, asking students to go on the board and do some problems, ok. That’s could be a difference, because the geometry students were challenged to do that” (personal communication (I), June 16, 2014).

Tom talked often of his need to make changes to his class due to discussions about program requirements that occurred during the collaboration meetings. For example, when the program was developed, technology integration was considered an important aspect of each of the courses. This represented a big change for Tom, as he does not typically implement instructional technology. During his first semester teaching the course, although he acknowledged the need for technology, he implemented very little, enough to fulfill the requirement of having some form of technology included in one of the course topics. He stated, “the big change for me is my stand towards technology… including more technology, but so far [my] solution was very superficial and satisfying the requirement” (personal communication (I),
July 15, 2014). He was happy with the instructional technology he was able to include, Geogebra, stating:

I like this program, especially that I found… a construction game on Geogebra…. you can construct a line to two points and you can construct circles. So in other words, you do have a straightedge and compass, and that’s about all. And then you progress their 15 levels of the game, or 16 I think, through the game and you progress when you compete the task (personal communication (I), July 15, 2014).

Summary.

The participants embraced roles as they worked together. These roles were quickly assumed by each of the participants, in part due to their knowledge of the grant and the college of education, where the program was designed, created, and ultimately implemented, and also due to their willingness to take on the roles. The roles became more defined and well established as the collaboration progressed. However these roles ultimately led to a power imbalance, hindering the collaboration.

Melina, the mathematics educator, emerged as the leader of the collaborative group. She determined the agendas for the meetings and ensured the group discussed items of importance and completed necessary tasks. Often, she helped the mathematicians through the tasks that needed to be done, such as the chalk and wire assessments and the critical assignments for the course. Tom and Doug, the mathematicians, were content to embrace a supporting role. They participated willingly in the meetings and in the discussions of their courses and students. They completed the necessary tasks and engaged with Melina in working on their courses and creating connections among them. As the collaboration progressed, the three collaborative team members
formed relationships and bonded. They looked forward to discussing the students and their respective courses, and were happy with the support they found in one another.

The group encountered challenges throughout their collaborative process, as is to be expected. The leadership role and position in the mathematics education department, where the middle grades program was created and housed, led to a power imbalance in the group. All of the group members perceived that Melina had more power. At times, the mathematicians did not mind “taking the backseat” or following her lead, but there were other times where they perceived they did not have enough say or the give and take of the collaboration was unequal. Administrative tasks, undefined goals, and an unknown authority also created tensions for the group. However, the supportive and open relationships formed among the group members facilitated the collaboration, giving the group members encouragement and willingness to work through the challenges.

The collaboration resulted in changes in the instructional methods of the participants. Doug incorporated new strategies such as group work and student led discussions of solutions to problems. He also had students come to the board to show and explain their work, which was new for him. Doug struggled with this at first because he does not like to give up his control of the classroom. However, he knew it was important for students to have these experiences, as they are preparing to become teachers. Tom had students come to the board to show and explain proofs and other solutions as well, which is not a typical teaching method for him. Tom also incorporated technology, which is encouraged in the middle school mathematics teacher preparation program. He is unfamiliar with instructional technology which made the incorporation difficult for him as it was out of his comfort zone. Melina taught and discussed teaching activities in her class which corresponded to content and tasks students were doing in
their mathematics class. While planning her classes, she often considered the content the students
were learning in their algebra and geometry courses, taught by Doug and Tom, respectively, and
tried to make connections to those topics.
CHAPTER 5:

DISCUSSION

Collaboration among mathematicians and mathematics educators has been called for as it has the potential to enhance the preparation of mathematics preservice teachers (CBMS 2001, 2012). However, the collaborative process is complex and challenging (Eddy & Mitchell, 2012; Konecki et al., 2012; Lele & Norgaard, 2005; Stoll et al., 2006; Vanasupa et al., 2012). The purpose of this study was to describe the collaborative efforts of a team consisting of a mathematics educator (Melina) and two mathematicians (Doug and Tom) as they worked together to co-plan and concurrently teach courses in a middle grades mathematics teacher preparation program. The study was guided by the following questions:

1. What approaches do a team comprised of a mathematics educator and two mathematicians use to facilitate their collaborative co-planning efforts as they prepare for and teach concurrent mathematics methods and mathematics courses for preservice middle grades mathematics teachers?

2. What factors support or hinder the collaboration?

3. In what ways does the collaboration affect the mathematics educator’s and mathematicians’ course planning and teaching?

In chapter 4, I presented the findings from the study as four major themes, as follows:

1. Roles were established and embraced, but ultimately led to an unequal share of power.

2. Administrative business, lack of authority, and undefined goals caused issues for the collaborative group.
3. Camaraderie brought the collaborative group together and facilitated the collaboration.

4. Participants made teaching and planning changes as a result of the collaboration.

Below, I provide a summary of the findings, present and discuss the conclusions from the findings, discuss the implications for practice, and recommend future research.

Summary & Conclusions

The collaborative team met 17 times throughout three semesters: Summer 2013, Spring 2014, and Summer 2014. During these meetings, the participants discussed their courses and their students, how to engage the students in the standards for mathematical practice, and how to make connections among their courses. They also spent time creating and refining mathematical tasks for students to work through in class or as homework and critical assessments, necessary for completing the mathematics teacher education program. Additionally, they spoke often of how to integrate instructional technology.

Hindering factors. The participants quickly established their roles as they began the collaborative work. These roles were assumed, in part due to their knowledge of the project and the college of education, where the program was designed, created, and ultimately implemented, and also due to their willingness to take on the roles. As the collaboration progressed, the participants embraced and continued in their adopted roles. Melina, the mathematics educator, emerged as the leader of the collaborative group, whereas Tom and Doug, the mathematicians, assumed passive roles. Research studies have found successful collaborations benefit from having established roles, such as the ones the participants assumed in my study (Vanasupa et al., 2012). As leader, Melina was willing to take charge: determining schedules, setting goals, and planning agendas for the upcoming meetings. Her leadership provided opportunities for the
group to come together and be productive. Because part of the collaborative focus was on supporting the mathematicians in the teaching of a course aligned with pedagogical practices taught in and advocated for by the education department, it is not surprising the mathematics educator emerged as a leader or mentor in the collaborative group, leaving the mathematicians to follow her lead.

However, as the collaboration progressed, the roles assumed by Melina, Doug, and Tom undermined what should have been a collaborative group of equals. Melina’s role as leader allowed her to be the superior in the collaboration, while Doug and Tom took subordinate positions. This led to feelings of inequality and passivity in Tom and Doug, and pressure for Melina. This is consistent with other studies where researchers have found one member assuming a leadership role is a major hindering factor to collaborative efforts (Lele & Norgaard, 2005; Vanasupa et al., 2012).

In their first person case study, Vanasupa et al. (2012), a group of instructors in higher education from various disciplines, attempted to collaborate to assign their students an interdisciplinary, integrated class project and create a manuscript detailing the collaborative project, yet encountered problems when one member of the collaborative team emerged as a “leader.” This caused a lack of autonomy for the subordinate members, leading to decreased motivation and engagement in the project. These studies’ findings led the researchers to conclude when establishing roles, hierarchical structures should be avoided (Vanasupa et al., 2012).

Similarly, in my findings, Tom and Doug, the subordinate members of the collaborative group, often perceived they were following Melina’s lead and waiting for instruction; they lacked full autonomy over their courses. In contrast to the Vanasupa case, where the leader did not realize the role she assumed, Melina recognized her leadership, and although at times pressured by the
role, assumed the responsibilities of planning and organizing the collaborative meetings and overseeing the collaborative efforts.

Due to Melina’s position in the education department and knowledge of the program, Doug and Tom often looked to her for direction and guidance. They did not challenge or object to Melina’s ideas or plans for the collaboration. This is consistent with findings from other collaborations, specifically that the subordinate members of a collaboration, may have a tendency to comply with a collaborative team member who they view as the “expert” in the situation (Wong, 2009). The subordinate members of a collaborative team often do not challenge their roles, or the leader, and there is typically no outward conflict, yet their subordinate position does reduce the effectiveness of the collaboration (Vanasupa et al., 2012). Similarly, in my study, I found Doug and Tom looked to Melina as the expert in the situation. They did not outwardly challenge her or the decisions she made. However, because they typically looked to her to tell them what to do, and waited for her to take initiative, they were not as active in the collaboration as they may have been if their roles required them to be more proactive.

The group encountered challenges throughout their collaborative process, as expected. Collaborations rarely operate without issues, tensions, and challenges. Melina’s role as leader and her position in the mathematics education department, where the middle grades program was created and housed, led to a power imbalance in the group. Melina had more power. At times, the mathematicians did not mind following her direction or choosing the “back row desk,” but there were other times where they perceived they were not equal partners in the collaboration. Power imbalance is suggested as one of the major hindering factors to collaborative efforts (Eddy & Mitchell, 2012). Collaborations have ultimately failed due to an unequal share of power among the collaborative team members (Vanasupa et al., 2012). The collaborators in the
Vanasupa case study failed to work collectively to produce a manuscript documenting their interdisciplinary course work in a timely manner due to hindrances and barriers in the collaboration (Vanasupa et al., 2012). Unlike the collaborators in the Vanasupa study, the collaborators in my study were able to accomplish their tasks, despite the power imbalance. The collaborators were able to make connections among their courses and implement critical tasks incorporating standards and accomplished practices the students needed to experience.

Results from this study suggest a possibility of other barriers that may affect collaboration not found in the studies included in the literature review. Specifically, the collaborators in this study struggled with unexpected administrative tasks, working for an unknown authority, and having undefined goals.

Although undefined goals and unknown authority were not explicitly reported as barriers to collaborative work, many researchers have concluded that a co-created, shared goal is one of the major necessities for a successful collaboration (see Konecki et al., 2012; Vanasupa et al., 2012). This suggests if the group had an opportunity to determine their own goals for the collaboration, they may have been more productive at meetings and been able to make more connections. If not for Melina taking charge and determining plans and goals, the collaborators may not have accomplished anything at all. Thus, it may be necessary, in some circumstances, for a leader to emerge in the group, at least for a period of time, to focus and engage the group. The leader, in this case, gave the collaborators tasks to work on and plans for how to complete that work. However, it is still imperative the other collaborative team members are in agreement with the goals created and set forth by the leader. Additionally, once the collaborative work is underway, collaborators should attempt to return to equal roles in the group, a possibility suggested by Eddy and Mitchell (2012), who propose that as relationships among collaborators...
develop and strengthen, it is possible for hierarchical distinctions to dissipate, thus creating a more balanced, equal partnership among them. If it becomes apparent that a leader is necessary, another possibility would be for the leadership role to shift among the collaborators, in order to drive the collaborative efforts, as found by Martin and Dismuke (2015). In their self-study of their collaboration, the two teacher educators examined the processes of planning and reflection they went through to make instructional changes to their concurrent sections of a writing methods course. The two researchers alternated taking the lead, as appropriate based on their background knowledge and experience.

The collaborators worked under the unknown authority, which in a way added a level to the hierarchical structure that formed as the collaborators established roles early on in the collaboration. Additionally, the idea of the unknown authority may have been created due to the fact that the collaborators did not initiate the collaboration. Each of them was asked to join the collaboration as part of the development of the middle grades mathematics teacher education program and agreed.

When facing the barrier of the unknown authority, at some point, it may have been beneficial for the collaborators to move past this unknown authority and make decisions among the three of them. This way, they might have made progress doing what they wanted to do assuming the “authority” would let them know if what was done was not appropriate. North, Clelland, and Lindsay (2018) describe the collaborators struggle with a similar situation. They were forced to condense the three separate courses they taught in the education department at the higher education institution where they worked into one co-taught course to be offered the following semester. They waited for the “authority” to tell them what topics needed to be covered in the course, how much time they would have for instruction. When they did not
receive answers to their questions, they decided to answer the questions themselves. Through their discussion and reflections during collaborative meetings, the collaborators developed an in-depth understanding of the problems and issues they were facing and progressed from “being controlled by the changes going on around [them] to taking control [them]selves” (p. 10). They became the leaders and eventually other colleagues and program leaders were relying on them for advice.

The unexpected administrative tasks the collaborators had to attend to was also a barrier. These tasks occupied time the collaborators had set aside to discuss their courses and make the connections among them for the benefit of the students. Having undefined goals also caused loss of time, as the collaborators were not able to use their collaborative time efficiently when they did not know what they were supposed to be doing during their collaborative meetings.

The unknown authority, undefined goals, and administrative tasks were likely interrelated. The collaborators felt compelled to complete administrative tasks and often referred to the unknown authority as the one who was requiring them to do so. Because the collaborators were waiting on the unknown authority to tell them initially what they should be doing and working on in their collaborative meetings, and did not receive instruction (until Melina took the lead), there were not any goals set for the group in the beginning of the collaboration, leaving the collaborators at a loss for what their purpose was.

Facilitating factors. Consistent with findings from other studies (Cox, 2004; Pegg & Panizzon, 2011; Vanasupa et al., 2012), I found the relationship forged by the collaborators facilitated their ability to make progress despite encountering challenges throughout the collaborative process. The collaborative group members formed friendships and bonded over
shared frustrations with their courses and students. The collaborative team members supported and helped one another when possible.

The collaborative group members enjoyed the opportunity to spend time discussing the students and their courses. The respect they each had for one another was often evident in meetings and they spoke highly of one another in interviews. This finding, that the group camaraderie helped to engender relationships and facilitate the collaboration, is in accordance with the facilitating factors found in other studies to be significant to building and sustaining a productive collaboration. Respect was identified by Stoll and Louis (2007), as one of the five principles which facilitate collaborative communities and by Cox (2004) as a quality necessary for community.

**Instructor change.** The collaboration resulted in changes in instructional practices for the participants, in the form of both planning for and teaching the courses. Doug incorporated new strategies such as group work and student demonstrations and explanations of solutions to problems. Tom had students demonstrate work on the board and incorporated technology. These pedagogical changes are consistent with recommendations to teach preservice mathematics teachers in the same manner they will be expected to teach their future students (Lloyd, 2013). Providing the preservice teachers opportunities to experience group work and peer-led demonstration and explanation of solutions while learning mathematics are the “authentic learning strategies that facilitate conceptual understanding of pedagogical practices” (p. 114). These experiences contribute to preservice teachers’ development of pedagogical content knowledge (PCK), which is necessary for effective mathematics teaching (Ball et al., 2001; CBMS 2001, 2012; Shulman, 1986). Melina helped Doug think through the implementation of
group work and discussed how it played out in the course. She also helped Tom plan the incorporation of instructional technology.

Participation in a collaborative community is a form of professional development (Bolam et al., 2005; Hamos et al., 2009) and professional development has been found to result in an increase in instructors’ knowledge (Bolam et al., 2005; Fennema et al., 1996; Henderson et al., 2011). Although much of the discussion about professional development focuses on teachers in K-12 settings, the results from this study shows there is potential for the same benefits at the university level. Specifically, one may argue the mathematicians in this study experienced meaning professional development in the form of the collaboration with a mathematics teacher educator and as a result, this experience provided the mathematicians an opportunity to consider different approaches for teaching mathematics in an effort to make their instruction more student-centered, which others have argued is beneficial for preservice teachers (Henderson et al., 2011; Lloyd, 2013).

Students in Melina’s class worked through various activities for teaching mathematical content for middle grades related to the mathematical content they were learning in their mathematics class. Melina planned her classes with the intention of making connections to topics covered in the algebra and geometry courses, taught by Doug and Tom, respectively. These connections provide opportunities for the preservice teachers to develop PCK, the specialized knowledge necessary for effective teaching (Ball et al., 2008; CBMS, 2001; Enzor, 2001; Lloyd, 2013; Shulman, 1986). The connections also provide opportunities for the preservice teachers to see the mathematics in a different context, potentially making the mathematics more relatable to preservice teachers’ experiences in the classrooms, an opportunity that is often lacking in preservice mathematics teacher education programs (Enzor, 2001).
Implications for Practice.

The findings from this study have implications for individuals who seek to engage in collaborative efforts, particularly those considering how they should be approached and facilitated to be successful while they overcome obstacles and challenges. First, establishing roles in a collaborative effort has potential to be effective, as long as the roles are not structured in a hierarchy and are agreed upon by all participants. Each collaborative group member should have responsibilities and their role should require their input and engagement in the collaboration.

Second, a power imbalance among collaborative group members will hinder the collaboration. Thus, it is important and necessary for participants in collaborations to alleviate power imbalances that have the potential to negatively affect the collaboration. The possibility of power imbalances should be identified and discussed at the onset of a collaboration so they can be addressed (Eddy & Mitchell, 2012). When these power imbalances are recognized, steps can be taken to ensure shared responsibility and equitable input. To address problems or challenges due to power imbalances, collaborative groups might establish a system for managing disagreements among members (Eddy & Mitchell, 2012). Should one member of the collaborative group emerge as a leader at any point, the leader can attempt to “transfer autonomy and decision-making power to others” by seeking their input (Vanasupa et al., 2012, p. 179).

Third, participants in future collaborations should spend time getting to know one another, help and support each other whenever possible, and attempt to develop relationships and bonds. The results of my study indicate that collaborations have potential for success if facilitating factors exist that outweigh the hindering factors. Specifically, when the collaborative
group members genuinely care for one another and hope for one another’s success, they are more likely to work through challenges and problems that arise, rather than allowing tensions and issues to destroy the collaboration. Additionally, these relationships have the potential to help group members overcome disagreements due to power imbalances (Eddy & Mitchell, 2012). When collaborators form relationships, they are more likely to view each other individually, separate from their rank, position, or discipline.

Finally, collaborations have the potential to spur and subsequently support instructional changes. Instructors who are interested in utilizing new instructional strategies may find support, help, and guidance through working collaboratively with colleagues who have experience with those strategies and who are working to make changes in their own courses. It would be most beneficial if the collaborative team consisted of “experts” in different desired instructional strategies so as to allay the possibility of a single leader emerging from the collaborative group.

**Implications for Research**

Researchers that have studied collaboration mainly focused on the product or outcome of the collaboration. There are few studies that concentrate on the process or collaborative efforts of the participants and my study adds to this area of research. However, there is still much more research to be done in this area.

Studies are needed to examine how other groups approach their collaborations. For example, a study may be designed to examine a collaborative group that employs an approach where each member assumes a specific role, looking specifically at how the roles and responsibilities influence the collaboration and intended outcomes. More descriptive case studies documenting collaborative efforts may provide in depth information about the collaborative
processes. Descriptive case studies provide an in-depth examination of collaborative approaches among groups. As we learn more about how collaborative efforts are approached and carried out, collaborative efforts may be planned and structured in ways that are more likely to be productive.

More studies are needed to explore factors that facilitate and hinder collaborations. It is unlikely a group of people will collaborate without any sort of challenge or obstacle posing a hindrance, thus studies are needed to determine how collaborative groups have overcome hindering factors. What may be learned from these studies may potentially be applied to other collaborative groups to ease the tensions of the collaborative process.

It is interesting in this case that the collaboration did not happen organically, the collaborators were asked to participate and accepted the invitation. Additionally, the mathematicians were not involved in the initial development and planning of the program, whereas Melina was, although that was not organic either. She was invited to participate in the development phase and accepted; she was not in a leadership role in that phase. More studies might delve further into this scenario. Researchers might examine how collaborators who initiate their own collaborations with specific plans and goals in mind differ from collaborators who are either invited to participate in a collaboration or who are obligated to collaborate.

Studies are also needed to confirm participation in collaborative efforts may result in instructor change. If collaborative efforts can effectively increase instructor knowledge and lead to change in teaching methods or beliefs, then collaborative efforts may be an effective form of professional development for instructors. This may be particularly useful for instructors of preservice teachers without an education background, such as the mathematicians in this study, to learn and implement teaching methods consistent with those the preservice teachers are learning in their methods courses.
Conclusion

This study adds to the literature on collaborations, specifically to the sparse literature focusing on collaborative processes rather than outcomes. I studied the collaboration from a third person point of view, providing a different perspective than much of the literature available on collaborative processes, which are often written in a first person perspective where the authors are also the collaborators.

I found the major hindering factor of the collaboration were the power imbalance due to the establishment of a hierarchical structure with a leader and subordinate members. The other hindering factors were the perception of working for an unknown authority, having undefined goals, and working on unexpected administrative tasks. The major facilitating factor was the camaraderie the group shared. The collaborators built bonds and relationships that encouraged them to continue the collaboration and work through the barriers they faced. I found the collaboration had a direct effect on the instruction methods and course planning for each of the collaborators.

Many of my findings were consistent with what is in the relevant literature. The collaborators initially benefitted from their chosen roles (Vanasupa et al., 2012) but the hierarchical nature of those roles and the resulting power imbalance eventually led to tensions and challenges for the group (Eddy & Mitchell, 2012; Lele & Norgaard, 2005; Vanasupa et al., 2012). The undefined goals caused challenges for the group because the collaborators did not have a co-created, shared vision for the collaboration, an important characteristic of successful collaborative efforts (Konecki et al., 2012; Vanasupa et al., 2012). Yet, the relationships formed by the collaborators in this study and their mutual respect for one another facilitated their efforts
and helped them overcome the obstacles they faced (Cox, 2004; Pegg & Panizzon, 2011; Stoll & Louis, 2007; Vanasupa et al., 2012). The collaboration resulted in the mathematicians’ inclusion of more student-centered mathematics teaching and the mathematics educator’s inclusion of activities and discussions of mathematical activities with direct connections to their mathematics courses, providing opportunities for students to develop PCK. These instructor changes are in line with the view that collaboration is a form of professional development, leading to potential instructor change (Bolam et al., 2005; Henderson et al., 2011).

There were unique aspects of the findings which create opportunities for researchers to investigate collaborative processes further, research necessary with the current recommendations and calls for collaboration in teacher education. I hope future collaborators may learn something about collaborations from the research I provided, and potentially use my findings to engender a positive, productive collaborative experience.
REFERENCES


Daly, C. J. (2011). Faculty learning communities: Addressing the professional development needs of faculty and the learning needs of students. *Currents in Teaching & Learning, 4*(1), 3-16.


APPENDIX A:

PROTOCOL FOR CLASS OBSERVATION

STEM Middle School Residency Program

LESSON OBSERVATION FORM

| Instructor: | Observer: |
| Course: | Week: |
| Semester: | Date Completed: |

PART II: IN-CLASS OBSERVATION

This form should be completed using the observer’s notes and information from the pre-observation interview.

| Date: | |
| Start Time: | 2:00 |
| End Time: | 3:15 |

INFORMATION ABOUT THE LESSON

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<td>Identify prior knowledge</td>
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<td>2</td>
<td>Introduce new concepts/topics</td>
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<td>3</td>
<td>Review concepts/topics</td>
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<td>4</td>
<td>Demonstrate Real-world/pedagogical applications</td>
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*Math and Math methods courses only - For each topic/objective covered in today's lesson, indicate evidence of process standard(s) and standards for mathematical practice observed using the codes below in the description.*

**Process Standards Observed (PS)**

- **PS1** problem-solving (Instructor choice of tasks that enable students to identify, apply, and adapt a variety of strategies to solve a problem)
- **PS2** reasoning and proof (Focuses on reasoning and proving mathematical ideas. Instructor expects and students provide explanations/justification, orally or in writing, how they obtain their solutions, and justify why their strategies are appropriate for arriving at their solutions)
- **PS3** communication (Instructor initiates and orchestrates discourse, scaffolds mathematical discourse. Instructor and students “talk” mathematics; students are encouraged to communicate their mathematical thinking clearly to the Instructor and their peers, both orally and in writing, using the language of mathematics)
- **PS4** use of representations (i.e., use of a variety of forms such as pictures, words, written symbols, graphs, charts, diagrams, manipulatives, real-world situations, to illustrate mathematical concepts and ideas)
- **PS5** connections and applications (Instructor choice of tasks enable students to connect and apply mathematics to other mathematical concepts, their own experience, to the world around them or to other disciplines)

**Evidence of Students Exhibiting Standards for Mathematical Practice (SMP)**

- **SMP1** Make sense of problems and perseverance in solving them
- **SMP2** Reason abstractly and quantitatively
- **SMP3** Construct viable arguments and critique the reasoning of others
- **SMP4** Model with mathematics
- **SMP5** Use appropriate tools strategically when solving a mathematical problem
- **SMP6** Attend to precision
- **SMP7** Look for and make use of structure
- **SMP8** Look for and express regularity in repeated reasoning

**ADDITIONAL OBSERVATIONS/COMMENTS**
APPENDIX B:
INTERVIEW QUESTIONS

Interview 1 Guiding Questions (used for all three participants)

Educational Background Questions

1. Where did you receive your education and what are your degrees in (Bachelors, Masters, PhD)?

2. How long have you been teaching (at this institution and others)?

3. How long have you been at this institution?

4. What classes do you teach?

5. How many of these classes are for undergraduate preservice teachers?
   a. For mathematicians:
   b. Have you taken any education courses?
   c. Have you ever taken any trainings, professional developments, etc. that focused on education?
      i. If yes to either of the above questions: What were they? What topics were addressed? What did you learn? Have you applied what you learned in the courses you teach? If so, what and how? If not, why?

Collaboration Questions:

1. What were your expectations when you agreed to participate in the collaboration?

2. Were those expectations met so far?
3. What do you hope the final outcome of the collaboration will be?

4. How do you see your role in the collaboration? Why?

5. Is/has the collaboration helping/helped you in planning and teaching your course?

6. How do you feel the collaborative experience is going? Why?

7. Do you think the collaboration has affected the way you planned for or taught the middle grades preservice teachers? If yes, how? If no, why not?
Interview 2 Guiding Questions – Melina

1. What are your expectations for the summer meetings next week?
   a. Do you expect it to be helpful for your planning for next spring?
   b. What do you hope to get from the meetings?

2. Do you expect the summer planning this year to be different from the summer planning last year? If so, how?

3. Why did you decide to split the meetings to have just you and Doug meet on certain days and you and Tom on others?

4. Can you describe how you envision the summer meetings?

5. You mention you want to talk to both mathematicians about things they want to change for next Spring, will you incorporate this into the summer’s meetings?

6. You mention that when you began planning, part of the problem was that you were working from theory and not experience and spent a lot of time just trying to figure out what you were doing, do you think this summer will be different? If so, how?

7. You mention that it became apparent after a few meetings that the mathematicians kind of acted like you were in charge (planning meetings, what you are going to do, etc.) rather than trying to figure things out together, but that at the same time it didn’t make you the authority because sometimes they wouldn’t do what you decided, do you think the summer will be the same or different?

8. You talk about how it was difficult to know what was really going on in the math classes because there was no coteaching and sometimes things that were discussed in the meetings were different than what actually went on in the class, can you think of a way to structure your collaborative meetings next Spring to change this?
9. You also talk about following an “authority” (pre-determined syllabi and requirements to use technology, make connections) in the beginning of the collaboration, but that you have started to internalize these things because of your experiences this semester. How do you think this might change the nature of the collaboration (make it different from last summer)?

10. What do you think could be done, if anything, to make the meetings more effective and engaging so that you wanted to meet and it wasn’t just a requirement?

11. When you think about how you teach your other classes for undergraduate preservice teachers in comparison to how you teach the middle grades math methods course, what are the similarities and differences?
Interview 2 Guiding Questions – Doug

1. What are your expectations for the summer meetings next week?
   a. Do you expect it to be helpful for your planning for next spring?
   b. What do you hope to get from the meetings?

2. Do you expect the summer planning this year to be different from the summer planning last year? If so, how?

3. What are your thoughts on splitting the meetings to have just you and Melina meet on certain days while she meets with Tom on others?

4. Do you and Tom ever discuss your classes or teaching (separately from the meetings)?

5. If you could plan the collaboration meetings, what would you do?

6. When you think about how you teach your other classes in comparison to how you teach the course for the middle grades education program, what are the similarities and differences?

7. In the last interview, you talk about your need to learn more about how to make group work effective. Have you thought about how/where you will learn this?

8. You also mentioned the possibility of trying a flipped classroom at some point in the future. If you tried this with the course for the middle grades education program, do you think you would need help/support with this? Where would you get that support?

9. You talked about the difficulties of having meetings with everyone’s schedule and being busy. What do you think could be done, if anything, to make the meetings more effective and engaging so that you wanted to meet and it wasn’t just a requirement?
10. You talk about wanting to do a “data dump” and talk about what you did and how it went and what might need to be changed (content, technology, tasks) during the summer meetings. Do you still intend to do this? Even if Melina has different ideas?

11. You mention that you have a hard time getting things done when they are still pretty far away. Are you feeling this same way about the upcoming meetings next week?

12. You also mention that the caliber of student was different than you expected in the spring. Do you think that will affect your planning for next year?
Interview 2 Guiding Questions – Tom

1. What are your expectations for the summer meetings next week?
   a. Do you expect it to be helpful for your planning for next spring?
   b. What do you hope to get from the meetings?

2. Do you expect the summer planning this year to be different from the summer planning last year? If so, how?

3. What are your thoughts on splitting the meetings to have just you and Melina meet on certain days while she meets with Doug on others?

4. Do you and Doug ever discuss your classes or teaching (separately from the meetings)?

5. If you could plan the collaboration meetings, what would you do?

6. When you think about how you teach your other classes in comparison to how you teach the course for the middle grades education program, what are the similarities and differences?

7. You mention that you have been receptive to different ideas because of collaboration with educators such as how content is presented and taught, specifically focusing on an inquiry based method of teaching. What is the inquiry based method of teaching? How is it done?

8. You talk about what educators want to achieve such as not just delivering content but being sure the students are proficient by monitoring understanding and how you have changed your practice towards this idea. How has your teaching changed to be more like educators? Can you think of specific examples? Have you made any changes directly because of the middle grades education program?
9. You mention that you weren’t convinced at first that we needed a separate course in this topic for middle grades preservice teachers, but now you understand the necessity. What caused the change?

10. You talk about being passive about the collaboration, allowing the educators to tell you what to do. With the upcoming summer meetings, will you try to be more actively involved?

11. You talked about how the two collaborations you were involved in were quite different as far as how they affected your teaching or planning and what the collaboration was like. Can you talk about how they were similar, if at all?

12. You say briefly that you feel like educators benefit more from mathematicians than vice versa during collaborative meetings (not learning about the education course, knowing the content, telling educator what you are doing but not hearing what she is doing). Can you elaborate more on this? Would you consider speaking up about this during the summer meetings?

13. What do you think could be done, if anything, to make the meetings more effective and engaging so that you wanted to meet and it wasn’t just a requirement?
Interview 3 Guiding Questions – Melina

1. What are your overall/general thoughts about the summer meetings?
   a. How do you think they went?
   b. Were they productive?
   c. What did you get out of them?
   d. What did you think about having the meetings split?

2. You mentioned last time that you weren’t sure how invested the mathematicians were in the technology and tasks, etc. Have your thoughts about that changed at all after the summer meetings?

3. Based on how the meetings went over the summer, and any other thoughts you may have put into the course since then, how do you envision this course for the spring? Any changes from last spring?

4. Since you were given a syllabus in the course proposal, did this affect how you felt you had to teach or plan the course?

5. Was there anything that made the collaboration easy/something that facilitated it?

6. Was there anything that made the collaboration difficult or challenging? Were there any limitations you found while working together?

7. Can you give an overall/general plan (even if it is brief) for the collaboration next Spring?
Interview 3 – Doug

1. What are your overall/general thoughts about the summer meetings?
   a. How do you think they went?
   b. Were they productive?
   c. What did you get out of them? (You had mentioned you had hoped to come out of the meetings with a plan for next spring and a good idea of how to incorporate technology).
   d. What did you think about having the meetings split?

2. Based on how the meetings went over the summer, and any other thoughts you may have put into the course since then, how do you envision this course for the spring? Any changes from last spring?

3. Since you were given a syllabus in the course proposal, did this affect how you felt you had to teach or plan the course?

4. Was there anything that made the collaboration easy/something that facilitated it?

5. Was there anything that made the collaboration difficult or challenging? Were there any limitations you found while working together?

6. Can you give an overall/general plan (even if it is brief) for this class for next Spring?

7. Where do you see yourself on this framework (Fennema et al., 1996)? Can you give examples?
Interview 3 – Tom

1. What are your overall/general thoughts about the summer meetings?
   a. How do you think they went?
   b. Were they productive?
   c. What did you get out of them?
   d. What did you think about having the meetings split?

2. Based on how the meetings went over the summer, and any other thoughts you may have put into the course since then, how do you envision this course for the spring? Any changes from last spring?

3. Since you were given a syllabus in the course proposal, did this affect how you felt you had to teach or plan the course?

4. You mentioned that you would like an opportunity to be challenged in the collaboration but did not feel that happen in the summer 2013 or spring 2014 meetings. Did you feel differently or the same about this during the summer 2014 meetings?

5. You mentioned that you wanted to learn more of the pedagogical rationale for the things the education department is asking you to do (technology, tasks, etc.) while also sharing your content knowledge. Did this occur during your meetings in the summer?

6. Was there anything that made the collaboration easy/something that facilitated it?

7. Was there anything that made the collaboration difficult or challenging? Were there any limitations you found while working together?

8. Can you give an overall/general plan (even if it is brief) for this class for next Spring?

8. Where do you see yourself on this framework (Fennema et al., 1996)? Can you give examples?
APPENDIX C:

IRB APPROVAL LETTER

April 9, 2014

Amanda Loyden
Secondary Education
Tampa, FL 33612

RE: Expedited Approval for Initial Review
IRB#: Pro00016683
Title: Collaboration among Mathematics Educators and Mathematicians: An Approach to Mathematics Teacher Education


Dear Ms. Loyden:

On 4/8/2014, the Institutional Review Board (IRB) reviewed and APPROVED the above application and all documents outlined below.

Approved Item(s):
Protocol Document(s):
Dissertation Protocol, ver 1.4-7-14

Consent/Assent Document(s)*:
Consent ver 1.4-7-14.pdf

*Please use only the official IRB stamped informed consent/assent document(s) found under the "Attachments" tab. Please note, these consent/assent document(s) are only valid during the approval period indicated at the top of the form(s).

It was the determination of the IRB that your study qualified for expedited review which includes activities that (1) present no more than minimal risk to human subjects, and (2) involve only procedures listed in one or more of the categories outlined below. The IRB may review research through the expedited review procedure authorized by 45 CFR 46.110 and 21 CFR 36.110. The research proposed in this study is categorized under the following expedited review category: