LESSON STUDY AS A COMPONENT OF AN INDUCTION PROGRAM FOR NOVICE TEACHERS

By

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ABSTRACT

Typically, beginning teachers need proper support as they transition to the classroom to be successful; they may not have the specialized skills and knowledge to teach mathematics effectively. Induction programs are designed to provide the needed support to novice teachers during their early years of teaching (Ingersoll & Strong, 2011); however, many induction programs within the US are not providing the necessary support to teachers to be successful (Wong et al., 2005). This study used a single case study to explore the effectiveness of lesson study as a component of an induction program for a novice mathematics teacher.

The researcher interpreted the novice teacher’s development through the lens of the situative perspective. According to this perspective, which is the combination of constructivist and sociocultural perspectives, learning is a process of the active construction of individual knowledge through interaction with others. To explore the effectiveness of lesson study as a component of induction, a novice teacher was selected to participate in one cycle of lesson study with three iterations of the research lesson. The novice teacher was a first-year mathematics teacher starting the alternative route for a practitioner license. The lesson study group consisted of the novice teacher’s professional learning community. Multiple data sources were collected before, during, and after the lesson study to identify changes in the participant. Through coding and categorizing the data from each iteration of lesson study, the researcher identified her development pathways in her disposition, cooperative relationships, and mathematical knowledge for teaching (MKT).

The researcher identified how the novice teacher developed through the course of the study. At the start of the study, the novice teacher was unsure of what constituted effective teaching practices. Through the progression of the study, she learned the importance of teaching through problem solving to promote productive struggle in the learning of mathematics. This had a positive effect on her disposition as she started to understand the benefits of perseverance and experienced the joys of mathematics sense making. As the teachers collaborated throughout the lesson study process, the nature of their conversations shifted from congeniality to collegiality. Through participation in lesson study, the novice teacher developed MKT. The multiple iterations of the research lesson and involvement of the knowledgeable other are two critical factors influencing the growth of the novice teacher. The findings from this research study demonstrate the compatibility of lesson study with characteristics of effective induction programs, but more research on the sustainability and scalability of the findings of this case study is needed. In conclusion, this study suggests that lesson study can provide the necessary components of induction.

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CHAPTER I: INTRODUCTION

Introduction

Mathematics educators are life-long learners who look to improve their "mathematical knowledge for teaching, their knowledge of mathematical pedagogy, and their knowledge of students as learners of mathematics" (NCTM, 2014, p. 99). Professional development programs are a means to improve teachers' knowledge and for teachers to improve their effectiveness over time. Lesson study is a teacher-directed professional development program to improve instruction and student learning (Lewis et al., 2009). Therefore, lesson study may be useful to teachers when they start teaching.

This study was an exploratory case study to investigate the effectiveness of lesson study as a component of an induction program for novice mathematics teachers. This introductory chapter provides brief information on induction programs and lesson study. It is followed by a description of the purpose of the study.

Background of Study

Engagement in professional development (PD) begins with pre-service teachers and continues throughout a teacher's career. A pre-service teacher's preparation typically involves a strong support group including content faculty, methods faculty, and in-service teachers, especially in preparation towards reform-oriented mathematics education (Bahr, 2013). Pre-service teachers participate in content and methods courses, which provide opportunities to begin the development of mathematics knowledge needed for teaching. Then they move to the classroom to practice and implement what they learned (Wang & Odell, 2002). However, it is unrealistic to expect them to transition into competent teachers without appropriate support systems (Morris, Hiebert, & Spitzer, 2009), and this is why induction programs are needed.

Teacher induction programs are designed for novice teachers and aim to provide the necessary support, tools, and knowledge to assist teachers at the start of their career (Ingersoll & Strong, 2011; Ingersoll, 2012; Kearney, 2014; Wong, 2004; Wong et al., 2005; Harris, 2015). Induction programs are especially beneficial for teachers who are certified via an alternative licensure route; critics of alternative licensure programs believe they do not provide teachers with adequate preservice training, thereby leaving them unprepared for life inside the classroom (Wayman et al., 2003). The general consensus is that induction programs within the United States are not providing the necessary support, tools, and knowledge to assist teachers at the start of their career (Wong et al., 2005). The following section will provide a description of the components and expectations of induction programs.

Components of Induction Programs

Induction is a way to transition teachers to the profession through a structured program that focuses on professional learning and emphasizes collaboration (Wong, 2004; Wong et al., 2005). According to Wong and colleagues (2005), “Induction is a highly organized and comprehensive form of staff development, involving many people and components, that typically continues for the first two to five years of a teacher’s career” (p. 379). Induction programs are not well established within the US; often disjointed and lack proper support and sufficient follow-up (Wong et al., 2005). In fact, there is an overall lack of policies on new teacher induction programs. In the US, only 15 states require induction programs for first- and second-year teachers (Goldrick, 2016). Although these 15 states have a program in place, there are no guarantees that the program is being used as intended, or that it is even an effective program.

Wang and Odell (2002) have identified the goals of induction programs to include reducing novice teachers' attrition and moving novices efficiently into the teaching culture, and they often require mentors to be extensive support for novices' learning to teach. Mentoring has historically been a way to provide support and encouragement to the novice teacher with an individualized relationship between a beginning teacher and a veteran teacher. Mentoring has become the main form of teacher induction programs in the US (Ingersoll & Strong, 2011; Wong et al., 2005), and often the terms of "mentoring" and "induction" are used interchangeably (Ingersoll & Strong, 2011; Sadiq, Ramzan, & Akhtar, 2017). However, even though mentoring programs are meant to help the novice teacher, their existence does not guarantee a quality relationship between the mentor and the novice teacher (Meyer, 2002).

An effective induction program can positively affect both the novice teacher and the mentoring teacher (Ingersoll & Strong, 2011; Ingersoll, 2012; Wong, 2004; Wong et al., 2005). When teachers are supported during their first few years, they will feel satisfied, allowing them to find their sense of belonging within the new school. Lewis (2014) further explained that teachers who are part of a unified and supportive department could successfully manage their stress, improving their self-efficacy. This improvement creates a desire for the teachers to want to stay at the school, which improves retention rates, which benefits both the school and the teacher. Schools with higher teacher retention rates also have increased student achievement (Ronfeldt et al., 2013).

Teaching has been identified as a highly stressful occupation (Lewis, 2014), which implies that the novice teacher needs support to navigate through their first few years of teaching. In particular, novice teachers need their mentor's support in choosing and implementing teaching methodologies, lesson planning, or handling unexpected student responses (Lewis, 2014). The implementation of Common Core State Standards in Mathematics is also challenging for new teachers (CSSM; Common Core State Standards Initiative [CCSSI], 2010). When these teachers do not have their mentor's support, they do not adequately implement standards-based teaching methodologies, and that can negatively affect their self-esteem. Induction programs are aimed to address these issues.

To properly assist new teachers with the transition into their classrooms, districts should utilize an effective induction program. Through an extensive literature review, McBride (2012) recommended that an effective induction program should incorporate: (1) collaboration of the teaching of colleagues; (2) sustained, structured, self-guided professional development; (3) observation of teachers teaching; and (4) being observed while teaching. He found that "new teachers need to collaborate with other teachers on issues such as classroom discipline, curriculum design, and lesson planning…It is also widely accepted that ongoing, structured professional development will help a novice in any career" (p. 89). An effective induction program can be the means through which novice teachers receive guidance and feedback from colleagues and other key educational stakeholders.

Lesson Study

Lesson study is a teacher-oriented, student-centered, job-embedded collaborative type of professional development (Lewis et al., 2009). As teachers work in groups to improve instruction, they "are able to develop a shared language for describing and analyzing classroom teaching, and to teach each other about teaching" (Stigler & Hiebert, 1999, p. 123). Teachers typically work in isolation, which can be difficult for new teachers (Ingersoll & Strong, 2011); therefore, utilizing lesson study during the first several years of teaching could prevent the novice teacher from feeling isolated.

The collaborative process of designing, teaching, analyzing, and improving a lesson through lesson study is a way for both veteran and novice teachers to enhance their knowledge and gain a deeper understanding of their content they teach by reflecting on all aspects of the lesson (Lewis et al., 2009; Lewis et al., 2012; Lewis, 2009). Because the novice teacher is still learning, this process could be a way to link knowledge gained as a pre-service teacher to their current teaching situation. Therefore, the lesson study approach could be a useful option for induction to learn and gain an understanding of teaching while situated in the classroom. Furthermore, the development of professional knowledge for teaching through lesson study is complex as Lewis and colleagues (2009) identified three categories of teacher's learning through lesson study: development of knowledge; development of disposition; and development of interpersonal relationships.

Through lesson study, teachers can develop different types of knowledge. Teachers are faced with many different situations in which their understandings and reactions can impact student learning and achievement. In fact, they are expected to possess the knowledge beyond mathematics content, but also the knowledge of general pedagogy, content-specific pedagogy, student thinking, and curriculum (Lewis et al., 2009). Specifically, for mathematics teachers, this describes Mathematical Knowledge for Teaching (MKT) (Ball et al., 2008).

Through lesson study teachers can also develop a productive disposition about knowledge, practice, and learning, which can include the following characteristics: curiosity, personal identity as a learner and researcher, motivation to improve, and the belief that changes in instruction can improve student learning (Lewis et al., 2009; Lewis, 2009). Disposition fits into the concept of mindset and behaviors. Throughout the study, disposition is referred to as the relation of productive and unproductive behaviors that may impact student learning of mathematics. The goal of lesson study is to improve teaching and understand how students think and learn, thus developing a teacher's disposition. In addition, lesson study provides the opportunity for a group of teachers to actively work together to foster student development. Each member within the lesson study group can provide different perspectives that can contribute to their own learning (Lewis et al., 2009). As the teachers work collaboratively to develop a lesson plan, they are also strengthening their professional community (Lewis et al., 2009).

Purpose of Study

To help novice teachers, many school districts require new teachers to be part of an induction program to help them become acclimated to their classrooms even though there is no statewide teacher induction system available. Even states that have such a program often do not require teachers to be a part of such a program, and some induction programs may not be effective (Wong et al., 2005). New teachers need assistance with both creating effective lesson plans and effectively implementing the lessons in their classrooms. LS could provide the needed assistance in both areas (Fujii, 2019). As teachers work to plan and implement lessons, they need to collaboratively reflect on identifying what did and did not go well within a given lesson. Through collaborative reflection, teachers receive timely feedback about the lesson to make necessary improvements, which assists with the teacher's evolution into being more effective.

By incorporating McBride's recommendations of: (1) collaboration with other teachers; (2) sustained, structured, self-guided professional development; (3) observation of teachers teaching; and (4) being observed while teaching; via a lesson study approach, an effective induction system could be created whereby both novice and mentoring teachers will grow to become more effective practitioners. Therefore, the purpose of this study is to explore how lesson study can be used and incorporated as a vital component of an induction program and to investigate the effect, affordance, and constraints of lesson study to acclimate the new teacher into the school. To achieve this overall goal, this study aims to address the following research questions:

1. How does LS help a novice teacher develop a productive disposition about mathematics teaching and learning?
2. How does LS help a novice teacher develop cooperative relationships with other teachers?
3. How does LS help a novice teacher develop mathematical knowledge for teaching?
4. What are the key factors supporting or hindering a novice teacher's learning through LS?

Significance of Study

When considering an effective induction program, Wang, Odel, and Clift (2010) share that "improved student learning is the ultimate goal of teaching and, therefore, an important component of an effective induction program" (p. 8). Through extensive research, common characteristics of induction programs and lesson study have been identified. Even though teacher induction programs have been thoroughly researched, a specific plan to support novice teachers through induction has not been suggested. The results of this dissertation provide information about how participation in lesson study can provide novice teachers with the necessary components of induction and can further inform professional learning community practices, which is important to build a culture of effective collaboration (NCTM, 2014). An effective collaborative culture can support effective teaching practices (NCTM, 2014; Stigler & Hiebert, 1999).

Definitions

Lesson study (LS). A LS is a teacher-oriented, student-centered, job-embedded collaborative professional development in which groups of teachers research lessons (Lewis et al., 2009).

Novice teachers. Teachers with less than three years of teaching experience.

Professional Learning Community (PLC). A PLC is a group of educators that work collaboratively to ensure that all students learn essential knowledge and skills (DuFour et al., 2006).

Chapter Summary

This chapter highlights that teacher induction programs are necessary and designed to acclimate novice teachers into the teaching profession; however, there are not well-established and effective induction programs in the US (Wong et al., 2005). LS, an international, innovative teacher professional development program, contains some of the critical components of effective induction programs; and yet has not been utilized as a mechanism of induction. Thus, this study was designed to examine how LS could be incorporated into induction programs.

CHAPTER II: FRAMEWORKS AND LITERATURE REVIEW

Introduction

The purpose of this study is to explore how lesson study can be used to acclimate novice teachers into the teaching profession and investigate the effectiveness of lesson study as a component of an induction program. The following paragraphs provide further information about the novice teacher. The following section consists of a description of the theoretical framework used for this study. It is followed by various analytical frameworks that depict the development of novice teachers, from which one was selected to view teacher growth. Finally, a review of the literature regarding professional development, induction programs, and lesson study is provided.

New teachers are expected to have the same responsibility as a teacher with many years of service; they are expected to teach a full load, make parent contacts, and be prepared for observational evaluations. The daily tasks of classroom management, daily and long-term lesson planning, and taking care of student needs can be demanding. These responsibilities can be overwhelming and stressful for new teachers. In fact, teachers leave the profession because they feel overwhelmed and not supported in their beginning years in the profession (Ingersoll & Strong, 2011). Studies have found "that anywhere from 30% to 50% of teachers leave the profession within 5 years" (Carver & Feiman-Nemser, 2009, p. 298). Having a well-organized supportive team can ease the pressure, keeping the novice teacher from feeling so overwhelmed (Lewis, 2014).

The teaching of mathematics is complex and requires teachers to have a deep understanding of mathematical knowledge for teaching (NCTM, 2014; Ball et al., 2008) in order to direct student explorations of mathematics; respond to unexpected student ideas; manage classroom discussions; create, align, modify, or implement curricula; and assess student understanding (Lewis, 2014). Not having a robust mathematical knowledge for teaching that is necessary to successfully carry out each of these aspects of teaching causes stress. Novice teachers need assistance when transitioning into the classroom as they do not hold all the essential knowledge and skill to be successful (Ingersoll & Strong, 2011). Such support is necessary for retention in the teaching profession. Induction programs should provide this support and bridge the gap from the preparation of pre-service teachers to competent in-service teachers (Morris, Hiebert, & Spitzer, 2009).

The novice teacher is an individual with less than three years of teaching experience. This individual can become a teacher through different pathways: the traditional or the alternative route. Traditional teacher preparation programs commonly serve undergraduate students with no prior teaching or work experience and generally lead to at least a bachelor's degree (United States Department of Education, 2016a). These programs usually include a student teaching requirement. However, the alternative route does not contain a student teaching requirement because these individuals are the teacher on record while participating in the alternative certification process. Such an approach has become more frequent and has various structures (Wayman et al., 2003). The alternative route allows individuals with at least a bachelor's degree to obtain a teaching certification without going through the traditional teacher education program. By not participating in a traditional program, "many have not seriously considered the required curriculum nor what professional teacher organizations consider best practice" (Foote et al., 2011, p. 401).

Furthermore, alternative programs have been criticized for their lack of pedagogical preparation (Wayman et al., 2003). To overcome the lack of preparation, the teachers are provided with a variety of support that may include university-based mentors, district-based mentors, school-based coaches, and assistant principals. In addition to the supportive personnel, the teachers take educational courses while they are navigating through their first year in the classroom (Foote et al., 2011). This route may require a passing score on the content teacher exam and an offer of employment.

Theoretical Framework

There are two broad schools of theories about teacher learning: constructivist and sociocultural. The combination of constructivist and sociocultural perspectives is a situative perspective (Borko, 2004; Greeno, 2003), where knowledge is situated and constructed through interaction with others. This sociocultural perspective is the theoretical perspective on mathematics teacher learning that will be used to view the novice teacher's learning process.

Due to the contextual, collaborative nature of LS, the theoretical perspective chosen comes from the idea of social practice. Specifically, the situative perspective (Greeno, 2003; Lave & Wenger, 1991) captures the context of LS in which learning is constructed through participation in communities of practice. The key ideas follow.

Ball and Cohen (1999) explain the significance of helping novice teachers learn in and from practice through collaboration with other teachers. During the LS process, facilitators and teachers work together to design, implement, and reflect upon research lessons; therefore, a situative learning perspective (Borko, 2004; Putnam & Borko, 2000) was adopted to guide this study. Situative learning focuses on the relationship between learning and the social situation in which it occurs (Lave & Wenger, 1991). It provides the context in which school classrooms become the place for novice teachers to practice and implement what they learn during their student teaching and induction years (Wang & Odell, 2002). Situative learning theorists perceive learning as changes in participation in socially organized activities and the individuals' use of knowledge as an aspect of their participation in social practices (e.g., Greeno, 2003; Lave & Wenger, 1991). Through participation, teachers transfer their identity, knowledge, and practice to their own classroom (Lave & Wenger, 1991). In fact, "educators need opportunities to see and to try out new approaches *in practice*" (Lewis et al., 2012, p. 370) to gain knowledge about teaching. Knowledge is defined as the information, understanding, or skill that is gained from experience (Merriam-Webster Dictionary, 2019). Therefore, the situative perspective supports the idea that learning occurs through authentic contexts, settings, and situations (Lave & Wenger, 1991) to apply new practices within the classroom.

Participation is described in terms of negotiating meaning through the accumulation of experiences resulting from active engagement in communities of practice (Wenger, 1998). It emphasizes the importance of collaborative learning among teachers and the contribution of shared knowledge for professional development. Teacher learning occurs through collaboration with other members of the community who have a shared interest or common concern for something they would like to improve upon. PLCs provide opportunities for teachers to interact and engage in collective inquiry (DuFour et al., 2006); they share knowledge and experiences, leading to opportunities to learn that relate to their everyday experiences.

In LS, teachers' learning can occur in different contexts, including their classrooms and participation in PLCs. These position teachers as individual learners and part of a social system. A significant portion of the knowledge of teaching can be acquired within the classroom. In fact, it should be situated in the practice of teaching to assist in the exploration and examination of the relationship between the theory and practice of teaching and learning (Wang & Odell, 2002).

Researchers have argued that learning has individual and sociocultural features and have characterized the learning process as construction and enculturation into a community of practice (Cobb, 1994). It is with the lens of the situative perspective that the researcher interpreted the novice teacher's development.

Analytical Frameworks

Numerous studies have discussed how to acclimate the novice teacher to the teaching profession. However, "the issue that arises is the acknowledgment of the necessity of induction without an understanding of what comprehensive, effective induction entails" (Kearney, 2015, p.15). In order to establish what comprehensive and effective induction entails, there should be an understanding that organizational socialization is a process of learning, and the novices' learning within the process should be acknowledged for induction to be successful (Kearney, 2015). The learning consists of the norms, values, and goals of the organization, as well as teaching practices

(Pogodzinski, 2012). Consideration of socialization in the investigation of new teacher induction (i.e., Pogodzinski, 2012; Kearney, 2015) has resulted in different frameworks. The different frameworks will be presented in the following sections; then, one is selected to view teacher development in this study.

Induction Frameworks

One theory for induction is Zey's (1984) mutual benefits model drawn from social exchange theory (Emerson, 1976), a theory concerned with the quality of interactions within the organization. Zey applied this theory to a mentoring relationship and suggested that the mentor, the novice teacher, and the organization benefit from the social exchange relationship.

The social capital theory (Lin, 2002) is another theory applied to teacher induction. Social capital refers to the social resources gained within a community. Based on his involvement in a multi-year study of novice teacher socialization, Pogodzinski (2012) created a conceptual framework rooted in social capital theory. In this theory, the resources available to novice teachers occur through social interactions that facilitate access to additional resources, changes in practice, and a commitment to teaching. The novice teachers become part of the school's culture by adopting its norms and practices by observing other teachers. Teacher relationships are based on the characteristics of the individuals, which include their values, goals, and philosophy of teaching. The characteristics influence the frequency and content of teacher interactions, which influence the levels of support and project expectations of the novice teacher. The interactions can occur with the mentor or with other colleagues. The teacher outcomes result from these teacher relationships; however, these relationships are not clearly outlined and sustained. The framework suggests that teacher development occurs through the resources gained through communities of practice.

The frameworks previously described involve mentoring as the induction program and focus on the importance of the school's social context needed for an effective induction program. However, these frameworks are limited because they restrict the induction program to mentoring but could be more useful if they were adapted to include other programs such as LS.

Lesson Study Pathways of Impact

Building on the situative perspective, Lewis and colleagues (2009) developed a framework for illustrating the impact on instruction and students' learning through lesson study (Figure 1). The lesson study cycle provides an opportunity for the novice teacher to learn within a community of practice to increase their knowledge for teaching, develop a positive disposition about teaching and learning, and develop instructional materials and tools. The community determines the purpose of their work; they agree on the goals; and they establish the norms for the group (Wenger, 1998). As a result, teachers could change their teaching practice and enhance students' learning. Unfortunately, the lesson study model does not explain how learning occurs through the process of lesson study. In fact, it oversimplifies the process of teacher growth by only acknowledging that learning occurs. The following model, the Interconnected Model of Professional Growth (Clarke & Hollingsworth, 2002), attempts to explain the process of teacher growth.

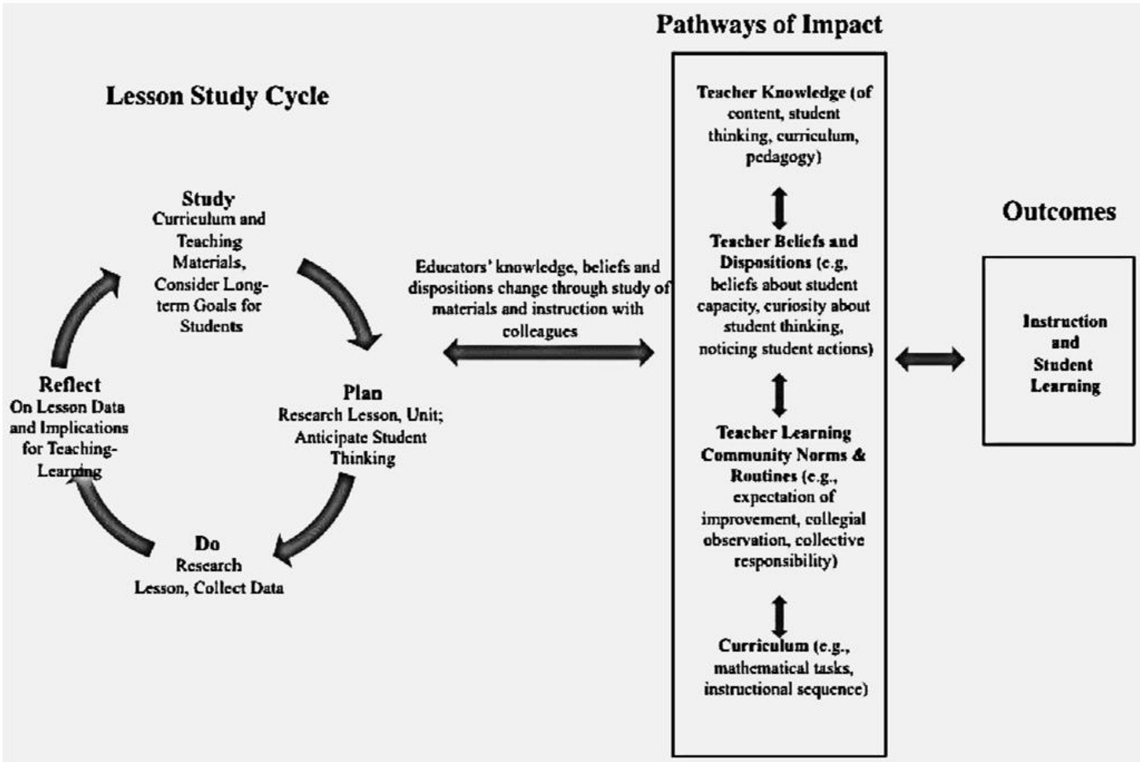


Figure 1. Lesson Study Cycle and Pathways of Impact (Lewis et al., 2009)

Extended Interconnected Model of Professional Growth

Clarke and Hollingsworth (2002) developed the Interconnected Model that recognizes possible pathways for teacher growth through reflection and enactment among four different domains, in which individual professional knowledge can grow and develop (Figure 2). From a situative perspective, teacher growth is constructed through social interactions, whereby the participants create and implement course materials. This model is consistent with a situative perspective because teacher growth can be seen through the change of practice resulting from their social interactions and subsequently acquired knowledge.

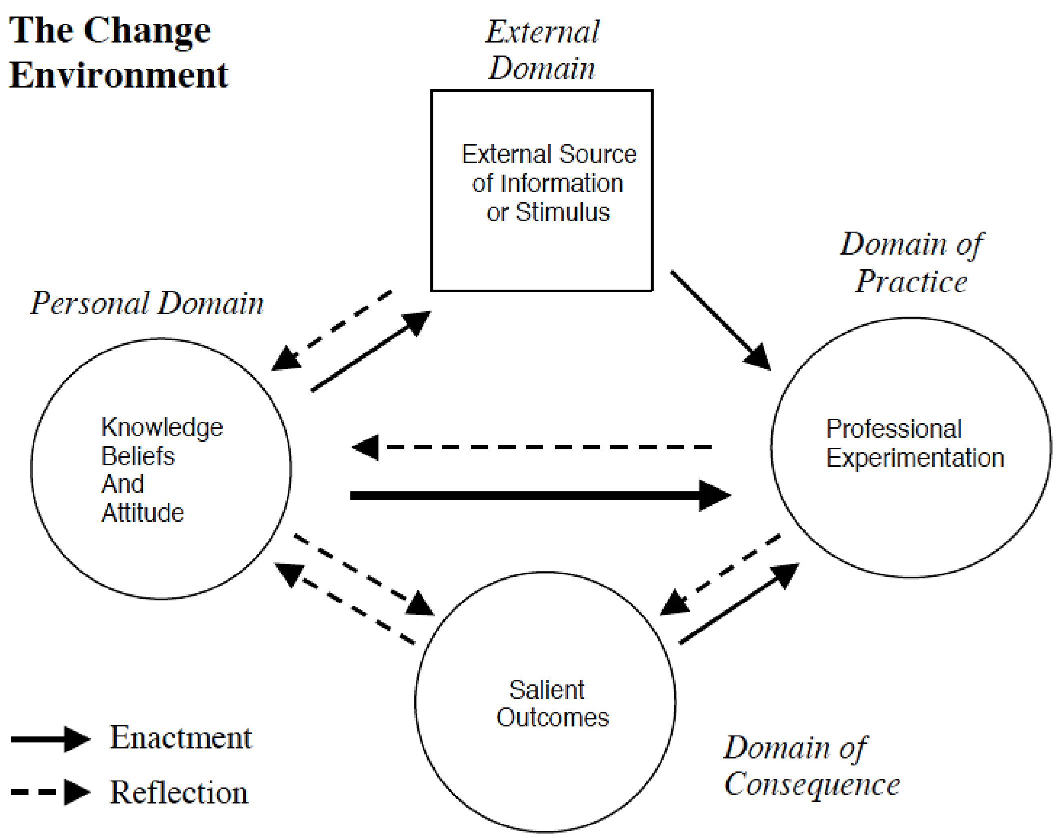


Figure 2. Interconnected Model of Professional Growth (Clarke & Hollingsworth, 2002)

The four domains of the change environment are: the external domain (the external source of information that influences teacher learning); the personal domain (teachers' knowledge, beliefs, and attitudes); the domain of practice (teachers' instructional practices); and the domain of consequence (student learning and other outcomes due to the consequence of teacher actions) (Clarke & Hollingsworth, 2002; Widjaja et al., 2017). This model shows that change in one domain results in a change in another domain through mediating processes of enactment or reflection.

Coenders and Terlouw (2015) extended upon the Clarke and Hollingsworth model (2002) (Figure 3) to illustrate Pedagogical Content Knowledge (PCK) growth by incorporating the developed material domain. The developed material domain represents the teachers making extensive personal modifications to the learning materials.

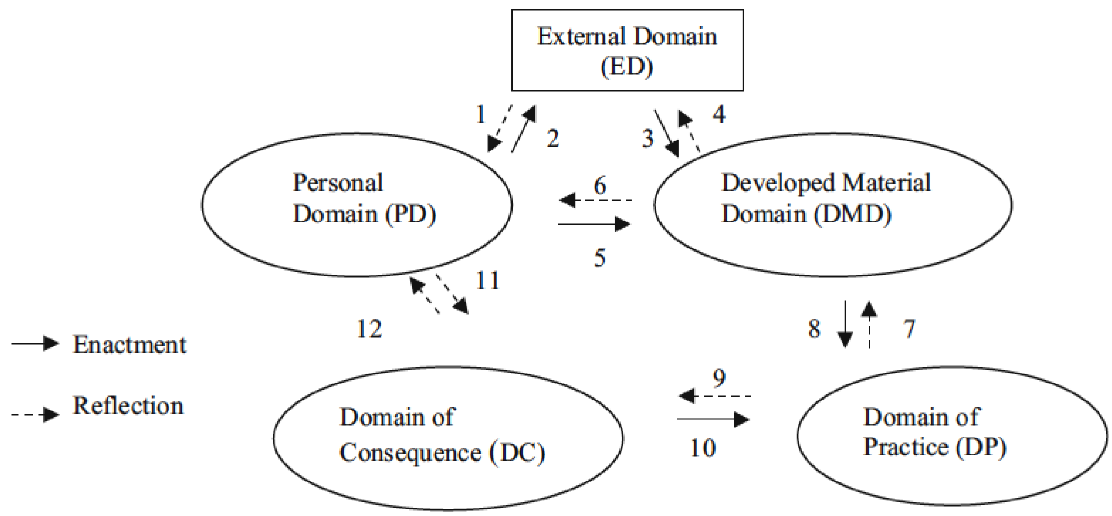


Figure 3. Extended Interconnected Model of Teacher Professional Growth (EIMPG) (Coenders & Terlouw, 2015)

Two phases for teacher growth are acknowledged through this model: *development phase* and *class enactment phase.* The *development phase* (Figure 4) consists of the interactions between the personal domain (PD), the external domain (ED), and the developed material domain (DMD). The teachers encounter unfamiliar material (ED) and will use their knowledge (PD) to create a detailed lesson plan (DMD). During the development phase of writing a detailed lesson plan, the teachers learn by utilizing different sources such as: professional publications, experiences from other teachers, and conversations with colleagues. Clarke and Hollingsworth (2002) identified these sources as components of the external domain. As teachers reflect on these sources, they may be able to envision how their students would react to a task to develop a detailed lesson plan. This phase may be a way to prepare teachers to use materials in the enactment of the lesson.

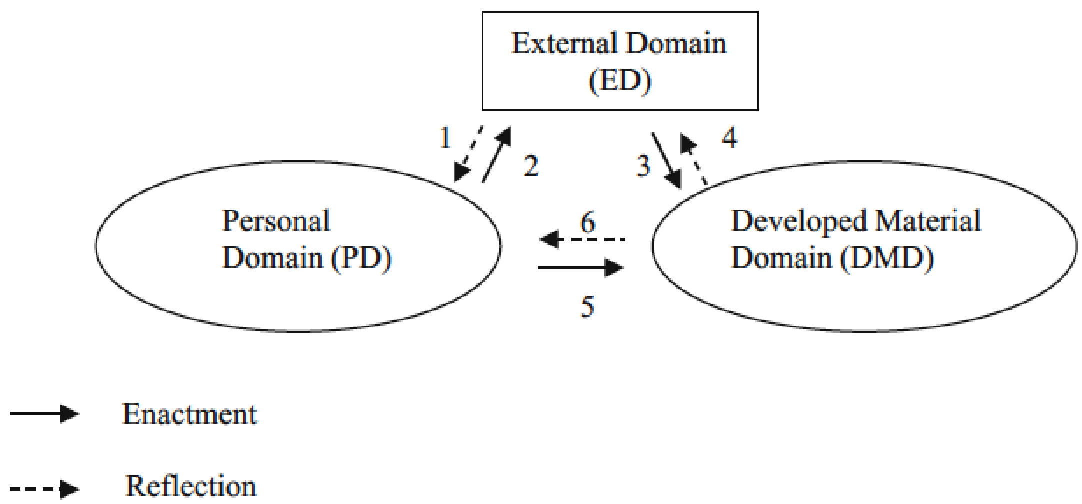


Figure 4. Development Phase (Coenders & Terlouw, 2015)

The *class enactment phase* (Figure 5) consists of the interactions between domain of practice (DP), domain of consequence (DC), and personal domain (PD). In this phase, the teacher will implement the lesson (DP) and observe noticeable student learning outcomes of the lesson (DC), which will influence the personal domain.

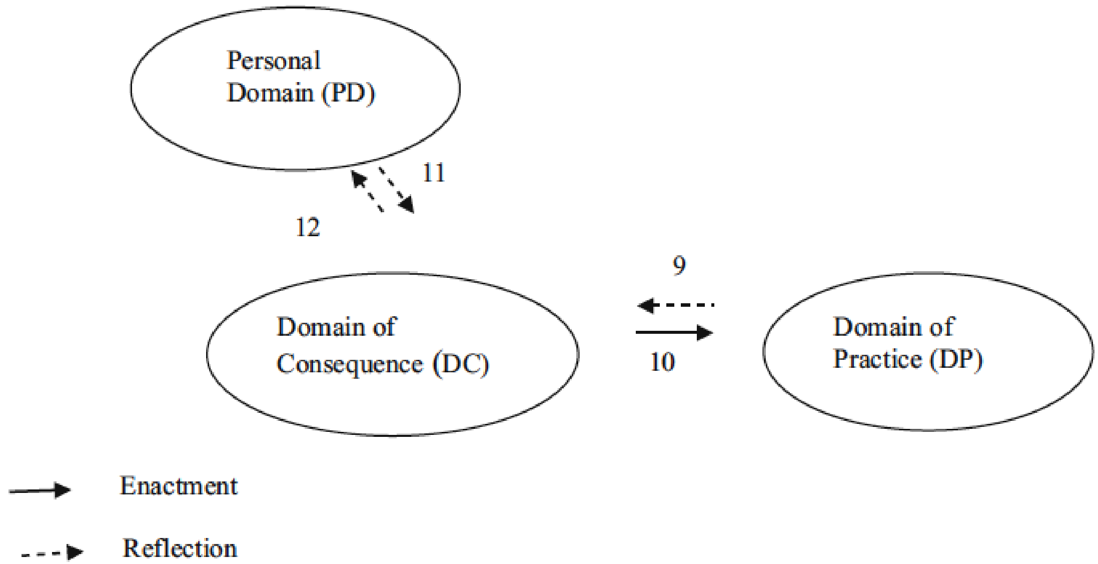


Figure 5. Class Enactment Phase (Coenders & Terlouw, 2015)

Together, the *development phase* and *class enactment phase* lead to changes in PCK (Coenders & Terlouw, 2015; Coenders & Verhoef, 2019). These phases are linked together with the *intermediate phase* (Arrows 7, 8) (see Figure 3). This is where the teachers choose to use the detailed lesson plan in class (Arrow 8) and reflect on the enacted lesson to make changes to the detailed lesson plan (Arrow 7). Together, the phases make up one cycle of lesson study, and each phase is situated in a different social situation.

Summary of Frameworks

Novice teachers need assistance in their transition to their role as in-service teachers. Induction programs are designed to help novice teachers gain knowledge for teaching, which can happen through observation and reflection. For novice teachers to gain knowledge and skill, they collaborate within a community of practice situated in the context of the classroom. Because this study was focused on the induction of novice teachers through LS, induction and LS frameworks were examined. To view the personal growth of the novice teacher, the EIMPG by Coenders and Terlouw (2015) was chosen to describe the development of the teacher's knowledge base through enactment and reflection between different domains and phases. This model allowed the researcher to recognize the complexities of teacher growth during LS.

Literature Review

While there are many forms of professional development that promote the knowledge and development of teachers, researchers have identified best practices to promote the development of professional learning. Professional development characteristics will be described, followed by the connection to induction programs and LS.

Professional Development

Professional development activities are designed to increase teachers' knowledge and skills, improve teaching practices, and contribute to personal, social, and emotional growth (Desimone, 2009; 2011). The core features of professional development that have been identified to improve teaching practice and achievement are: active learning to provide opportunities for teachers to become actively engaged in the analysis of teaching and learning; content focus to enhance and deepen teachers' content knowledge; coherence incorporating experiences that are consistent with teachers' goals and encourage continuing professional communication among teachers; sustained duration of the activity; and collective participation of groups of teachers (Desimone, 2009).

Furthermore, teachers need to understand the teaching practices that support student learning (NCTM, 2014). Professional knowledge needed to support student learning is acquired through active engagement within a community of practice. The specific professional development features that will be described are active learning, content focus, and collective participation.

Active Learning. Professional development programs should engage teachers in authentic activities that they encounter in their classrooms. The activities may consist of observing teachers or being observed, followed by discussion, and examining student work (Desimone, 2009). These activities encourage the teachers to try out ideas with their students to discuss the experiences with their colleagues to continue to learn and grow.

Content focus. Professional development programs should provide opportunities for teachers to develop their mathematical knowledge. Therefore, teachers need to engage in activities that focus on subject matter content and how students learn the content. Effective mathematics teachers need to do more than just present tasks; they are expected to know and understand mathematics in such a way that supports student learning (Ball et al., 2008). Shulman (1986) proposed a particular knowledge needed for teaching that he termed pedagogical content knowledge. Ball and her colleagues developed a framework known as mathematical knowledge for teaching (MKT) (Ball et al., 2008) by expanding on Shulman's (1986) work (Figure 6). MKT is a framework that describes the knowledge needed to teach mathematics effectively.

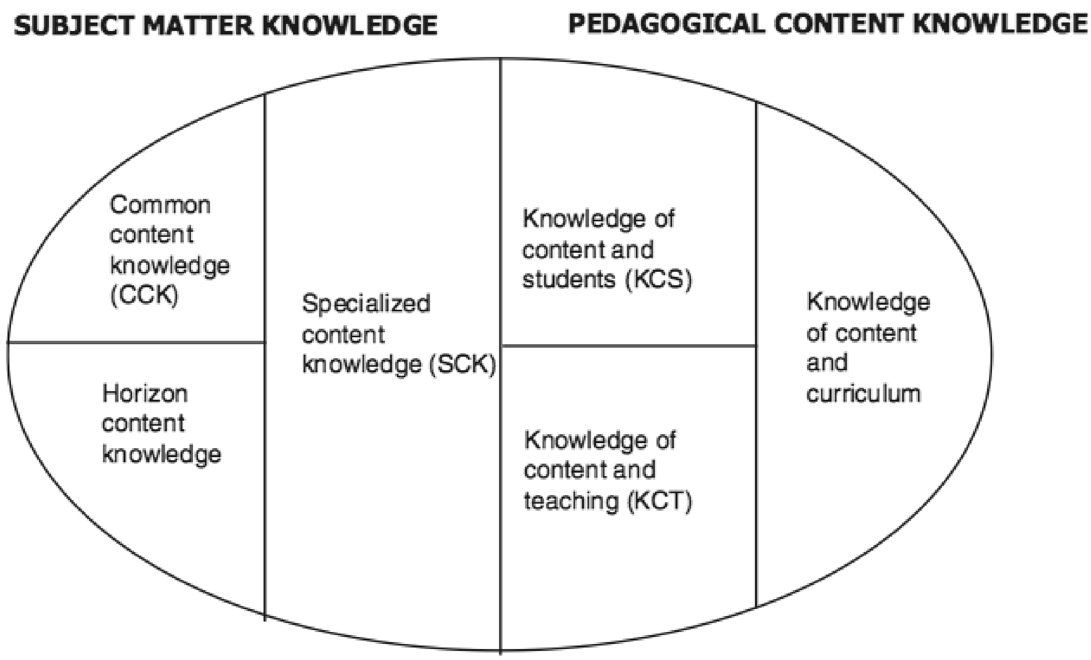


Figure 6. Domains of Mathematical Knowledge for Teaching (Ball et al., 2008)

The framework is divided into two categories: subject matter knowledge and pedagogical content knowledge; each category is further divided into three domains. Included under subject matter knowledge: Common Content Knowledge (CCK) is the knowledge and skill not unique to teachers but used in settings beyond teaching; Specialized Content Knowledge (SCK) is the knowledge unique for teaching; and Horizon Content Knowledge is an awareness of how the topics within the curriculum are related. Pedagogical content knowledge includes: Knowledge of content and students (KCS); Knowledge of content and teaching (KCT); and Knowledge of content and curriculum. The mathematical knowledge for teaching combines mathematical proficiency with the ability to guide discussions, modify problems, and make decisions that will encourage student learning.

Collective participation. When teachers are in the same school, content, and grade level, they discuss the concepts and skills from their experiences, share materials, and sustain changes over time (Garet et al., 2001). Participation in collaborative professional learning can encourage the teachers to learn through reflective practices. In fact, professional learning communities (PLCs) have been identified to engage in collaborative learning to improve their practice, improving education for their students (DuFour et al., 2006).

Induction Programs

Teacher development starts when the teacher is first introduced to teaching practices during the pre-service preparation and continues through the induction program (Figure 7).

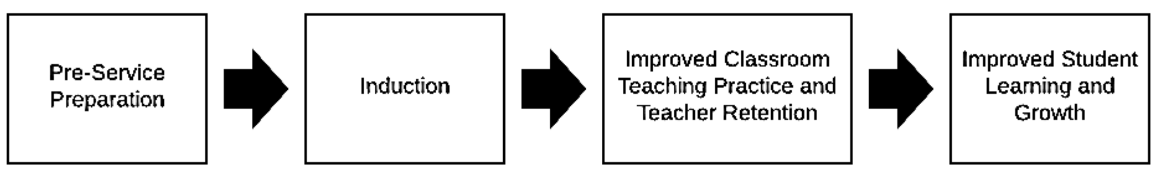


Figure 7. *Teacher Development (Ingersoll & Strong, 2011)*

Induction programs are intended to link pre-service teaching to in-service teaching and come in different forms, such as workshops and mentoring (Ingersoll & Smith, 2011; 2004). Therefore, these programs may be viewed as a specific type of professional development designed for beginning teachers. “New teachers learn best in a community which enables them to develop a vision for their practice; knowledge about teaching, learning, and children; dispositions about how to use this knowledge; practices that allow them to act on their intentions and beliefs; and tools that support their efforts" (Darling-Hammond & Baratz-Snowden, 2007, p. 120). Through induction, teachers improve classroom teaching, which, in turn, improves student learning. Teachers need guidance and opportunities to see practices modeled and to analyze how, when, and why the techniques can impact teaching practices (Darling-Hammond & Baratz-Snowden, 2007).

McBride (2012) researched essential components of teacher induction programs. He hypothesized that implementing an induction program will result in higher retention rates of newly hired teachers. He used a nationally represented sample of teacher data from the NCES 2009-2010 Beginning Teacher Longitudinal Study to investigate the association between induction programs and retention rates. McBride reviewed more than 100 sources and identified nine of the most commonly listed components: (1) experienced mentor; (2) collaboration with other teachers; (3) sustained professional development; (4) support from principal; (5) observe others teaching; (6) being observed; (7) release time for meetings; (8) reduced teaching load; and (9) networking. Even though nine features have been identified, experienced mentors and different observation methods describe the idea that novice teachers need guidance and opportunities to see practices modeled; and those components will be described.

Experienced Mentor. Researchers have identified the most common theme in the literature on features of an effective induction program to be having a knowledgeable mentor in the same subject area or grade (e.g., McBride, 2012; Strong, 2005; Wang & Odell, 2002). Mentoring has been shown to "improve teacher confidence, knowledge, and instruction; raise student achievement; and increase retention" (Desimone et al., 2014, p. 88). It provides new teachers with a local guide to assist in becoming acclimated to the culture of the new school through emotional support and technical assistance (Ingersoll & Strong, 2011; Wong, 2004; Wang & Odell, 2002). The mentors' role is a supportive role that should support new teachers through problem-solving. Such a supportive role can encourage new teachers to reflect on their decisions and promote a sense of independence (Loucks-Horsley et al., 2010; Peterson & Williams, 1998; Wang & Odell, 2002). Having a mentor in the same subject and grade can provide more productive interactions between the new teacher and the mentor (Desimone et al., 2014). Collaborating with the mentor can help the novice teacher design lessons that can promote student learning (Carver & Feiman-Nemser, 2009).

Observations. Observations provide teachers with a way to acquire new ideas and skills that occurs within the school. New teachers need opportunities to observe other teachers as well as be observed and receive feedback about their teaching (Patton et al., 2005). Observations provide the novice teacher with an opportunity to actively learn about teaching practices when followed by discussions with their mentor to engage in reflection.

Lesson Study

Lesson study is a continuous method of collaborative professional development that promotes teacher learning by utilizing cycles of collaborative planning, implementing the lesson with observation, post-lesson debriefing and reflection, and revision (e.g., Huang et al., 2014; Huang & Shimizu, 2016; Kang, 2016; Lewis, 2016; Takahashi et al., 2013). "Through live research lessons, written reports, videos, and networking with colleagues, LS builds and spreads knowledge about teaching and learning, creating a system that learns" (Lewis & Hurd, 2011, p. 14). LS provides an environment where teachers can "try it out and see if it works" to identify what can be improved (Obara & Bikai, 2019, p. 139). By implementing the lesson in the context of the classroom, teachers learn about their teaching strategies from the observation of student outcomes (Huang et al., 2017). LS has been utilized for pre-service teacher preparation and in-service teacher professional development (Huang et al., 2018) and may be an effective process to link pre-service teacher preparation to practicing teachers' practice. Furthermore, induction programs should be a structured professional development program that focuses on professional learning and emphasizes collaboration (Wong, 2004; 2005); however, these programs are often disjointed and lack proper support and follow-up (Wong, 2005). Therefore, LS may be a viable approach to acclimate the novice teacher as it provides many components of effective induction programs, as summarized in Table 1.

Table 1

Comparison of Induction and Lesson Study

A comparison of characteristics of Induction and Lesson Study	
Induction	LS
Experienced Mentor in the same subject and grade level	Knowledgeable others
Collaboration with other teachers	Collaboration with other teachers
Support from Principal/administration	Support from Principal/administration
Observe mentor and/or veteran teachers	Observe teachers within LS
Be observed while teaching by a mentor or expert teachers	Be observed while teaching by LS group

Benefits of Lesson Study. Lesson study offers teachers beneficial aspects by developing MKT, teaching practices, collaborative communities, and disposition. These benefits will be explained further.

Mathematical Knowledge for Teaching (MKT). LS is content focused and can contribute to the development of PCK and MKT. Mathematical knowledge for teaching has been defined as “the mathematical knowledge needed to carry out the work of teaching mathematics” (Ball et al., 2008, p. 395). In fact, when teachers collaborate and discuss each other’s ideas, they are able to make connections and develop their knowledge for teaching (Murata et al., 2012). The structure of LS (research and plan lessons; observe the lesson; and post-lesson discussion) provide teachers opportunities to enhance their knowledge (Yoshida, 2012). Coenders and Verhoef (2019) worked with beginning and experienced science teachers to develop PCK through collaborative lesson planning. Collaborative planning provide the teachers with the opportunity to discuss their PCK, which contribute to the teachers' gained knowledge. Kang (2016) conducted a LS to deepen MKT. Through this study, the teachers were able to identify the importance of comparing two or more mathematical tasks to discuss the content and teaching. After such a discussion, the novice teachers were more skilled in selecting conceptually rich and pedagogically powerful tasks. The novice teachers were able to identify the importance of generating classroom discussions to expose student misconceptions, which also helped develop teacher anticipation of common errors.

Teaching Practice. LS incorporates key features of professional development and has been identified to change instructional practice (Rock & Wilson, 2005). Ni Shuilleabhain and Seery (2018) explored how LS can influence the change in teaching practices. Specifically, the teachers' pedagogical approaches changed to support students in communicating their mathematical thinking. The teachers became aware of the influence of group size and desk arrangements during group work and decided to include student presentations of mathematical work to encourage student communication. Rock and Wilson (2005) found that LS encouraged teachers to use differentiated instructional strategies. Pang (2016) described a study that focused on how teachers can effectively implement the *Five practices for orchestrating productive mathematical discussions* (Smith & Stein, 2011) through a course-based LS. The teachers were encouraged to use the five practices to focus on student thinking. Takahashi and colleagues (2013) observed six LS groups from across the US that attempted to develop teaching through problem solving (TTP) strategies as a way to incorporate Common Core State Standards in

Mathematics (CCSSM) (CCSSI, 2010). Takahashi and colleagues (2013) identified that through lesson study:

> Teachers can actually observe students during the research lessons and collect data on student thinking, can query the instructor about the rationale for various instructional decisions, and can discuss and debate elements of TTP with other educators who have seen the same lesson, but may have a different viewpoint, or may have observed a student with a distinctively different experience. (p. 244)

LS provided the teachers with an opportunity to discuss and observe CCSSM (CCSSI, 2010) with teachers that observed the same lesson and to gain an understanding of effective teaching practices. Takahashi and McDougal (2016) introduced a new form of LS called collaborative lesson research (CLR) to help with the improvement of mathematics teaching in the US. They identified six important features for CLR: (1) A clear research purpose; (2) *Kyouzai kenkyuu* (study of teaching materials)*;* (3) A written research proposal; (4) A live research lesson and discussion; (5) Knowledgeable others; and (6) Sharing of results. From the experience, teachers shared that their mathematics pedagogical knowledge improved. The authors believe that US schools should use CLR to best implement CCSSM (CCSSI, 2010). In addition to changing instructional practices of mathematics teachers, science teachers have learned to engage students in meaningful learning activities, which include selecting and designing activities (Coenders & Verhoef, 2019).

Collaborative Community. Teaching in the US is mainly done in isolation, which can be difficult for new teachers (Ingersoll & Strong, 2011). In fact:

> Reflection and analysis are often individual activities, but they can be greatly enhanced by teaming with an experienced and respected colleague, a new teacher, or a community of teachers. Collaborating with colleagues regularly to observe, analyze, and discuss teaching and students' thinking or to do "lesson study" is a powerful, yet neglected, form of professional development in American schools. (NCTM, 2000, p. 19)

Collaboration means working together to develop solutions when faced with challenges and encouraging high-quality teaching practice, professional learning, and student-centered learning. The culture of collaboration provides an environment consisting of a set of norms for school faculty to be committed to their own learning and of their peers, in addition to supporting student achievement (DuFour et al., 2006).

Community connotes individuals linked by a common interest. So, a collaborative community consists of like-minded individuals working together to improve students' learning. DuFour and colleagues (2006) have defined a PLC to be "composed of collaborative teams whose members work *interdependently* to achieve *common goals* linked to the purpose of learning for all" (p. 3). LS is a collaborative process in which the research lesson is analyzed and improved. Collaborative lesson planning helps teachers produce a well-structured lesson plan (Huang et al., 2017; Coenders & Verhoef, 2019). The PLC provides a "knowledge base which guides professional decision making and practices; methods for developing the knowledge base through research and practice and norms" (Chauraya & Brodie, 2017, p. 225). Having teachers work collaboratively can positively affect teachers' attitudes (Campbell & Lee, 2017). Through collaboration, teachers are able to utilize and learn from each other's ideas at each phase of the lesson study cycle (Takahashi, Lewis, & Perry, 2013).

It is through the communities of practice that the teachers collaborate to improve teaching. Communities of practice is a process of social learning that occurs when individuals with a common interest collaborate for an extended period to improve their craft (Lave & Wegner, 1991). Improvement is made within the group by asking questions, sharing information and resources, and discussing ideas. The teachers learn as they observe others, listen to each other, and share their ideas with each other in the group (Trust & Horrocks, 2019). A knowledgeable other can help guide the group with questions. Researchers have emphasized the importance of the knowledgeable other ensuring the success of LS (i.e., Takahashi, 2014; Takahashi & McDougal, 2016; Huang et al., 2017). Takahashi (2014) conducted a study to examine the role of a knowledgeable other; and identified their roles to include: (1) bringing new knowledge from research and curriculum; (2) showing the connection between theory and practice; and (3) helping others learn how to reflect on teaching and learning.

The group meetings are a time for the teachers to share ideas that will support student learning. To have a collaborative community, teachers should change their dialog from congenial conversations to collegial conversations (Nelson et al., 2010). Teachers may ask technical questions to their peers; such questions may pose "how often or at what point in a new unit this approach should be implemented" (Nelson et al., 2010, p. 176). Congenial conversations remain pleasant, and collegial conversations can lead to personal and emotional conflict. However, collegial conversations can encourage professional learning by investigating "teaching-learning connections and to identify and negotiate differences and similarities in beliefs about what constitutes good teaching and meaningful learning" (Nelson et al., 2010, p. 176). Perry and Lewis (2009) identified an increase in mathematical thinking through collaboration. The novice teachers developed their PCK and MKT knowledge through collaboration (Coenders & Verhoef, 2019; Kang, 2016). Furthermore, LS has been documented to sustain PLCs, improve teachers' knowledge and teaching, and improve students' learning (e.g., Huang & Shimizu, 2016; Lewis et al., 2009).

As teachers engage in collaborative professional learning, they can learn from each phase of the LS cycle (Takahashi et al., 2013). During the debriefing sessions, the teachers engage in reflective practices by discussing instructional elements that were observed (Obara & Bikai, 2019). The teacher may bring student work to the debriefing session to provide evidence of student thinking and learning. The artifacts provided assist in deciding if the mathematical goals were met. The next step will be making decisions on the improvement of the lesson. Through this process, the group of teachers improves their knowledge of teaching, learning, and students (Lewis et al., 2012). Kang (2016) found that LS is an effective professional development model to enhance MKT. The participants provided concrete examples from the research lesson to assist in bridging the gap between the knowledge of teaching and their practices. The teachers were expected to focus on specific evidence of student learning and relate it to the teaching practices.

Disposition. A productive disposition is one of the five strands of mathematical proficiency (NRC, 2001) and is defined as "habitual inclination to see mathematics as sensible, useful, and worthwhile, coupled with a belief in diligence and one's own efficacy" (p. 116). This strand is different from the others because it includes a person's identity and beliefs, and the other four strands focus on cognitive processes. Beliefs are core to a productive disposition. If a teacher does not have productive beliefs towards teaching or students' learning, then they cannot have a productive disposition. Developing a productive disposition requires opportunities to make sense of the mathematics, understand the benefits of perseverance, and experience the joys of mathematics sense-making. A productive disposition develops along with the other strands of mathematical proficiency and is needed for the development of the other four strands (NRC, 2001). Furthermore, the strengthening of the other four strands helps to build a productive disposition.

Productive dispositions in mathematics can be developed in all learners, and teachers can play an important role in its construction. Teaching for mathematical proficiency requires similar interrelated components. Specifically, the strand of productive disposition for teaching mathematics has been defined as "mathematics teachers' malleable orientation toward—and concomitant beliefs, attitudes, and emotions about—their own professional growth, the subject of mathematics, and its teaching and learning that influences their own and their students' successful mathematics learning" (Jacobson & Kilpatrick, 2015, p. 402). Jacobson and Izsák (2015) defined productive disposition to include "teachers' motivation, beliefs, and attitudes about mathematics as a subject, teaching and learning mathematics, and their own professional growth" (p. 468). These definitions illustrate that productive disposition for teaching mathematics is intertwined with teachers' knowledge and practice (Jacobson & Kilpatrick, 2015). Teachers' attitudes and beliefs can influence the decisions that can hinder or promote effective instructional practices (NCTM, 2014). NCTM (2014) outlined a set of productive and unproductive beliefs about the teaching and learning of mathematics (Table 2).

Table 2

Beliefs About Teaching and Learning Mathematics

Beliefs about teaching and learning mathematics	
Unproductive beliefs	Productive beliefs
Mathematics learning should focus on practicing procedures and memorizing basic number combinations	Mathematics learning should focus on developing understanding of concepts and procedures through problem solving, reasoning, and discourse.
Students need only to learn and use the same standard computational algorithms and the same prescribed methods to solve algebraic problems.	All students need to have a range of strategies and approaches from which to choose in solving problems, including, but not limited to, general methods, standard algorithms, and procedures.
Students can learn to apply mathematics only after the have mastered the basic skills.	Students can learn mathematics through exploring and solving contextual and mathematical problems.
The role of the teacher is to tell students exactly what definitions, formulas, and rules they should know and demonstrate how to use this information to solve mathematics problems.	The role of the teacher is to engage students in tasks that promote reasoning and problem solving and facilitate discourse that moves students toward shared understanding of mathematics.
The role of the student is to memorize information that is presented and then use it to solve routine problems on homework, quizzes, and tests.	The role of the student is to be actively involved in making sense of mathematics tasks by using varied strategies and representations, justifying solutions, making connections to prior knowledge or familiar contexts and experiences, and considering the reasoning of others.
An effective teacher makes the mathematics easy for students by guiding them step by step through problem solving to ensure that they are not frustrated or confused.	An effective teacher provides students with appropriate challenges, encourages perseverance in solving problems, and supports productive struggle in learning mathematics.

NCTM, 2014, p. 11

Through LS, teachers can change their dispositions about student learning (Lewis, 2016; Lewis et al., 2009; Huang et al., 2014; Huang & Shimizu, 2016). In a study by Katelawala, through collaborative planning, teachers created a joint lesson plan in which they were able to observe their students engage in valuable discussions that contributed to a shift in beliefs (Katelawala, 2012). Kang (2016) provided articles about MKT and PCK for novice teachers. The teachers then reflected on the readings and identified how the readings related to their practice, inspired and excited them. They expressed the desire to use their knowledge of MKT to maximize classroom interactions.

Challenges to Lesson Study. Lesson Study was introduced to the US through *The Teaching Gap* (Stigler and Hiebert, 1999) and gained interest with teachers and administrators around 2005 (Yoshida, 2012). Even though many schools and districts are conducting LS, there are challenges that need to be considered to properly implement LS. The challenges that will be discussed are time and the knowledge of LS.

Time. In order for the teachers to learn through LS, they need to devote time to the practice. From their study consisting of two lesson study teams, Coenders and Verhoef (2019) concluded that engaging in collaborative lesson planning meant that the way the teachers typically planned had to change. In his study of four elementary school teachers engaging in lesson study, Kotelawala (2012) observed that if teachers were absent from the collaborative meetings, the lesson study group felt they could not move forward. Also, having the time released from teaching to observe and debrief can be difficult (Kotelawala, 2012), and the use of video as a tool (Desimone & Garet, 2015;

Borko et al., 2008) may assist with observations and reflections. Videos can provide an alternative way to observe the lessons that are still situated in the classroom.

Knowledge of Lesson Study. Adapting LS to the US has been problematic. When the participants have limited knowledge and limited resources, then LS cannot be successful. In the US, there is a misunderstanding about LS (Yoshida, 2012; Lewis, 2016). By modifying the structure of LS, the purpose may be negated and cannot be considered LS. Yoshida (2012) shared that some educators collaborated on the design of a lesson plan but did not follow through with observations or debriefing sessions. To help teachers understand LS, Kang (2016) explains the importance of stating clear, specific guidelines for teachers new to LS.

Lesson Study and Novice Teacher. A literature search within the EBSCO database of research focusing on novice teacher learning and LS resulted in three articles. These three articles demonstrated beneficial aspects of LS for novice teachers, including the development of knowledge for teaching, teaching practices, collaborative communities, and disposition. Having only three articles to review, indicates the need for further research of novice teachers and LS. Specific details related to these three articles follow.

Coenders and Verhoef (2019) conducted a LS of beginning and experienced teachers, where the experienced teacher taught the first lesson, and the beginning teacher taught the revised lesson. The teachers in the study consisted of two lesson study groups within the Netherlands, chemistry and multidisciplinary. The researchers used EIMPG to interpret teacher growth. Specifically, the goal was to identify what the teachers were learning and to identify where their knowledge originated; examining the two phases contributed to the understanding of what contributed to teacher learning. The phases consist of the development phase and the class enactment phase. The development phase is where the teachers encounter unfamiliar pedagogies, discuss these in terms of student learning, and design a lesson plan. This is followed by the class enactment phase, where the designed lesson is enacted, and the students' results are discussed. The researchers found that going through the development phase followed by the class enactment phase was crucial to gaining new PCK knowledge and beliefs.

Kang (2016) utilized LS to foster collaboration among novice teachers to deepen MKT. The five novice mathematics teachers who participated in the LS were enrolled in a master's program in Georgia and ranged from one to three years of teaching experience. The five mathematics teachers deepened their knowledge through LS, especially in terms of tasks and anticipation of errors. The five novice teachers came to the study with a lack of formal conception of MKT. Novice mathematics teachers may lack the knowledge of what MKT entails; therefore, the teachers need exposure to relevant literature to review as they prepare for LS. The study showed that novice teachers could successfully participate in LS if they are provided with clear, specific guidelines.

Kotelawala (2012) conducted two lesson studies with students in a mathematics methods course who were in-service teachers teaching for two to four years. These teachers were also pursuing their masters and were in a mathematics methods course. They were split into two groups: the middle school group and the high school group. The teachers collaboratively planned a lesson that allowed the teachers to discuss a variety of teaching strategies. Critical observations from peers provided insight into the lesson. The researcher encouraged the teachers to practice reflection, evaluation, and revision during debriefing sessions to strengthen the lesson. This study identified three areas of development: collaborative planning, lessons from critical observations, and lesson revision. Collaborative planning provided an environment for the teachers to share and discuss similar teaching struggles. However, when groups do not teach in the same socioeconomic environment or when teachers were absent from the meetings, the teachers struggled with productive collaborative meetings. Many methods courses consider teacher questioning, prior student knowledge, and student discussions, but the LS allowed the teachers to see these topics in practice. The teachers acknowledged the importance of reflecting on the lesson, and they learned to make adjustments to improve the lesson.

Summary of Literature Review

Induction programs should support and retain novice teachers; arguably, the US does not have well-established and effective programs (Wong, 2005). Research suggests that induction programs should provide opportunities for the novice teacher to actively learn through collaboration, which can be done through observations followed by reflective discussions. It is reasonable to hypothesize that LS could be an effective component of an induction program because it is a form of teacher-oriented, student-centered, job-embedded collaborative professional development designed to improve teaching quality and develop teachers' instructional expertise (Lewis et al., 2009). It entails teachers being observed or observing their peers, followed by reflective discussions with more than just an individual mentor. Lesson study participants engage in active learning, encouraging them to actively engage in meaningful discussion, planning, and practice (Lewis, 2016; Lewis et al., 2009; Obara & Bikai, 2019). Active collaboration during LS benefits teachers by encouraging them to specify students' learning goals, devise a mathematical task, and design the lesson structure to maximize students' engagement (Pang, 2016). This active collaboration can be especially beneficial for novice teachers. Additionally, having multiple perspectives creates a collaborative community in which the teachers can reflect upon and collaborate about their teaching beliefs and strengthen their knowledge, which should, in turn, increase student learning. Because of the challenges inherent in conducting LS in the US, the knowledgeable other plays an essential role in helping LS be effective (Takahashi, 2013). This review of the literature only identified three studies that focused on novice teachers and LS, and thus there is a need to explore this relationship further.

Chapter Summary

This chapter included a review of the theoretical framework that supported this study to view the learning process. Through the situative perspective, learning is viewed as authentic participation in the discourse and practice within a community that is a process of active individual construction from within an interactive and social environment (Putnam & Borko, 2000; Cobb, 1994). This chapter also references literature examining professional development programs as teachers can learn through a variety of activities. Professional development programs are designed to provide teachers with the opportunity to increase their knowledge, improve teaching practices, and change their beliefs about student learning (Desimone, 2009). One form of professional development, geared specifically toward novice teachers, consists of induction programs, which are designed to provide novice teachers with the necessary support during their early years of teaching (Ingersoll & Strong, 2011; Wong, 2004). The Extended Interconnected Model of Professional Growth by Coenders and Terlouw (2015) was selected for this study to focus on the growth of the novice teacher because it describes individualized pathways for describing reflection and enactment. The following chapter will provide details of the methodology based on this literature review.

CHAPTER III: METHODOLOGY

Introduction

This chapter will begin with a description and justification of the research design. Then a description of the context for this study is outlined, including information about the state, district, school, and PLC. This is followed by a description of the participants of the study as well as a description of the instruments and procedures of the study, and finally, a description of how the data were analyzed to answer the research questions.

Nature of Study

As stated in Chapter 1, this study aims to address the following research questions related to lesson study as the key component for induction programs:

1. How does LS help a novice teacher develop a productive disposition about mathematics teaching and learning?
2. How does LS help a novice teacher develop cooperative relationships with other teachers?
3. How does LS help a novice teacher develop Mathematical Knowledge for Teaching (MKT)?
4. What are key factors supporting or hindering a novice teacher's learning through LS?

To address these questions, a qualitative study was utilized to explore how the novice teacher professionally grew through a lesson study cycle. A qualitative study produces a vast amount of detailed information about a case being studied (Patton, 2015). The specific form of qualitative research methodology used for this study was a case study

(Yin, 2018). A case study is defined as "an empirical study that investigates a contemporary phenomenon in depth and within its real-life context, especially when the boundaries between phenomenon and context are not clearly evident" (Yin, 2018, p. 52). This dissertation aligns with a case study design because the study examined key moments of the development of a novice teacher as she engaged in LS. A case study allows an in-depth description of teacher development within the context of the classroom. Furthermore, case studies have been used to study teacher professional growth (Coenders & Terlouw, 2015; Coenders & Verhoef, 2019). Qualitative data surrounding the case in the form of video and interviews were collected and transcribed to obtain an in-depth understanding of the learning experience throughout the LS cycle.

Context

Due to the contextual, collaborative nature of LS, the context of this study needs to be described. Situative perspective views teacher learning as arising through multiple settings, and therefore it is required to acknowledge the different contexts in which teachers participate (Putnam & Borko, 2000). The novice teacher in this study taught and collaborated within a particular context comprised of the state, district, school, and PLC.

State

The study took place in a southeastern state where the state ranked near the bottom of the mathematics subsection of the ACT in 2018. Only 28% of the students met the mathematics benchmark score, compared to 40% nationally (ACT, 2018).

District

The study was conducted within a suburban school district that has transitioned to an integrated math program. Integrated math includes combined elements of algebra I, algebra II, and geometry. Instead of having individual courses and standards for each course, students would go through three years of integrated math that would develop math skills over time. In 2017 (RCS, 2019), the district enrollment totaled more than 44,000 students. The demographics of the school district include 60.3% white students, 20.2% African American, 14.1% Hispanic, 4.9% Asian, and 0.3% Native American. 22.7% of students were economically disadvantaged, and 9.7% needed special education. The graduation rate was 95.3%.

School

The study took place at a high school. In 2017, the school enrolled approximately 1900 students in grades nine through twelve, 50.1% white, 18.2% African American, 24.1% Hispanic, 7.3% Asian, and 0.1% Native American. Also, 31.6% of students were economically disadvantaged, and 9.1% were students with disabilities. The graduation rate was 96%.

Professional Learning Community (PLC)

Teachers in this district are required to participate in a PLC. A PLC is a group of educators who work collaboratively in an ongoing collective inquiry process to ensure that all students learn essential knowledge and skills (DuFour et al., 2006). The participants in this study formed the PLC. This PLC consisted of five teachers from the same school who taught the same content and met weekly during their common planning period. They had been collaborating for two and a half months before the start of the study. When teachers are in the same school, teaching the same content in the same grade level, they are able to discuss the concepts and skills from their experiences, share materials, and sustain changes over time (Garet et al., 2001). The PLC had not previously participated in LS and served as the LS group for this study.

Knowledgeable Other

Dr. Lasky, the district's mathematics specialist for grades nine to twelve, whose dissertation was about implementing mathematics teaching practices through LS, served as the knowledgeable other for this LS. Dr. Lasky is a former high school mathematics teacher who has worked with many LS projects. He was also facilitating several LS projects within the district during the period of conducting this study. For this study, he brought his knowledge and expertise in mathematics teaching and conducting LS through facilitating the LS.

Participants

This case study focused on a first-year high school mathematics teacher. The novice teacher was assigned to a PLC, which served as the LS group. Because many induction programs have mentors, the novice's mentor was an active participant in the PLC.

Novice Teacher

Kelly has a bachelor's degree in Biology with a microbiology concentration and a minor in public health. She was an associate scientist in the department of metabolics at Bayer Pharmaceuticals for five years, where she was responsible for analyzing data with respect to drug efficacy. During that time, she earned her master's in biology. Kelly left the company to be a stay-at-home mother and worked for the school system as a mathematics and science tutor for two years before moving to a new district and working as an educational assistant. After one year of working as an educational assistant, she decided to work towards becoming a mathematics teacher. Kelly studied for the Praxis exam and passed in December 2018. The following semester she started the alternative route towards earning her practitioner license and enrolled in two classes at the local university while she was the teacher on record. The enrolled courses were (1) Planning and Assessment and (2) Problem-based Instructional Methods. Kelly had not read literature regarding the mathematical teaching practices (NCTM, 2014) before the study. Kelly taught for two and a half months prior to the beginning of this study. She was assigned to teach Integrated Math I and was assigned the role of the PLC lead. The PLC meetings were held in her classroom.

PLC Group

Because Kelly has been assigned to teach Integrated Math I, her PLC served as the LS group for this study. The PLC consisted of five teachers who were teaching Integrated Math I during this study. These teachers included Kelly, Jessie, Lisa, Linda, and Brian. Jessie has a master's degree in education with a specialty in mathematics and has been teaching for seven years. Lisa has a bachelor's degree in mathematics and a master's degree in education. Lisa has been teaching for eleven years. Lisa was Kelly's mentor. Linda has a bachelor's degree in mathematics education and has been teaching for twelve years. This was Linda's first year at this high school. Brian has his bachelor's degree in management and human relations and has been teaching for two years. These teachers had the same planning period to conduct their meetings. The PLC meetings occurred during the teachers' common planning period in Kelly's classroom.

Sources of Data

Multiple data sources were collected throughout the LS cycle to best understand the experiences of the novice teacher. To form a detailed account of the novice teacher, classroom observations and semi-structured interviews were conducted. In addition, the researcher collected research lesson plans, relevant student work, video of research lessons and debriefing sessions, written comments from the observation protocols from the participating teachers in the PLC, reflective journals from the novice teacher, and researcher's field notes. The multiple sources of data were collected to corroborate evidence and to achieve triangulation (Patton, 2015). The application of triangulation enhances the validity and reliability of the results. Further elaboration and details of the sources of data will be described in the next section. In addition, Table 3 summarizes how the data sources relate to the research questions. This is followed by the role of the researcher in this study.

Data Sources

Belief instrument. The teacher's belief survey (Appendix D) that was adapted from *Principles to Actions: Ensuring Mathematical Success for All* (NCTM, 2014) was administered before and after LS to gauge the changes in the novice teacher's views about teaching and learning mathematics. The novice teacher rated her agreement with the different beliefs about the teaching and learning of mathematics. This survey was used in preparation for the interview. The interview was designed to further elicit the novice teacher's explanation of her choices on the survey.

Observation protocol. The observation protocol (McGatha et al., 2018) (Appendix A) was a means to identify teacher actions in relation to the teaching practices. The teachers used the observation protocol to guide their written comments (Appendix B) about the observed lessons. The comments served as indications for the researcher to understand the teachers' thoughts that were not made during the debriefing sessions.

Lesson plans. The groups' lesson plans used the TTLP planning template (Appendix E) for the research lessons. Throughout the LS process, they were collected to analyze the changes and how the cycle influenced the changes. The lesson plan provided a written account of the groups' views of the Mathematical Teaching Practices (NCTM, 2014).

Student work. Any necessary student materials (artifacts, worked task, exit ticket) were collected during the LS process. This allowed teachers to discuss student understanding and to identify if the goals of the lesson were achieved.

Videos. Videos of the research lessons and debriefing sessions were recorded to allow the researcher to add field notes after the lessons and sessions. The first and third videos of the research lessons were the lessons the researcher utilized, as these were the lessons the novice teacher implemented. The videos were used to document specific statements. The LS participants used the recorded lessons to observe the lesson. They watched the recorded research lessons with the observation protocol.

Journals. Throughout the LS process, the novice teacher completed journal entries (Appendix F). These entries focused on the development of mathematical knowledge for teaching and views of teaching and learning.

Interviews. Semi-structured interviews were conducted with the novice teacher before (Appendix G), during (Appendix H), and after (Appendix I) the LS. The interviews focused on the views of teaching and learning, mathematical knowledge for teaching (Ball et al., 2008), the function of the PLC, and the usefulness of LS. A semi-structured interview allowed the researcher to ask clarifying questions as needed to gain a better understanding of the novice teacher's views.

The multiple data sources described are presented in Table 3 in relation to the research questions.

Table 3

Research Questions in Relation to Data Sources

Research Question	Data Source
1. How does LS help a novice teacher develop a productive disposition about mathematics teaching and learning?	Belief instrument Classroom Observations Planning Sessions Debriefing Sessions Interview Self-reflection
2. How does LS help a novice teacher develop mathematical knowledge for teaching?	Classroom Observations Planning Sessions Debriefing Sessions Lesson Plans Interview Self-reflection
3. How does LS help a novice teacher develop cooperative relationships with other teachers?	Planning Sessions Debriefing Sessions Interview Self-reflection
4. What are key factors supporting or hindering a novice teacher's learning through LS?	Planning Sessions Debriefing Sessions Lesson Plans Interview Self-reflection

Role of the Researcher

The researcher was a key instrument in this study because the researcher collected data by examining documents, observations, and interviews (Creswell, 2007). The researcher has ten years of high school teaching experience. In addition, the researcher participated in a LS before joining the PhD. program and collaborated on a research article based on that LS when starting the program. These experiences have contributed to the preparation to serve as an instrument for this study.

Procedure Followed for this Study

The procedure of this study will be described in the following sections and will provide detailed descriptions of the data collection process. A research timeline (Table 4) is included to clarify when each event occurred during the study. Prior to data collection, the researcher received approval from the Institutional Review Board to conduct this study. Permission to conduct this study was also obtained from the school district and the school principal.

Table 4

Research Timeline

Dates	Phase	Activities
October 21- October 23	Before Lesson Study	Pre-Observation Self-Reflection 1 Pre-Interview
October 23- October 29	Reading	Read: *Taking Action: Implementing Effective Mathematics Teaching Practices in Grades 9-12* (2017) Chapters 1 and 10 Self-Reflection
October 29 October 31 November 7 November 14	Planning Meetings	Self-Reflection Discussion of MTPs, goals, content Created lesson
November 18 November 20	Research Lesson 1	Research Lesson 1 Debrief Session Self-Reflection
November 25 December 3	Research Lesson 2	Research Lesson 2 Debrief Session Self-Reflection
December 5 December 11	Research Lesson 3	Research Lesson 3 Debrief Session Self-Reflection
December 12- December 18	After Lesson Study	Post-Observation Self-Reflection Post-Interview

Before Lesson Study

Before the lesson study cycle was initiated, the researcher gathered data to better understand the beliefs and practices of the novice teacher and the relationships of the novice teacher with others. To accomplish this goal, the novice teacher completed the belief instrument (Appendix D) prior to the interview. The researcher observed the novice teacher within her classroom, utilizing the Observation Protocol (Appendix A). Following the observation, the novice teacher completed the self-reflection journal 1 (Appendix F), expressing her views and beliefs of teaching and learning. A PLC meeting was observed to understand the norms of the meetings and to observe the roles of the members. In addition, the novice teacher reflected on her part and participation in the PLC meeting. The researcher then conducted a semi-structured interview (Appendix G) with the novice teacher reflecting on the belief instrument and the observed lesson.

Reading. After the observations and interview, the novice teacher and her PLC read *Taking Action: Implementing Effective Mathematics Teaching Practices in Grades 9-12* (Boston et al., 2017), which provides detailed accounts of the Mathematical Teaching Practices in a high school setting. The teachers did not read the entire book but focused on chapters one and ten to introduce the mathematical teaching practices. Following the reading, the teachers discussed contents within the book, and the novice teacher reflected on her views and beliefs of the teaching practices by completing journal 2 (Appendix F). Kelly provided copies of the notes she made of her reflections on the reading to the researcher.

Lesson Study

During the months of October through December, the participants participated in lesson study which consisted of four stages: planning, teaching and debriefing, re-teaching, and the final reflection. These stages constitute one lesson study cycle; each teaching of the research lesson was an iteration within the lesson study cycle. The participants planned the lessons and debriefed about the lessons during their common planning period. All research lessons had the same goal: to promote productive struggle through the implementation of mathematically rich cognitively demanding tasks. The students were expected to solve systems of linear equations as they reasoned through an assigned task. Even though the final lesson contained a different task than the prior lessons, it was reasonable to identify teacher growth because the mathematical goals were still the same in each research lesson. As Lewis and Hurd (2011) explain, "Lesson study is not primarily about producing a lesson. It is about developing the knowledge, dispositions, relationships, and windows into each other's classrooms that we need to improve instruction and to make our schools places where we will all continue to learn" (p. 14). The lesson study group consisted of the PLC members and Dr. Lasky. Each stage of the lesson study was video recorded and will be described in the following sections.

Planning. During the planning phase, the participants met four times to prepare their lesson, due to having limited time to collaborate during their common planning period. Each meeting was recorded and consisted of three guided meetings and one unguided meeting. The participants met to establish the group norms, discuss the Mathematical Teaching Practices, select a teaching goal, and to select a content goal.

At the start of the first meeting, the group established their norms. Dr. Lasky provided suggestions to assist in the understanding and purpose of lesson study by explaining what it is to the group:

> Lesson study is a cycle, and it is starting with planning. So, we've planned a lesson, and then one person will teach it while the others observe in some

> capacity, and then afterward, we reflect upon that lesson. So, we talk about the strengths and weaknesses, and recommendations for improvement of the lesson. Now all of that is focused on the lesson; it's not focused on the teacher. Okay, that is key; we will not talk about the teacher. We'll talk about the lesson: how can we structure the lesson in a different way; what other questions can we ask them; or how can we rework the task a little bit; or whatever it may be. It's about the lesson, and then we'll revise that lesson based on those recommendations. (Planning Meeting 1, 10/29/19)

The PLC developed a research theme guided by the following two questions (Lewis & Hurd, 2011):

1. What qualities will students have when they finish the school year?
2. What are the qualities of our students now?

After reflecting on these questions, Kelly shared the following:

> One of the biggest things in trying to get kids to make connections is fear. They don't want to be wrong. They don't know if they're even on the right track, and they don't want to look stupid in front of their friends. And then it's just everybody's afraid, so either no one says anything, or everybody's yelling random things. So, I don't know how to build their confidence in a way so that they're not afraid to take chances and to really think about something. (Planning Meeting 1, 10/29/19).

Kelly shared that she wants her students to take risks to gain understanding. She further shared that she struggles in providing students with opportunities to engage in productive struggle because of offering assistance too soon. From these statements, the group decided that they should focus on implementing tasks that promote reasoning and problem solving as well as creating opportunities for productive struggle; this resulted in the research theme of developing problem solvers who persevere when faced with challenges.

Then the PLC decided on a topic by considering the following questions (Lewis & Hurd, 2011):

1. What topics are difficult for students to learn?
2. What topics do teachers find difficult to teach?
3. What standard would you like to understand better?

The group chose systems of linear equations. Once they agreed on the topic, the teachers discussed what task to use for the research lesson. The teachers worked together to create a detailed lesson plan utilizing the Thinking Through a Lesson Protocol (TTLP) (Smith et al., 2008) (Appendix E) to assist the teacher to effectively use the mathematics teaching practices (NCTM, 2014). The lesson plan was emailed to everyone. The TTLP is divided into three sections: part 1: selecting and setting up a mathematical task; part 2: supporting students' exploration of the task; part 3: sharing and discussing the task. The lesson plan starts by identifying clear and specific learning goals as well as identifying expectations of how the students will work through the task. Part 2 focuses on monitoring students as they work through the task by identifying questions to pose to the students that will move them to the mathematical goal. Part 3 identifies how to orchestrate the class discussion to highlight the mathematical goals of the lesson.

Teaching. Kelly, the novice teacher, taught the first research lesson to demonstrate her interpretation of the designed lesson. The lesson was recorded for the PLC group to observe with the Observation Protocol (Appendix A) and provided written comments of the lesson (Appendix B) after school to prevent loss of instructional time. The written comments helped the teachers prepare for the debriefing sessions. Student materials were collected following the lessons, which included their work, solutions, and exit tickets.

Debriefing. The group met during their planning period to discuss and analyze the lesson. The teacher who taught the lesson provided self-reflective comments about the lesson and her teaching, followed by other group members. The teachers were encouraged to address what occurred during the lesson (e.g., what worked, what did not work, what could be changed, etc.) and started by discussing what they liked about the lesson. The teachers were asked to provide critical feedback with concrete evidence to support their statements. The debriefing session ended with general comments from Dr. Lasky. The novice teacher reflected on what she learned from watching, debriefing, and revising Research Lesson 1 by completing journal 3 (Appendix F).

Re-teaching and debriefing. Jessie, a member of the PLC, taught the second iteration of the research lesson. This lesson was recorded for the PLC group to observe with the Observation Protocol (Appendix A) and provided comments of the lesson (Appendix B) after school to prevent loss of instructional time. The group discussed the second teaching and proposed possible improvements. The same process of debriefing, self-reflecting (Appendix F), and making revisions was repeated for a third lesson that Kelly taught.

Debriefing and Final reflection. At the end of the final debriefing session, the teachers discussed the outcome of the lesson study by considering the following questions (Lewis & Hurd, 2011):

1. What was learned about the subject matter and about the curriculum?
2. What was learned about student thinking and about teaching?
3. What insights were gained from the lesson study about the productive habits in learning practices as teachers?
4. What have you learned, and how do these ideas apply to your classroom work?
5. What changes have occurred during your PLCs?
6. Would you participate in lesson study again? Why?

Lesson study assists in linking the current qualities to the ideal qualities of the students (Lewis & Hurd, 2011). As teachers learn about the curriculum and the students, they are able to build their knowledge about teaching. These questions encouraged the teachers to reflect on the lesson study cycle and to think about their next steps. The final debriefing session closed with Dr. Lasky asking the group of teachers to "think about one to three things that we've taken away from this process. One thing that we are either going to implement or think about as we reflect upon our own lessons every day" (Debriefing Session 3, 12/11/19). The novice teacher reflected on the lesson and comments of the teachers, and the collaboration of finalizing the lesson plan when completing journal 4 (Appendix F).

After Lesson Study

The researcher observed the novice teacher with the Observation Protocol (Appendix A) after the completion of lesson study to investigate whether lesson study had impacted the enactment of the Mathematics Teaching Practices (NCTM, 2014). That was followed by a semi-structured interview to understand the novice teacher's development through lesson study (Appendix I). The novice teacher reflected on her final lesson by completing journal 5 (Appendix F) and completing the belief instrument (Appendix D).

Data Collection

The four planning meetings and three debriefing sessions occurred during the teachers' collaborative planning period for thirty to forty-five minutes. The three research lessons were 50 minutes and were video recorded to accommodate everyone's schedule. The videos were discussed during the teachers' planning period. The planning meetings, debriefing sessions, research lessons, and interviews were video recorded using a Swivl. A Swivl robot holds an iPad to video record and rotates to track the teacher. One Swivl and one iPad were used for recordings with three markers. The three markers for the Swivl were placed with the novice teacher, the knowledgeable other, and the middle of the PLC group during the planning meetings and debriefing sessions. During lessons, the markers were clipped to the teacher, placed with one student group, and placed where presentations would occur. The markers for the Swivl are sources of audio collection. The researcher was present during the meetings and lessons to observe and write notes. The novice teacher emailed her reflective journals to the researcher. The interviews occurred after school for a duration of thirty minutes and were video recorded. All videos were transcribed verbatim. In addition to the videos, the researcher collected student work at the end of the lessons.

Data Analysis

The case of the novice teacher, Kelly, was described in terms of her professional growth in disposition, MKT, and cooperative relationships throughout the LS process. The primary data sources include the first and third videos of the research lessons, as these were the lessons the novice teacher implemented, videos of the debriefing sessions, interviews, and reflection responses. The data sources in relation to the research questions are displayed in Table 3. To address the research questions, the researcher generated corresponding interview and reflection questions, as shown in Table 5.

Table 5

Research Questions in Relation to Interview and Reflection Questions

Research Question	Interview or Reflection Question
1. How does LS help a novice teacher develop a productive disposition about mathematics teaching and learning?	R1-R4, R9, R10-R12, R15-R17, R20-R22, B4-B6, D1, A3, A6-A8, A10
2. How does LS help a novice teacher develop cooperative relationships with other teachers?	R5-R8, R14, R19, R24, B11-B13, A1, A7, A11
3. How does LS help a novice teacher develop mathematical knowledge for teaching?	R13, R18, R23, B1-B3, B5-B10, D1-D4, A2-A4, A7-A9
4. What are key factors supporting or hindering a novice teacher's learning through LS?	R14, R19, R24, D5, A5, A11

Note. R = Reflection, B = Before Lesson Study Interview, D = During Lesson Study Interview, A = After Lesson Study Interview.

The data was transcribed, then organized and analyzed in chronological order. This allowed the researcher to compare the data from each phase and iteration of LS to identify changes of the novice teacher. The researcher annotated the data prior to the coding process to assist in making sense of the data, and then read through the data again and made notes based on each research question. Classroom observations of the first and final lessons provided evidence of enacted knowledge of teaching, which were then used along with the novice teacher's responses to the interview questions to identify changes in teaching practice. Statements the novice teacher made throughout the study were used to support the claims made of the changes.

Qualitative software was used to assist with the organization and coding of the data. The researcher used the annotations as a guide in the coding process and reflected on the definitions during this process. Codes were developed based on the definitions the researcher used for cooperative relationships, productive disposition, and the six domains of MKT. Coding began by using the domains within MKT (Common Content Knowledge, Horizon Content Knowledge, Knowledge of Content and Curriculum, Knowledge of Content and Students, Knowledge of Content and Teaching, Specialized Content Knowledge). Codes for cooperative relationships were collegial and congenial conversations. Codes for productive disposition were productive and unproductive beliefs. Further explanations can be seen in the following sections. Ethical issues and issues of trustworthiness were addressed throughout the study and will be discussed.

Mathematical Knowledge for Teaching

Mathematical Knowledge for Teaching (MKT) (Ball et al., 2008) is considered more than just being able to identify whether an answer is right or wrong. Teachers need an understanding of the mathematics to be able to analyze the students' work. Furthermore, teachers' knowledge was utilized in the development of the lesson because they needed to consider an appropriate task, anticipate student work, and make decisions on how to sequence the student outcomes. The Mathematical Knowledge for Teaching (Ball et al., 2008) domains were used to categorize (Figure 6) the data. The researcher went through the different transcriptions and identified relevant statements that reflected each domain of MKT, as seen in Table 6. This allowed the researcher to identify changes within the different domains of MKT. The researcher made notes while reading through the data, as seen in the following example when Kelly was describing what a teacher should do during a lesson, "During a lesson, teachers should be engaging their students; so, keeping their interest and sparking their interest" (Kelly, Interview 1, 10/21/19). The researcher made a note that this described predicting what examples students find interesting; this was coded as: Knowledge of Content and Students (KCS). During this interview, Kelly also stated that "They (the teachers) should be moving around the room; they should be formatively assessing as they go." The researcher described this as teacher monitoring. Both examples are descriptions of Pedagogical Content Knowledge. Once the data was annotated, the researcher went through the data and coded according to these codes, as seen in Table 7.

Table 6

Categories of MKT

Subject Matter Knowledge	Pedagogical Content Knowledge
Common Content Knowledge • Use of mathematical terms, Ability to complete student work Specialized Content Knowledge • Examine/understand unusual solution methods to problems • Recognize what is involved in using a particular representation Horizon Content Knowledge • Understand how mathematical ideas are connected in curriculum	Knowledge of Content and Students • Anticipate • Facilitate students • Scaffold Knowledge of Content and Teaching • Sequencing of instruction/examples/student work • Use of student's remark to make mathematical point • Pause class to redirect Knowledge of Content and Curriculum • Knowledge of instructional material • Vertical knowledge

Table 7

Examples of MKT Codes

Code	Example
Common Content Knowledge (Use of mathematical terms)	“That’s a function family.” (Kelly, Research Lesson 1, 11/18/19)
Specialized Content Knowledge (Examine/understand unusual solution methods to problems)	“A lot of kids are used to using ‘x’ and ‘y,’ so if you say to solve for ‘y,’ but they use ‘s’ and ‘c,’ will they wonder which one is the ‘y’?” (Linda, Planning Meeting 4, 11/14/19)
Horizon Content Knowledge (Understand how mathematical ideas are connected in curriculum)	“Connections that can be made, especially in integrated one, is tying slope to congruent triangles” (Dr. Lasky, Planning Meeting 1, 10/29/19)
Knowledge of Content and Students (Anticipate)	“I never thought about what the students were going to think, I just thought about the end goal. I never thought about what roadblocks they would hit along the way; what things didn’t make sense. I also never thought that they could solve some of these things a little differently than I would think about. I never took that into consideration when I was planning a lesson and not it’s helpful; it makes sense.” (Kelly, Final Interview, 12/18/19)
Knowledge of Content and Teaching (Use of student’s remark to make mathematical point)	“Did you hear what he said? He said you have to make an equation.” (Kelly, Research Lesson 1, 11/18/19)
Knowledge of Content and Curriculum (Knowledge of instructional material)	“I found a bunch of tasks that came from the curriculum guide; I’ll pass them out so you can read them.” (Kelly, Planning Meeting 3, 11/7/19)

The researcher compared the codes of each phase of LS to help build the case. After coding was completed, the researcher narrowed the codes based on frequency and focused the growth of the novice teacher on Knowledge of Content and Students and Knowledge of Content and Teaching. After comparing the different phases of the study, the main differences were identified. The differences focused on the two domains: Knowledge of Content and Students and Knowledge of Content and Teaching.

Disposition

The researcher used the following definition of disposition: “teachers’ motivation, beliefs, and attitudes about mathematics as a subject, teaching and learning mathematics, and their own professional growth” (Jacobson & Izsák, 2015, p. 468). From this definition, the researcher chose to focus on the teacher’s beliefs and attitudes when analyzing disposition because they are the characteristics that portray effective teaching practices, which create the conditions for student academic improvement. The researcher coded the data as productive and unproductive beliefs. The researcher started the process by analyzing the initial journal entry and compared the results of the teaching and learning beliefs survey. Once a comparison was made, the researcher used the initial interview for clarification and to corroborate the initial findings of the novice teacher’s beliefs. Many of the initial statements started with the stem: “I don’t think;” or “I don’t know;” or “I didn’t;” or “I struggle.” These doubtful statements were identified as unproductive beliefs because, as explained in Chapter 2, uncertainty can hinder implementing effective teaching practices. The researcher would go back to watch the video recordings to identify the context in which these statements were made. The following example identifies Kelly making a reflective statement: “I struggle with letting them (the students) struggle” (Planning Meeting 1). This statement was annotated as a reflective statement in which Kelly acknowledged a weakness; therefore, the statement was coded as a productive belief. The researcher went through the data and coded it according to productive or unproductive, as seen in Table 8.

Table 8

Examples of Disposition Codes

Code	Example
Productive	I struggle with letting them struggle, (Kelly, Planning Meeting 1, 10/29/19)
Unproductive	I’m highly overwhelmed, I don’t know…I don’t know how to move forward. (Kelly, Planning Meeting 2, 10/31/19)
Unproductive	I felt like that other task, I couldn’t solve it very easily, so I thought the kids were going to struggle with it. (Kelly, Planning Meeting 4, 11/14/19)

In addition to doubtful statements, statements also correlated with the beliefs about teaching and learning mathematics (Table 2), such as the following statement: “I don’t think it’ll (focus on letting students discover) work if they don’t have the skill,” relates to an unproductive belief found in the table. An example of productive struggle was identified from the final interview with the novice teacher in which she was supportive of productive struggle in learning mathematics: “they need to struggle in order to really cement these ideas so that they can keep them with them” (Kelly, 12/18/19). The final interview also discussed results from the teaching and learning beliefs survey. The novice teacher took the survey at the close of the LS, and it was used to discuss her beliefs at the close of the study. The researcher also analyzed the planning and debriefing meetings for statements that hinder or support effective teaching practices.

Cooperative Relationships

The researcher analyzed videos of the debriefing sessions and listed occurrences of the different types of conversations: congenial and collegial. The types of conversations were defined in Chapter II, where congenial conversations remain pleasant and collegial conversations can encourage professional learning. The PLC conversations that consisted of polite sharing of teaching strategies were classified as congenial talk, as seen in the following dialog:

> Dr. Lasky: So, do you have any ideas for tasks yet?
>
> Kelly: Brian had a good one.
>
> Brian: So last year, when I did this, the very last thing I did was a task, and I brought in stuffed animals and put them in groups. So, they (the students) had to create a company that created that stuffed animal. They had to create a system that would allow them to identify what would be the best for production. They had to create a name for their company, create a name for their toy, how much they wanted to sell it for and how much it would cost, and they had to graph it out on a big poster board then present it to the class…it was cool. (Planning Meeting 2, 10/31/19)

Technical questions have been defined as a type of question that is classified under congenial talk. When Dr. Lasky stated, "I'm trying to understand, so, you got one graph of cost of selling?" (Planning Meeting 2, 10/31/19), he was asking for clarification about the task. However, critical questions that ask about the effectiveness of the task or teaching strategy were classified as collegial talk, as seen in the following dialog:

> Lisa: That second guess and check (during the presentations) was doing something weird.
>
> Kelly: Yeah, I think they lucked into that (their answer).
>
> Dr. Lasky: Yeah, I don't know what they were doing. So, one thing that might have worked is to have the class help them (the presenting group) finish.
>
> (Debriefing Session 3, 12/11/19)

Collegial conversations focus on the idea that the teachers work towards improving their instructional practices and student learning.

Focusing the Novice Teacher's Growth Through the Use of EIMPG

Coenders and Terlouw's (2015) Extended Interconnected Model of Teacher Professional Growth (EIMPG) provided the framework for data analysis. The model (Figure 8) was used to visualize the novice teacher's professional growth throughout the study. The researcher used codes that were related to mathematical knowledge for teaching (Ball et al., 2008), disposition, and cooperative relationships in order to identify changes during LS. Identifying themes through coding allowed the researcher to identify professional growth in terms of the Extended Interconnected Model of Teacher Professional Growth (Coenders & Terlouw, 2015). This model provided the researcher with the means to identify changes during the *development phase* (Figure 4), which included developing the research lessons or during the *class enactment phase* (Figure 5), which was the teaching of the research lesson. In the development phase, the teachers discussed materials and pedagogies that may affect student learning to create a detailed lesson plan. Class enactment of the detailed lesson plan provided an opportunity to observe students and reflect on the lesson. The data was gathered during the different phases and examined for teacher change. The researcher identified changes made to the research lessons by examining the data sources (Table 3) and comparing them to each cycle of LS. The researcher used the comparisons to identify key factors or moments that may have impacted the development of the novice teacher and form conclusions about the novice teacher's personal domain. This provided the researcher with the opportunity to study growth patterns that led to the change of the novice teacher.

The Extended Interconnected Growth Model (Coenders & Terlouw, 2015) allowed the researcher to identify growth patterns that were individualized for the different types of change. Teacher growth occurs from the process of enactment and reflection. The adapted model used to describe teacher changes in this study can be seen in Figure 8. The external domain in this study consisted of information from *Taking Action: Implementing Effective Mathematics Teaching Practices in Grades 9-12* (Boston et al., 2017), information from the knowledgeable other, and the discussion of different pedagogies and materials from the LS group. The developed materials domain consisted of the detailed lesson plan developed through collaborative planning. The domain of practice included the implementation and observation of the research lessons. The domain of consequence consisted of the salient outcomes related to student understanding (i.e., problem solving or mathematical goals). Finally, the personal domain consisted of the novice teacher's disposition and MKT.

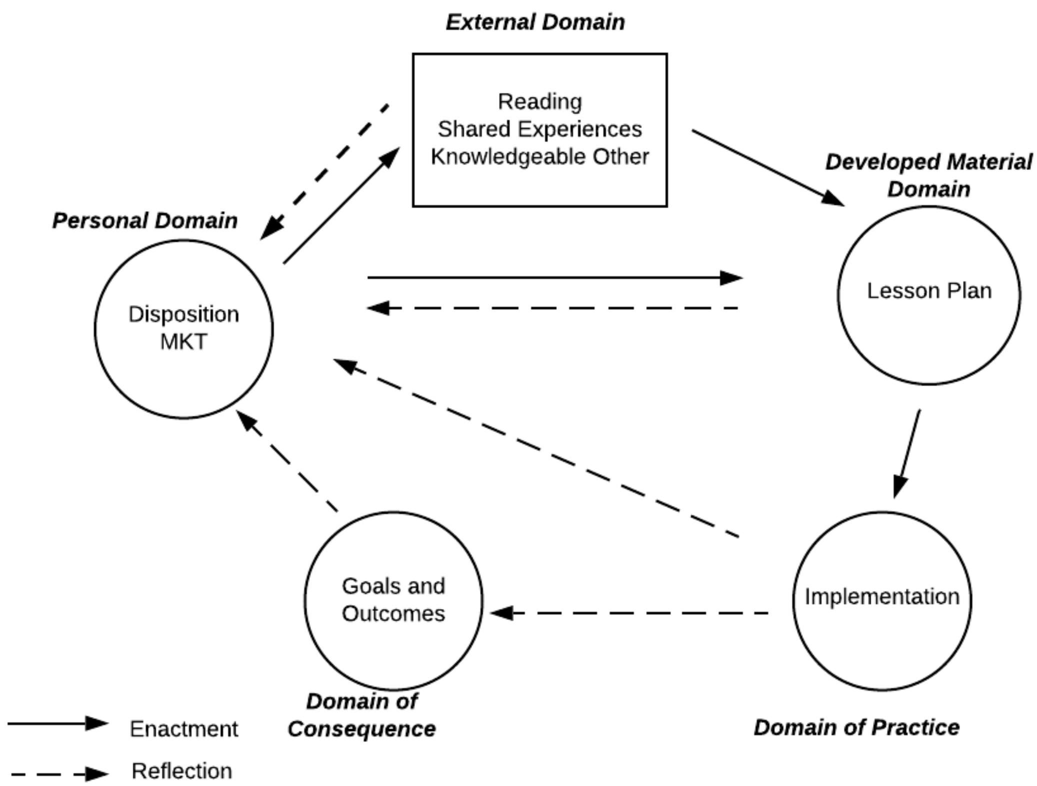


Figure 8. Adapted Extended Interconnected Model of Teacher Professional Growth (Coenders & Terlouw, 2015)

Qualitative Software

Qualitative data analysis software (Patton, 2015) assisted with the analysis of the data. Transcriptions of the research lessons, debriefing sessions, interviews, and self-reflections were organized with the use of NVivo. The researcher manually coded data according to the time in which the events occurred. NVivo allowed the researcher to easily annotate and create memos throughout the data. By coding within NVivo, the researcher could see each piece of evidence within its context and make sense of the data within its context as NVivo was helpful to sort through the data.

Ethical Considerations

Qualitative studies can encounter ethical issues during data collection and analysis; therefore, precautions must be established to protect the participants (Patton, 2015; Creswell, 2007). This study was presented to the Instructional Review Board (IRB) for approval and acquired informed consent from the participants (Yin, 2018). The researcher used pseudonyms for the protection of the participants.

Trustworthiness

For qualitative data to be considered trustworthy, the researcher must consider the credibility, dependability, and transferability of the study. Credibility refers to the researcher accurately representing the participants. To establish credibility, the researcher collected multiple forms of data to corroborate the evidence. Because the human being is the instrument of data collection, this requires the researcher to reflect on the potential bias (Bloomberg & Volpe, 2016). In this study, the researcher is a teacher in the same district and the same school. However, the researcher has not been part of the Integrated Math I PLC.

Dependability refers to whether one can track the processes and procedures used to collect and interpret data (Bloomberg & Volpe, 2016). To accomplish this, the researcher provided a detailed and thorough explanation of how the data was collected and analyzed. The researcher met with Kelly regularly to verify that she was being accurately represented. Finally, transferability refers to the fit or match between the research context and other contexts (Bloomberg & Volpe, 2016). The researcher provided detailed descriptions of the participants and the context of the study.

Limitations

There are limiting factors when conducting qualitative studies determined by the researcher's sensitivity and integrity. Because the analysis of qualitative research is determined by the researcher’s perspective, the case study is subjective. To overcome this limiting factor, the researcher consulted with the doctoral supervisor. Research must generalize from the case study, not from the case (Yin, 2018). During the course of the study, careful attention was given to the explanations with a variety of data sources to corroborate any claim that was made.

Delimitations

Limitations relating to objectives, time, location, and sample are not in the control of the researcher and are considered the delimitations of the study. A high school was chosen for this study and may not be generalizable to other schools. In addition, there are a variety of classifications of novice teachers. Teachers are considered novices during their first three years of teaching. This study worked with a first-year teacher. In addition, teachers can come to the profession directly from a teaching degree or choose to change careers. The results provide insight into the understanding of LS as a component of an induction program; however, these decisions may affect the transferability to other settings.

Chapter Summary

This chapter described the methodology used for this study. A case study was used to explore a novice teacher's acclimation process over a three-month period. Lesson study was used within the acclimation process to facilitate her growth and development in the teaching profession. The researcher provided detailed and thorough descriptions of the case and the associated participants. The research context, data sources, procedures, and data analysis were also described. The design of the lesson study consisted of three iterations, of which the novice teacher taught the first and third research lessons; a member of the PLC taught the second research lesson. The researcher collected data from various sources to examine the development in the understanding of mathematical knowledge for teaching (Ball et al., 2008), disposition, and participation in the PLC. Having thick case descriptions helped support the credibility, dependability, and transferability of this study. In addition, care was taken during the analysis of data to limit concerns related to researcher subjectivity. The following chapter contains the results of the study.

CHAPTER IV: RESULTS

Introduction

This study used a single-case study (Yin, 2018) to explore how lesson study can be used as a component of an induction program to develop the novice teacher's mathematical knowledge for teaching (Ball et al., 2008), disposition, and cooperative relationships with other teachers. The single case analysis allowed the researcher to identify changes that were made at different stages of the lesson study cycle, which included observing the PLC as they collaboratively designed their research lesson. To lay a foundation for understanding the results, a chronological narrative of the lesson study is provided with thorough descriptions of each event. Then, the results are presented according to each research question. Finally, the pattern of teacher growth is described with the support of the EIMPG. The chapter ends with a summary of the findings.

Lesson Study Narrative

A chronological narrative of lesson study is provided in this section to offer information on the planning meetings, research lessons, and debriefing sessions. The narrative is provided to illustrate how the novice teacher can develop through the support of lesson study.

Planning Meeting 1

In preparation for the first research lesson, the PLC met four times. In the first meeting, the teachers discussed the Mathematical Teaching Practices (NCTM, 2014). Dr. Lasky administered the Teacher Practice Self-Assessment, in which the teachers put an X along the continuum to best represent their administration of each teaching practice.

Through this self-reflection, Kelly identified the teaching practices she feels uncertain about. The teachers shared what they believed to be their strengths, then Dr. Lasky asked, "what might be one that you would like to continue to work on?" (Planning Meeting 1, 10/29/19). Kelly responded with, "I struggle with letting them (the students) struggle because I just want to make it better and build their confidence, and I jump in too soon" (Planning Meeting 1, 10/29/19). As a result, the goal of the LS focused on developing problem solvers who persevere when faced with challenges during a lesson on systems of linear equations. Systems of linear equations was the chosen topic because it was a topic the novice teacher was nervous about teaching and a topic the team thought would be practical based on their pacing guide. To accomplish this, the group focused on two practices: Implement tasks that promote reasoning and problem solving and Support productive struggle in learning mathematics.

Planning Meeting 2

In the second meeting, Dr. Lasky started by providing more information about the two practices. He encouraged the teachers to think about what productive struggle would look like. Dr. Lasky reminded the teachers that providing an appropriate task can allow the students to grapple with the mathematics in such a way that "we're giving them a chance to discover…and make connections between mathematical ideas" (Planning Meeting 2, 10/31/19). Before creating the lesson, the participants identified what specific learning goals they wanted the students to master: 1. Write a system of equations to represent a problem context; 2. Solve systems of equations; 3. Interpret the solution to a system of equations in terms of the problem situation.

Planning Meeting 3

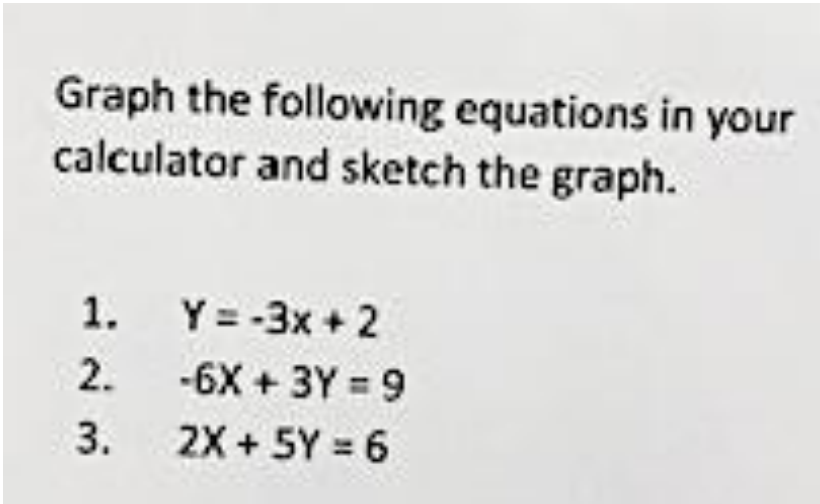
The goal of the meeting was for the group to choose an appropriate task for the research lesson. Kelly started the meeting by sharing different tasks she came across and shared her concern in the process: "I don't know what the best ones (tasks) to use would be" (Planning Meeting 3, 11/7/19). In order to select an appropriate task, the group revisited their goals (LS and content goals for the students).

Planning Meeting 4

Kelly reflected on the task the group chose and decided to change it because she had her doubts about the task. The changes were presented to the group to finalize the lesson plan for the first research lesson. During this meeting, the teachers considered anticipated solution paths and some potential questions to pose during the lesson. The group discussed the structure of the starter problem. Because graphing was an anticipated solution pathway, the teachers felt it would be important to practice graphing and to practice rewriting the equations from standard form to slope-intercept form. Substitution was another anticipated solution pathway; therefore, they included a starter problem that would require substitution to solve.

Research Lesson 1

The first lesson was taught by Kelly and started with bell work that aimed to review graphing linear equations (Figure 9) that were written in two different forms: slope-intercept and standard form. The bell work also consisted of another way to look at substitution through the use of emojis (Figure 10).



Graph the following equations in your calculator and sketch the graph.

1. Y = -3x + 2
2. -6X + 3Y = 9
3. 2X + 5Y = 6

Figure 9. Kelly's bell work to encourage graphing

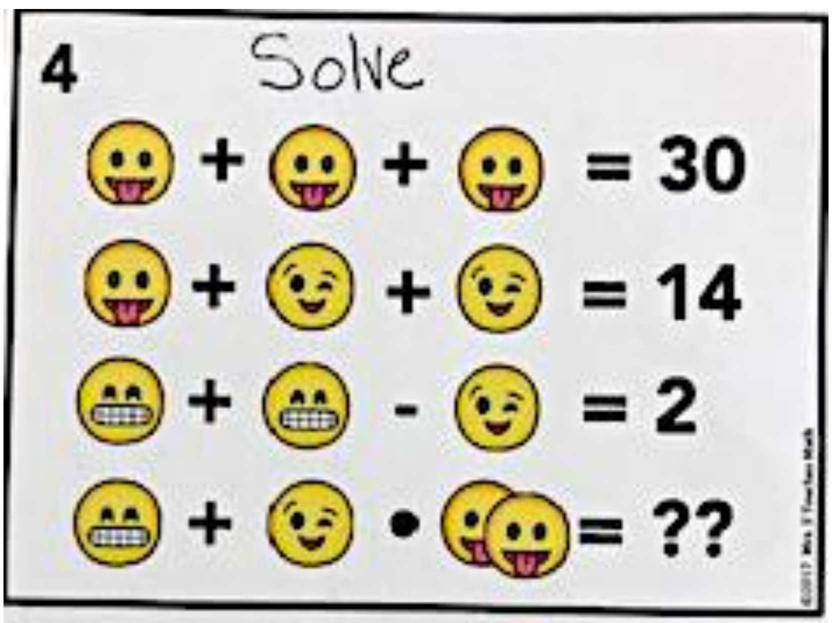


Figure 10. Kelly's bell work to encourage substitution

After the bell work, Kelly projected the task (Figure 11) to the class. She informed the class that she wanted them to use their prior knowledge and utilize what they reviewed to answer two questions: 1. How much does each case of soda cost? and 2. How much does each case of chips cost? After the task was presented, Kelly defined a case of soda and a case of chips by saying that "when we're talking about the sodas, it's the twelve-pack of cans, that's what I'm thinking of. And cases of chips, I'm thinking of those Frito-Lay cases with thirty of them in there" (Kelly, Research Lesson 1, 11/18/19). Throughout the task, Kelly promoted problem solving: "My goal is to see how we all get to the answer; what processes are we using" (Research Lesson 1, 11/18/19).

Gaby and Paul went shopping together for drinks and snacks for the student council fundraiser.

Gaby bought 5 cases of soda and 4 cases of chips. Her total bill was $65.

Paul bought 6 cases of soda and 7 cases of chips and his total bill was $100.

How much did each case of soda cost?
How much did each case of chips cost?

Figure 11. Task

The students worked together in groups using the projected problem. As the groups collaborated, Kelly circulated the room to monitor the students' progress. When the students needed guidance, she often directed them to make an equation. The class ended with each group sharing their work and solution strategy for the task.

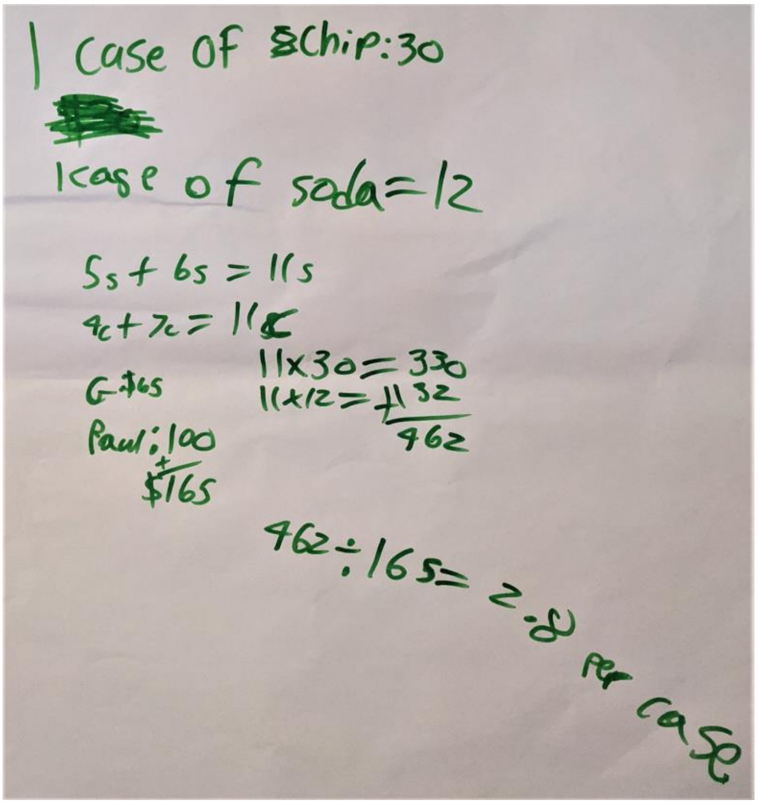


Figure 12. Student solution

For example, one student was invited to present his solution, as shown in Figure 12, and explained as follows:

> So, we know that one case of chips contains 30, and one case of soda contains 12. So, instead of doing it separately, we decided to add Gabby's amount of cans and Paul's amount of cans together, and we got 11. And we also decided to do the same for chips, and we got 11, too. So then 11…11 packages times 30, because that's how much are in it, equals 330 and then 11 packages times 12, because that's how many sodas are in it, equals 132. So, we added them together and got 462 in total. So, we added Gabby's total and Paul's total and got $165. So, we did

462 divided by 165 equals two dollars and eight cents per case. (Research Lesson 1, 11/18/19)

This student's explanation of the work presented the teacher with an unexpected misconception. The teacher did not anticipate the students to focus on the size of the cases to answer the question.

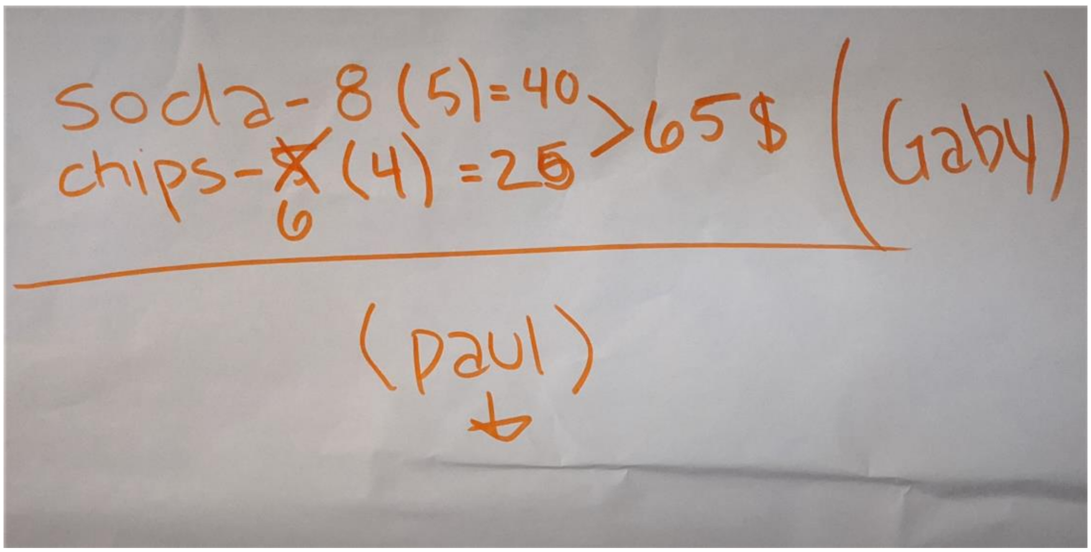


Figure 13. Student solution using guess and check

Another solution utilizing guess and check was presented (Figure 13), and Kelly focused on the methodology and not the accuracy of the multiplication. The student explained her process as follows:

Student: So, we only solved for Gabby. For the soda, we said it was $8, and for the whole pack of chips, it was $6 because 8 times 5 equals 40 and 6 times 4 equals 25. And when you have 40 and 25, it's 65. When we tried to fill in 8 and 6 for Paul, it wouldn't give us the right thing. We were just guessing numbers.

Kelly: They were guessing numbers; is that a valid method?

Class: Yes.

Kelly: So, they used guess and check; and did it work for you?

Student: It only worked for Gabby.

Kelly: So, it only worked on the first one; so, what would you have to do next?

Student: Change it.

Kelly: Change it; so, guess a different number. So that is a valid solution path to this. You can guess and check, and they knew that those numbers wouldn't work in the second one, so they would have to guess some different numbers. (Research Lesson 1, 11/18/19)

When the next group presented, they began by identifying everything they knew. Kelly pointed out that this information could be combined into two equations using variables to emphasize the quantities represented (Figure 14).

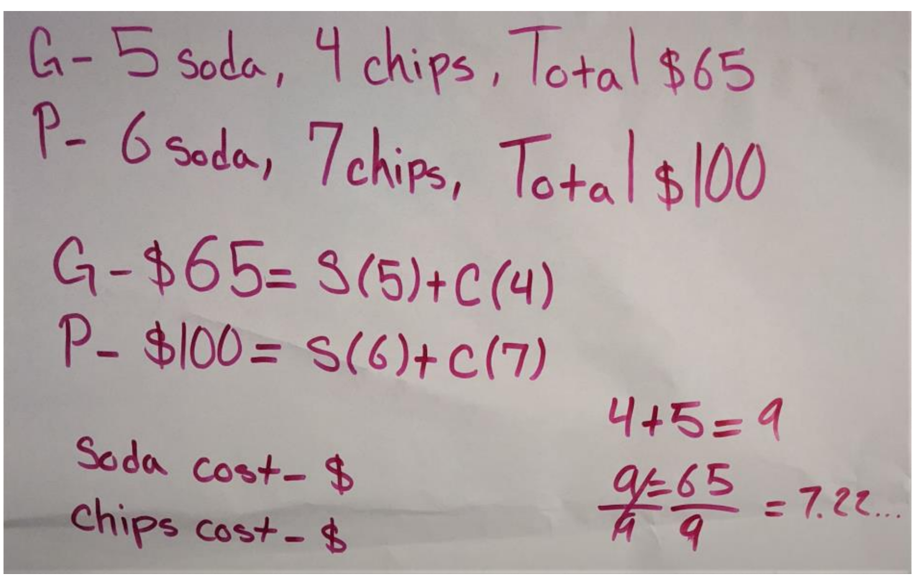


Figure 14. Student solution with equations

To close the lesson, Kelly used the equations from Figure 16 and graphed the equations to illustrate that the solution was where the two equations intersect. This task intersected at $5 per case of soda and $10 per case of chips. After the explanation of the system of equations, Kelly had the groups identify what the variables in the system of equations represented on their exit ticket (Figure 15).

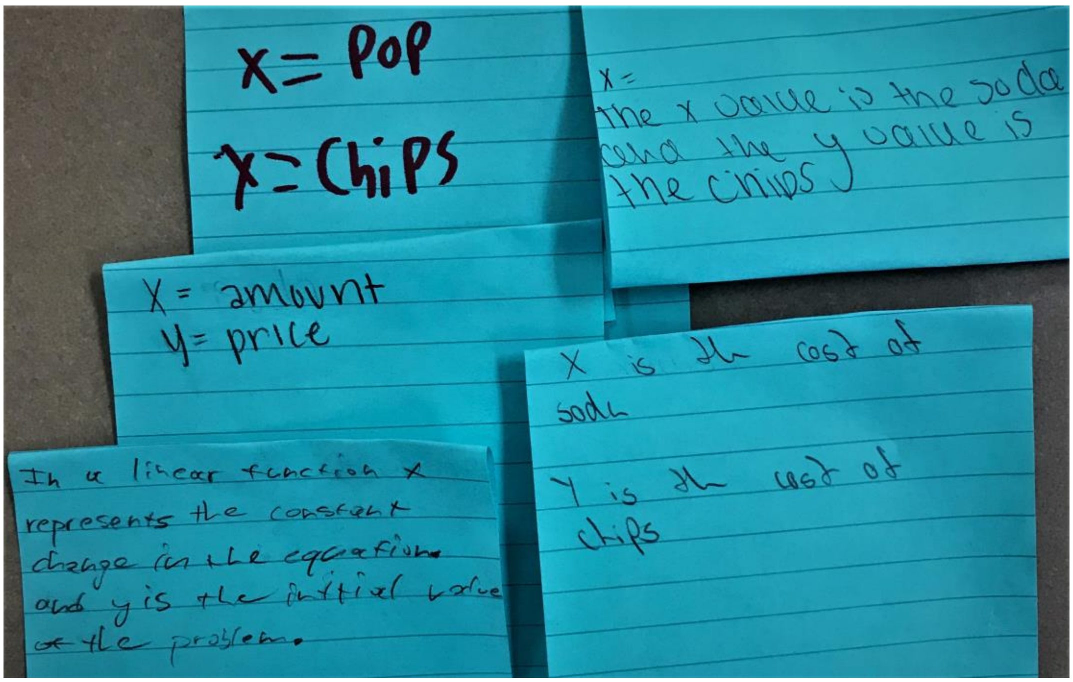


Figure 15. *Students' exit tickets*

Lesson 1 Debrief

Dr. Lasky started the meeting by reminding the group that the focus of the discussion is the lesson and how to improve the lesson and not the teacher. He continued by saying: “Let’s highlight the strengths, weaknesses, and recommendations for improvement because we’re going to be teaching this again. So, we want to think about what changes we want to make to either the task itself, the structure of the lesson, or how we're presenting student work, that kind of thing" (Debriefing Session 1, 11/20/19). The debriefing session turned to Kelly to share her thoughts on the lesson.

> I was disappointed in the fact that there weren't that many different solution paths…I'm wondering if it was my questioning. Was I not giving them something to think about that could help them move to a solution path? I was frustrated…because I would say something, and I would come back, and I would say, 'well think about how we can make this into an equation' or 'how many equations do we need?' And I would come back, and there would be no equations. (Debriefing Session 1, 11/20/19)

Kelly also proceeded to question whether providing 45 minutes towards this lesson was a sufficient amount of time. Dr. Lasky acknowledged the concern and directed the group to focus on the structure of the lesson. He questioned whether the instructional time was purposeful.

> We really want to make sure if we're spending that much time that it's intentional and get students to think in the ways that we want them to lead into the task…it kind of depends on what solution paths we want to bring out in the task. (Debriefing Session 1, 11/20/19)

Lisa, Kelly's mentor, followed up with Dr. Lasky's point by suggesting a change of the variables: "Do you think it might help if one of the equations was not x and y…maybe if we use a and b" (Debriefing Session 1, 11/20/19).

During this debriefing session, the participants discussed the structure of the lesson by starting with the starter problem. Dr. Lasky identified that this time should be intentional and should "get students to think in ways we want them to," that leads them to the task. He suggested using only one piece of the starter problem to provide scaffolding to the students. He also suggested providing private think time for students. This would allow the students to provide unique ideas to share with the group. As the students work in their groups, he suggested walking around to see what the different groups were doing in order to select and sequence the group presentations and to make connections to their presentations.

In addition to discussing the structure, the participants discussed ways to improve the task. They looked at the solution paths and established that they should change the wording of the task from finding the cost of the case of soda and case of chips to: 1. How much does each case of soda cost? And 2. How much does each pack of chips cost? This may alleviate the confusion of students trying to find the price of the combined cases.

Research Lesson 2

The second lesson was taught by Jessie and started with bell work that aimed to review systems of equations through graphing (Figure 16). This was a suggested change from the previous lesson. The students were expected to rewrite the equations from standard form to slope-intercept form to assist with graphing. Jessie emphasized that the lines should be extended across the grid.

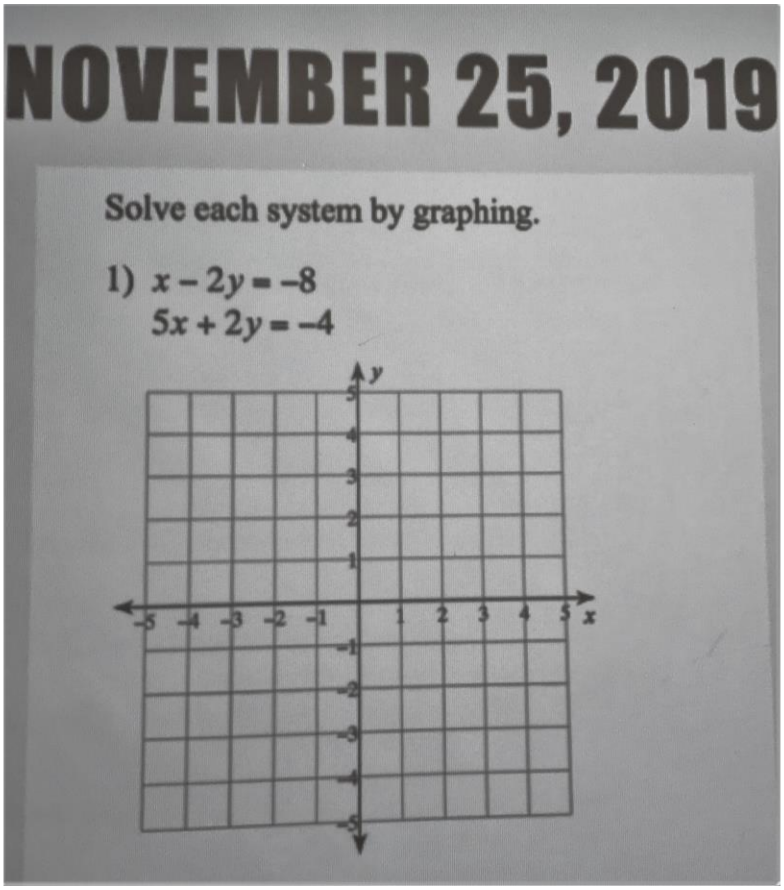


Figure 16. Jessie's bell work

After the bell work, Jessie handed out the task (Figure 17) to the students and encouraged them to work in their groups to answer the questions through a strategy of their choice. The suggestions she provided to the students were to: read through the task, identify what is important, acknowledge what to solve for, and choose a strategy to use for the task.

Name:___________________________

Gaby and Paul went shopping together for drinks and snacks for the student council fundraiser.

Gaby bought 5 cases of soda and 4 packs of chips. Her total bill was $65.

Paul bought 6 cases of soda and 7 packs of chips and his total bill was $100.

How much did each case of soda cost? How much did each pack of chips cost?

<u>Instructions:</u>

You may use whatever method you'd like to solve the problem. Do any preliminary work on this page. When you're ready, transfer your completed work to a piece of chart paper and prepared to describe what you did to the class.

Figure 17. Task

As the students worked, Jessie circulated the class to monitor the students' progress. She acknowledged that many groups had created equations and would follow that up with "what can you do with the two equations to find the cost?" (Research Lesson 2, 11/25/19). Jessie had the students turn in their work and return to their seats at the end of the allotted time. The work was discussed in no particular order. In fact, the presentations occurred as Jessie was picking up the chart paper from the stack where the students turned in their work.

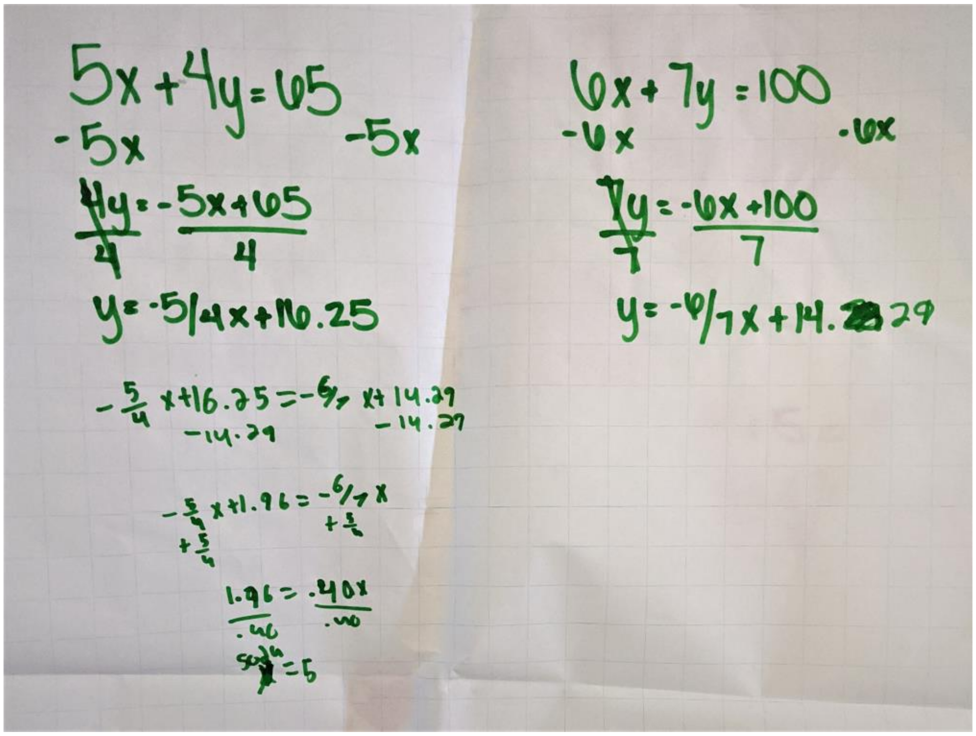


Figure 18. Student work

The presentations started with a student explaining their work to the task, as seen in Figure 18:

> We got the equations, and we used two variables. Then we solved for y, and then we combined the equations and solved it. We got that $x = \$5$ and $y = \$10$.
>
> (Research Lesson 2, 11/25/19)

When Jessie picked up the chart paper seen in Figure 19, Jessie asked the group what equations were used. The student responded with the two equations to be: $y = 16.25 - \frac{5}{4}x$ and $y = -\frac{6}{7}x + 14.29$. Jessie used this as an opportunity to ask if other groups came up with the same equations and finished by stating the correct solution was $5 and $10.

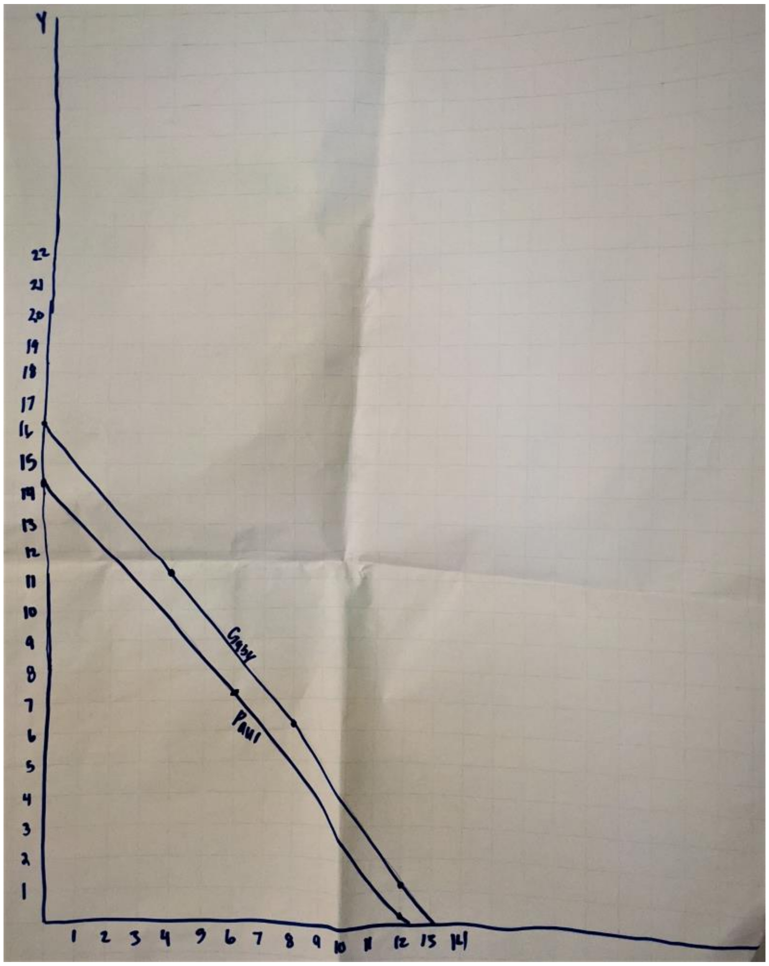


Figure 19. Student work

The lesson closed with Jessie having the students reflect on their method to solve the task. She asked the students to identify whether they would stay with the same strategy or change their strategy to solve the task.

Lesson 2 Debrief

Jessie began the debriefing session by sharing her thoughts on the lesson:

> I think having the time displayed was good for them. Having the timer helped because they were like, we need to be doing this because there's only this much

> time left…I was trying not to lead them to a specific strategy; it was more of asking what can you do now that you have these two equations written. I don't know if it was beneficial not to suggest some kind of strategy or at least go over possibilities because they would get to a certain point and be like, I don't know what to do from here. (Debriefing Session 2, 12/3/19)

After Jessie shared her thoughts on the lesson, Dr. Lasky turned to the group to provide feedback. Kelly commented that she liked the bell work and stated, "I wrote less is more about your bell work" (Debriefing Session 2, 12/3/19). Jessie acknowledged that the students were expected to convert the equations from standard form to slope-intercept form to graph the equations. She expected that the students would use the bell work to help them self-guide during the task. Kelly also asked about Jessie's thoughts on individual think time. Jessie shared that she was concerned about having enough time and decided not to provide private think time.

Dr. Lasky took a moment for the group to reflect on their lessons and asked if this type of lesson was a typical format for the students. Kelly shared that the students are typically faced with a task after the material has been taught and not as a discovery lesson where the students need to problem solve. Dr. Lasky moved the discussion to consider the structure of the lesson as they move forward. He started discussing the structure by considering time and stated:

> Time, like how much time we're going to give them for individual think time; how much time we're going to give them for group discussion; and then, let's consider the cycle between small and whole group discussion. So, if they're

> struggling for four or five minutes, let's pause the class, have that whole group discussion about either: something one group did or something that you noticed, or here's a question to think about to help them progress in their thinking. (Debriefing Session 2, 12/3/19)

He also shared that there are moments the teacher may need to pause the small group discussions and make them a whole group discussion by sharing his rule of thumb:

> My rule of thumb is if there's about four or five minutes of we're not really getting anywhere, or I'm seeing this one misconception come out throughout some of these groups, then we pause and share ideas and use that to move forward. (Debriefing Session 2, 12/3/19)

The final thing Dr. Lasky discussed was about the closing of the lesson:

> The other thing I was thinking about is how we share our ideas at the end…how do we want to sequence those in a way that makes sense and help students make connections between those pathways. (Debriefing Session 2, 12/3/19)

The debriefing session closed by summarizing the recommendations for Kelly to consider when teaching the final lesson. This included: individual think time, providing an individual copy of the task, a purposeful starter problem, use of a timer, and the objective of the lesson to be perseverance in problem solving.

Research Lesson 3

Kelly taught the final lesson, and she started by focusing the class on their "I can" statement. The class's I can statement was to persevere in problem solving. Once the class identified the statement, Kelly asked, "what does persevere mean?" Once she felt the students understood that they would not give up, Kelly shifted their attention to the bell work to review solving systems of linear equations (Figure 20).

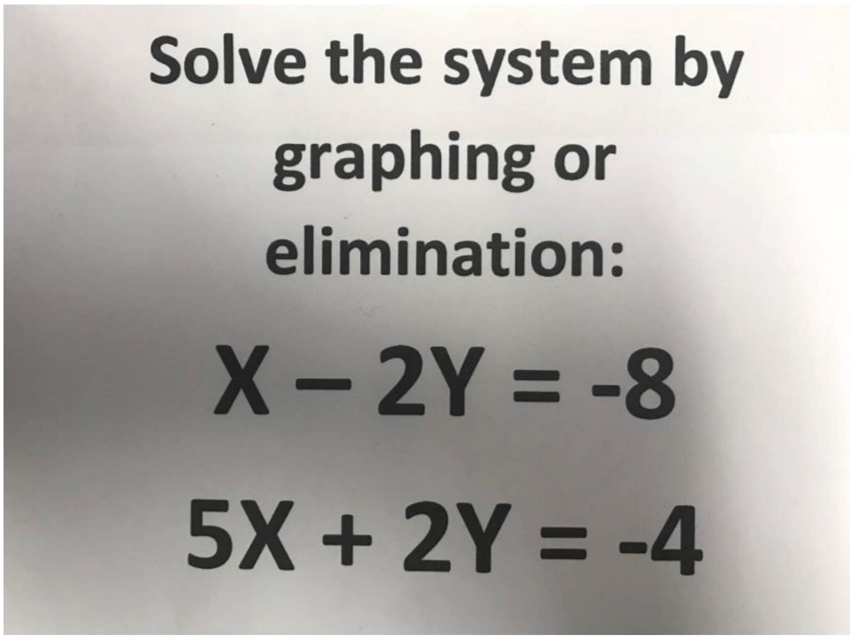


Figure 20. Kelly's bell work to encourage graphing and elimination

After the class discussed how to solve the starter problem, Kelly provided every student with the task (Figure 21) and informed the class to use any method to determine the cost of each taco and the cost of each side.

- Kenzie and Ethan decide to have dinner at Tacos R Us.
- Kenzie buys 3 tacos and 2 sides. Her total bill is $13
- Ethan buys 4 tacos and 3 sides. His total bill is $18.

(Disclaimer ☺: The tacos are a different price than the sides.

All sides cost the same price. The price of the tacos and the price of the sides are whole numbers.)

Using any method you wish, determine the cost of each taco and the cost of each side.

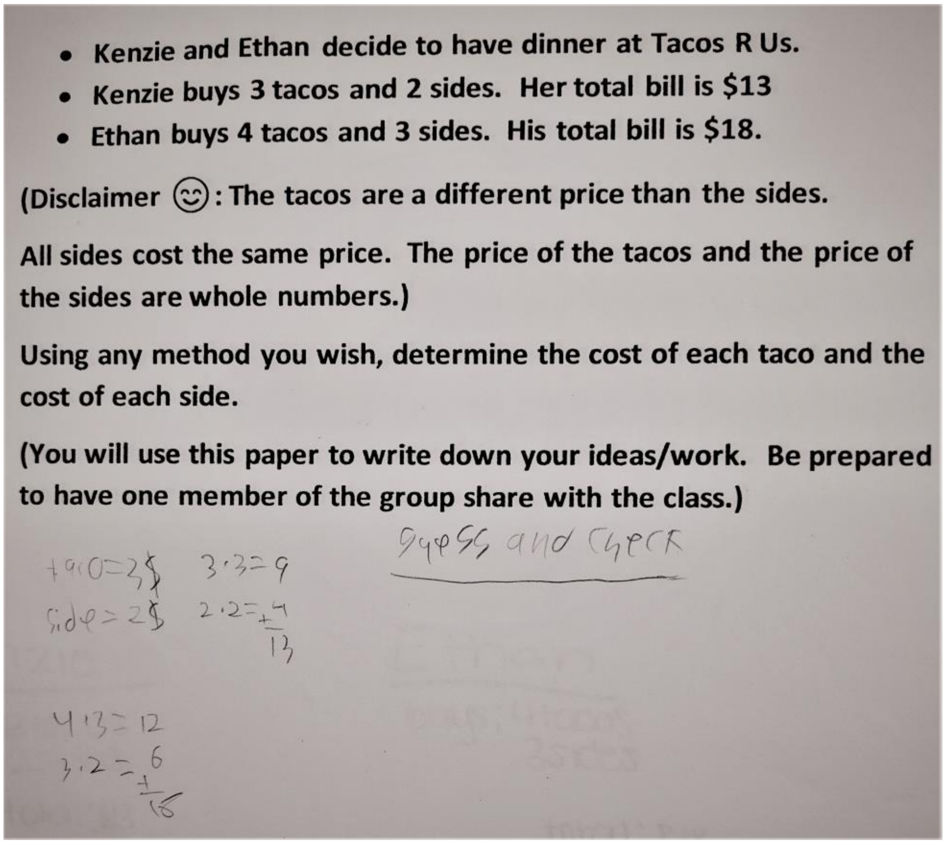
(You will use this paper to write down your ideas/work. Be prepared to have one member of the group share with the class.)

Figure 21. Task

She provided three minutes of individual think time for the students to write down their ideas. After the three minutes, she directed the students to collaborate with their groups to discuss solutions and solution pathways. As the groups collaborated, Kelly circulated the room to monitor the students' progress and to provide assessing questions.

> I like that you have two equations and two variables; that's good. Something happened here; you've got a good start. You added those (the equations), but did anything eliminate? So how can you make something eliminate? (Research Lesson 3, 12/5/19)

The class ended with each group sharing their work and solution strategy for the task. The first group (Figure 22) presented, used guess and check to work through the task.



- Kenzie and Ethan decide to have dinner at Tacos R Us.
- Kenzie buys 3 tacos and 2 sides. Her total bill is $13
- Ethan buys 4 tacos and 3 sides. His total bill is $18.

(Disclaimer ☺: The tacos are a different price than the sides.

All sides cost the same price. The price of the tacos and the price of the sides are whole numbers.)

Using any method you wish, determine the cost of each taco and the cost of each side.

(You will use this paper to write down your ideas/work. Be prepared to have one member of the group share with the class.)

guess and check

taco=3$ 3·3=9
side=2$ 2·2=+4
13

4·3=12
3·2=+6
18

Figure 22. Student work using guess and check

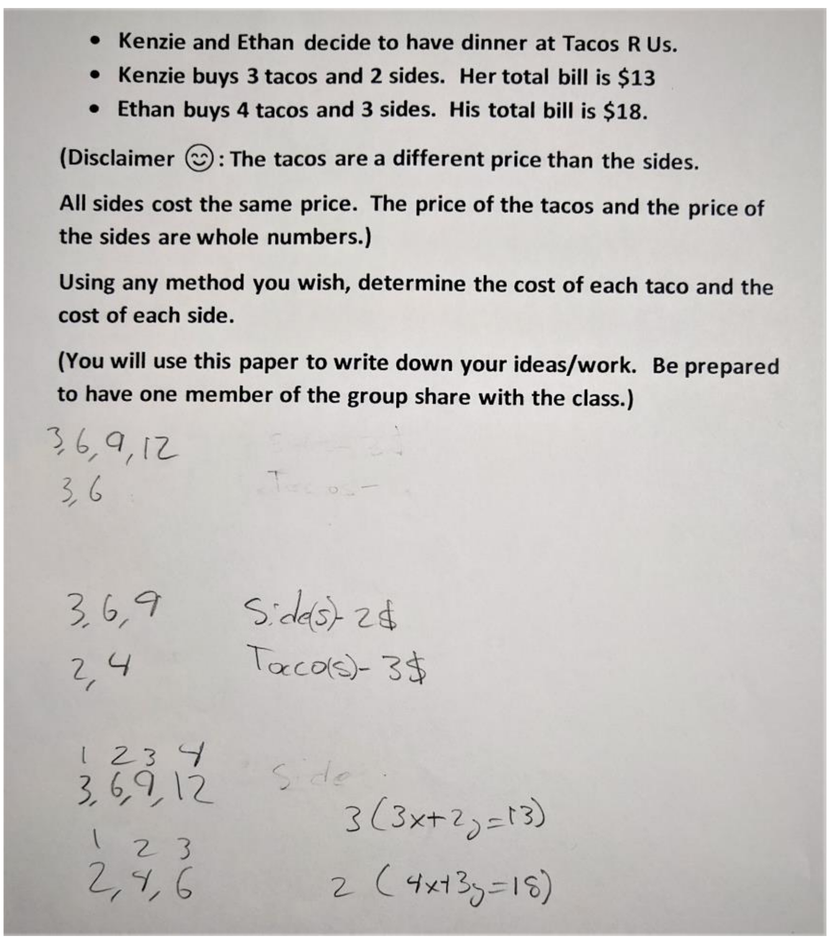
The student put his work under the document camera and proceeded to share his thought process:

> So, what I did, I put three dollars for the tacos and two for the side, and because Kenzie bought three tacos, I did three times three and got nine. Then I did two times two because of the two sides, and that's four. So, nine plus four and got thirteen. That worked for Kenzie, and to make sure my answer was right, I checked it with Ethan. I did four times three because Ethan has four tacos, got twelve; then, I did three times two and got six; and twelve plus six is eighteen. (Research Lesson 3, 12/5/19)

Kelly then moved to a group that attempted to set up equations. The student shared that:

> Kenzie had three tacos and two sides, so we did $3x + 2y$, and her total was thirteen, so we did $3x + 2y = 13$. Ethan had four tacos and three sides, so $4x + 3y = 18$. But we didn't solve it. (Research Lesson 3, 12/5/19)

This provided Kelly with an opportunity to ask: "How do you think you could have solved that? What do you think you would pick?" After posing these questions, this was an opportunity for Kelly to segue to the next group. However, the presentation did not go as planned and instead showed more guess and check (Figure 23).



- **Kenzie and Ethan decide to have dinner at Tacos R Us.**
- **Kenzie buys 3 tacos and 2 sides. Her total bill is $13**
- **Ethan buys 4 tacos and 3 sides. His total bill is $18.**

(Disclaimer ☺: The tacos are a different price than the sides.

All sides cost the same price. The price of the tacos and the price of the sides are whole numbers.)

Using any method you wish, determine the cost of each taco and the cost of each side.

(You will use this paper to write down your ideas/work. Be prepared to have one member of the group share with the class.)

Figure 23. Student work (guess and check with support of equations)

That presentation was followed by a student sharing his work on the process of elimination (Figure 24):

> I saw that there were no variables that were the same, so I multiplied by the y-values and got: $9x + 6y = 39$ and $8x + 6y = 36$. Then I saw the 6y and the 6y, so I decided to subtract and got $1x = 3$. Then divided each side by one and got $x = 3$. Then I plugged it into this one ($9x + 6y = 39$) and got $27 + 6y = 39$; subtracted 27 from each side and got $6y = 12$. Then divided by six and got $y = 2$. (Research Lesson 3, 12/5/19)

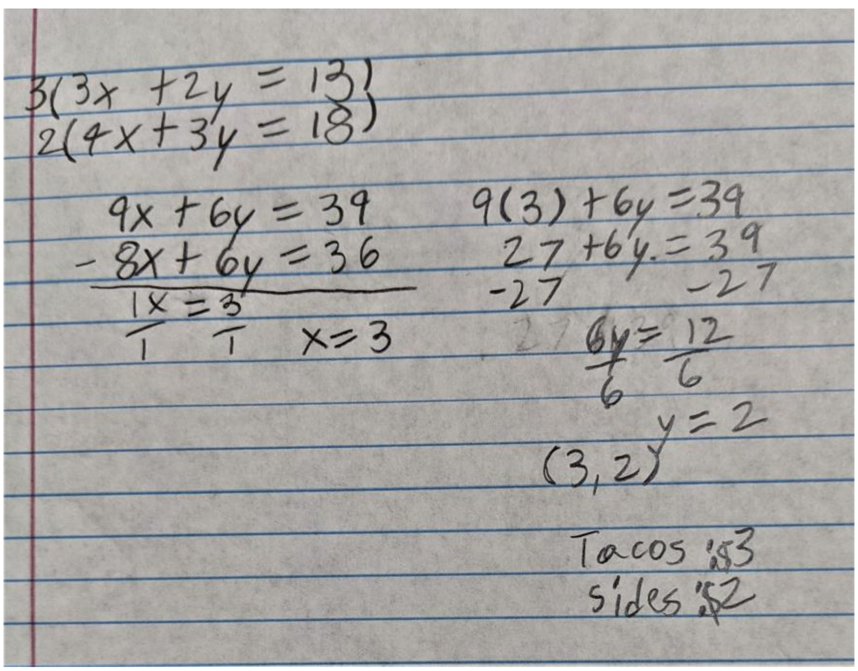


Figure 24. Student work using elimination

After some of the presentations, Kelly pointed out to the students, “those of you who used guess and check, that’s a valid method (of solving) when you have nice small numbers.” Then a student chimed in, “that’s why I was trying to figure out this way (elimination method) because when the numbers get bigger…ugh.” And Kelly followed up, “exactly, when the numbers get bigger, you might want to use this method (elimination method).” This class has a supportive atmosphere in which students were willing to show their mistakes. All groups presented their work; a member from the final group chose to show where he got lost. After the presentations, Kelly had the students interpret the results on an exit ticket (Figure 25) by identifying “what the solution meant in terms of the context of the problem” (Research Lesson 3, 12/5/19).

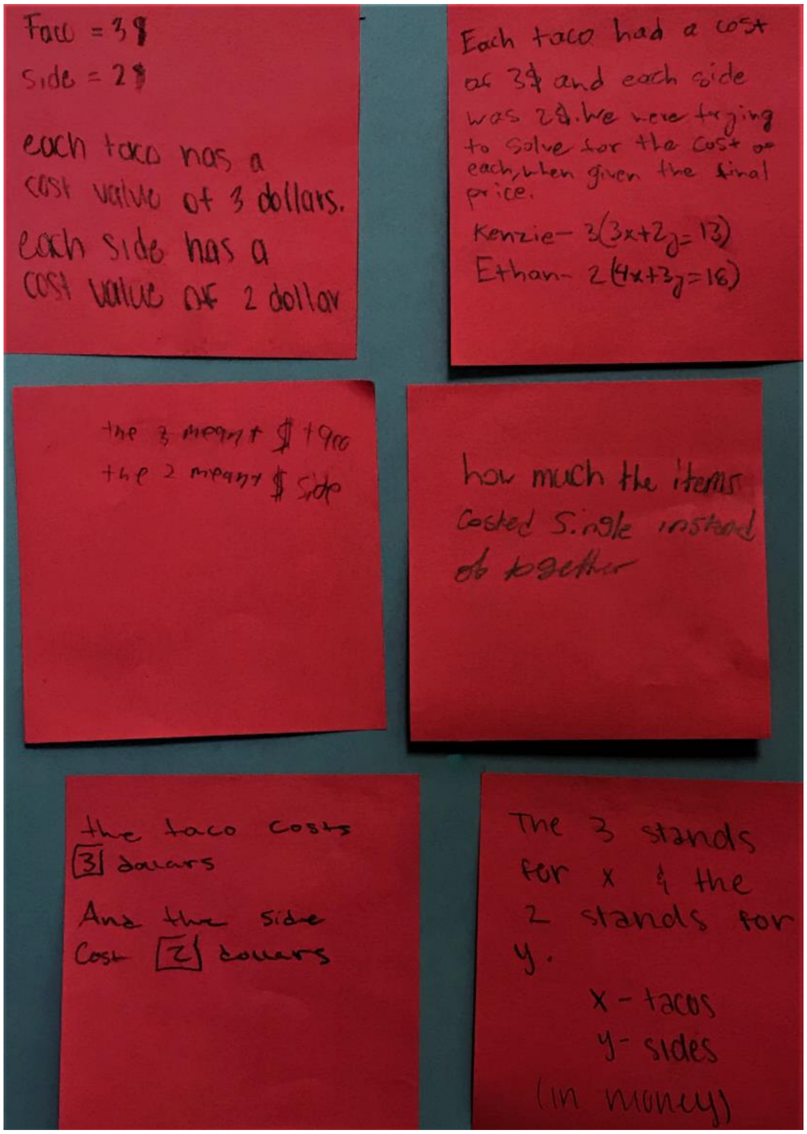


Figure 25. Students' exit tickets

Lesson 3 Debrief

After Research Lesson 3, the participants and Dr. Lasky met to discuss the research lesson and to discuss the entire LS. The discussion began with Kelly sharing her thoughts on the lesson.

> So, I thought it went much better. When I was looking over the kids' work again, there were different methods. I felt like they were thinking more this time…and it might have been because the goal was to persevere in problem solving. So, I don't know if maybe that got them thinking like, okay, we're actually going to have to work this out and see what we get. But I felt like they were more willing to do that and more willing to be wrong, and more willing to talk to each other. I was surprised that they didn't remember it (systems of equations) right away. (Debriefing Session 3, 12/11/19)

The participants all agreed that the changes of including a goal that encouraged problem solving, having a purposeful starter problem, and having a structure to the lesson that included individual think time were beneficial to achieving the mathematical learning goals: 1. Writing a system in context, and 2. Understanding the solution in context.

Dr. Lasky added to the discussion, which mainly addressed the structure of the lesson. He agreed that a strength of the lesson was the structure of the lesson in which she "started with individual, and then group, and then whole." He suggested summarizing why $(-2, 3)$ is a solution at the end of the starter problem by stating, "Here's why it's a solution and thinking about why $(-2, 3)$ is a solution to the first one; why it's a solution to the second one; and because it's a solution to both, then it's a solution to the entire system" (Debriefing Session 3, 12/11/19). The teachers discussed that no one had graphed the starter problem, so an opportunity to compare the methods was missed. Dr. Lasky suggested that a way to guarantee that ideas are discussed is to have fake student work. Another topic of discussion was about the whole class discussion; Dr. Lasky asked for Kelly's rationale for the sequencing of the presentations. Kelly intended to start with the guess and checkers followed by the more complex methodologies, but she struggled with seeing different methods within the same group. So, when the group was called, a different approach was presented than intended; therefore, the suggestion was to identify the individual's method to be presented. Dr. Lasky shared an article: "Orchestrating Discussions," with the participants that discussed how to have an effective whole-class discussion.

The debriefing session ended with the participants sharing what they will take away from the LS experience. Many participants shared that they want to try to do more lessons like this (teaching through problem solving). Kelly shared that a big take away for her was "less is more…less words, less problems, less…just make them count." Dr. Lasky closed the meeting by sharing his takeaways:

> The goal is critical and in two ways: 1. I really like the goal of this lesson, which was to persevere in problem solving…it didn't give away the math that we wanted them to discover, and then secondly how important the goal is at the end to really focus their attention on…so the goal was number one, and the number two was how important turn and talk could be as either an unknown strategy that a student shares or to just never share anything a student can say. (Debriefing Session 3, 12/11/19)

After the sharing of takeaways, the participants thanked Dr. Lasky for his time and advice.

Summary of Observed Changes

There were many changes that occurred between Kelly's first teaching the lesson and the final teaching. The research lesson was more focused, and the structure of the lesson was improved to include private think time for the students. The bell work was also more focused on making the idea of solving systems of equations visible. Furthermore, the students felt confident in their learning and wanted to attempt another task like what they experienced to solidify their understanding of the topic. Each phase of the LS was necessary to provide insight into these changes. The planning meetings provided opportunities for the participants to share experiences. Teaching the lessons provided Kelly with the opportunity to grapple with the lesson plan. The debriefing sessions gave the group time to reflect and discuss the goal of the lesson so that they could alter the structure and bell work to better meet the goals of the lesson.

Analysis of the Novice Teacher

The novice teacher was the focus of this study. The researcher gathered data on the novice teacher through interviews, videos of the research lessons, and debriefing sessions. The data results are presented in terms of three stages: Stage 1 represents the time period from the start of the study through the first research lesson; Stage 2 is the second research lesson and second debriefing session; Stage 3 is the final research lesson through the final interview (see Table 4 for timeline). The results are described through each research question, followed by a discussion of the overall changes in terms of the growth network.

Research Question 1: How does LS help a novice teacher develop a productive disposition about mathematics teaching and learning?

Productive disposition refers to the teacher's attitudes and beliefs that can promote effective instructional practices (see chapter 2 for detail). To capture the changes in disposition, the researcher conducted interviews and gathered data on the novice teacher through reflection journals, videos of the research lessons and debriefing sessions.

Stage 1: Kelly was conflicted with what constitutes productive beliefs.

The initial interview occurred after Kelly provided the researcher with her belief survey and first journal entry. The interview consisted of asking Kelly to clarify statements made in her journal entry and on her survey. The Teaching and Learning Beliefs survey (Appendix D) consisted of twelve statements, as shown in Table 2: Beliefs about teaching and learning mathematics. The survey was to examine whether she agreed or disagreed with the given statements. Kelly strongly disagreed that the role of the teacher is to tell students exactly what definitions, formulas, and rules they should know and demonstrate how to use this information to solve mathematics problems. This implies that she believes that the teacher should not tell the students what they should know but instead should facilitate discourse to develop understanding. Overall, Kelly disagreed with statements that illustrated unproductive beliefs and agreed with statements that illustrated productive beliefs, as seen in the following table (Table 9), which reveals productive beliefs.

Table 9

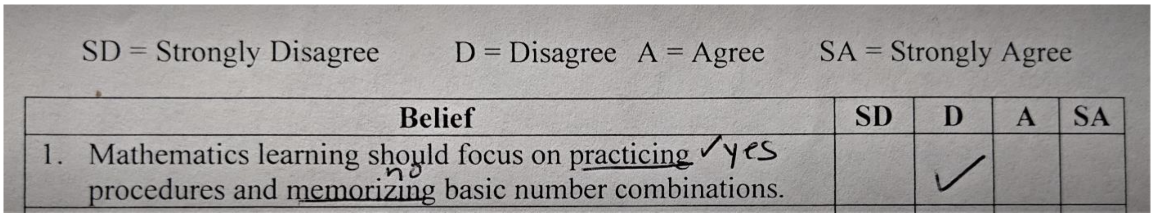
Kelly's Responses to the Belief Survey

Belief	Productive or Unproductive	Kelly's Response
1. Mathematics learning should focus on practicing procedures and memorizing basic number combinations	Unproductive	Disagree
2. The role of the teacher is to tell students exactly what definitions, formulas, and rules they should know and demonstrate how to use this information to solve mathematics problems.	Unproductive	Strongly Disagree
3. All students need to have a range of strategies and approaches from which to choose in solving problems, including, but not limited to, general methods, standard algorithms, and procedures.	Productive	Strongly Agree
4. The role of the teacher is to engage students in tasks that promote reasoning and problem solving and facilitate discourse that moves students toward shared understanding of mathematics.	Productive	Strongly Agree
5. Mathematics learning should focus on developing understanding of concepts and procedures through problem solving, reasoning, and discourse.	Productive	Strongly Agree
6. An effective teacher makes the mathematics easy for students by guiding them step by step through problem solving to ensure that they are not frustrated or confused.	Unproductive	Disagree
7. Students can learn to apply mathematics only after the have mastered the basic skills.	Unproductive	Disagree
8. Students can learn mathematics through exploring and solving contextual and mathematical problems.	Productive	Strongly Agree
9. An effective teacher provides students with appropriate challenges, encourages perseverance in solving problems, and supports productive struggle in learning mathematics.	Productive	Strongly Agree

(continued)

Belief	Productive or Unproductive	Kelly's Response
10. The role of the student is to memorize information that is presented and then use it to solve routine problems on homework, quizzes, and tests.	Unproductive	Strongly Disagree
11. The role of the student is to be actively involved in making sense of mathematics tasks by using varied strategies and representations, justifying solutions, making connections to prior knowledge or familiar contexts and experiences, and considering the reasoning of others.	Productive	Strongly Agree
12. Students need only to learn and use the same standard computational algorithms and the same prescribed methods to solve algebraic problems.	Unproductive	Strongly Disagree

Kelly indicated productive beliefs in the survey responses; however, she demonstrated conflicting beliefs from her initial interview. During the initial interview, when asked about her beliefs, Kelly shared a productive belief by stating that "it (a lesson) needs to be more of critical thinking and less of what you can reproduce" (Kelly, Interview 1, 10/21/19). However, the rest of the interview contained statements that contradicted the beliefs found in the survey. An example of that occurred when she disagreed with the statement: students can learn to apply mathematics only after they have mastered the basic skills (on the survey as unproductive beliefs), and stating in the interview that "I feel like we're supposed to kind of push the skills practice aside and focus on letting the student discover things, but I don't think it'll work if they don't have the skill" (unproductive belief in the interview). This illustrated contradictory statements about productive and unproductive beliefs towards teaching and learning. As seen in Figure 26, Kelly identified ‘yes’ to mathematics learning should focus on practicing, illustrating that she believes there is a need for practicing procedures in the classroom.



SD = Strongly Disagree D = Disagree A = Agree SA = Strongly Agree

Belief	SD	D	A	SA
1. Mathematics learning should focus on practicing ✓yes procedures and memorizing (no) basic number combinations.		✓		

Figure 26. Kelly's survey response to statement one

Before the first interview, the researcher observed a typical lesson, which was then discussed in the first interview. Kelly stated during the interview that a more effective closing to the observed lesson would have been her “explaining (to the students) why I showed that (video) to lead into scatterplots and correlation, and then wrapping it up at the end with where that’s going to lead” (unproductive). This conflicted with her answer on the survey in which she disagreed with: An effective teacher makes the mathematics easy for students by guiding them step by step through problem solving to ensure that they are not frustrated or confused, and disagreed with: the role of the teacher is to tell students exactly what definitions, formulas, and rules they should know; and yet agreed with the role of the teacher provides students with appropriate challenge, encourages perseverance in solving problems, and supports productive struggle in learning mathematics (productive). Kelly’s responses in the interview conflicted with her survey because explaining to the students is a form of guiding the students step by step to ensure they are not confused in the learning of the mathematical goals and does not provide her with the opportunity to support the students through productive struggle in the learning of mathematics. From the interview, Kelly demonstrated that she was uncertain about effective teaching practices.

The LS started with the four planning meetings, and throughout these meetings, Kelly stated many uncertain and contradictory statements that inhibited her growth towards a productive disposition. Such statements included: "I'm highly overwhelmed, I don't know…I don't know how to move forward" (Kelly, Planning Meeting 2, 10/31/19). These statements demonstrated an attitude of uncertainty. Because productive disposition relates to the attitudes and beliefs that can promote effective instructional practices, such an attitude can negatively impact teaching practices. This indicated that Kelly grappled with the teaching practice: implement tasks that promote reasoning and problem solving. This was described as thinking about "how can we get students to explore and discover the idea rather than being told (the steps)" (Dr. Lasky, Planning Meeting 1, 10/29/19). After teachers shared their views on how to support students to persevere by chunking the material, Kelly shared her concern: "by chunking, aren't we driving them to the answer? That's what I'm afraid of" (Kelly, Planning Meeting 1, 10/29/19). That fear was revealed in the other meetings. As the teachers were reading through different tasks to select one for the research lesson, Kelly turned to the other teachers and said, "I don't know, what do you think" and also stated: "I don't know what the best one (task) to use" (Planning Meeting 3, 11/7/19). Once the task was chosen, Kelly looked to her peers for guidance in filling out the lesson plan template because she was insecure about filling it out. She showed this as she shared with her peers, "I wrote down some questions that are not very deep (about what the variables mean)" (Planning Meeting 4, 11/14/19).

Immediately after teaching the first research lesson, Kelly stated to the researcher that she considered not having students present their work because she could not see any relevance to showing and discussing incorrect and incomplete solutions (Field Notes, 11/18/19). She further shared with the researcher that she felt like a bad teacher for letting the students struggle and did not understand how letting them struggle would be considered productive (Field Notes, 11/18/19). This demonstrated that Kelly did not understand how to support students through productive struggle as they learned mathematics. Kelly posed the same question to each group after their presentations, which was: "any questions for the group?" After the last group presented, Kelly closed the lesson by stating:

> When you graph the system, $\begin{pmatrix} y = -\frac{5}{4}x + \frac{65}{4} \\ y = -\frac{6}{7}x + \frac{100}{7} \end{pmatrix}$, and where they (the two lines) cross (the point at which they intersect) is the solution. If you use 5 and 10, would it work (as a solution for the system)? If you need to know the answer, it's 5 and 10 (the point $(5, 10)$ is the solution). So, the soda was $5 per case, and the chips were $10 per case. Before you take a break, I want you to write two sentences in your groups, and I want you to tell me what the variables represent. (Kelly, Research Lesson 1, 11/18/19)

Kelly closed the lesson by stating the solution of the task to the students. This illustrated her uncertainty of how to facilitate the closing of a lesson. She reflected on this closing and shared to the LS group that "I felt like when it ended…I didn't feel like they had grasped it; I didn't feel like I left them with a way to put it together" (Kelly, Debriefing

Session 1, 11/20/19). Her reflection illustrated her uncertainty on how to facilitate the closing of the lesson.

Throughout the first stage, Kelly struggled to understand and implement effective teaching practices. She acknowledged productive beliefs through the survey but struggled to implement them in her teaching.

Stage 2: Kelly was willing to try different strategies in the classroom.

After the second lesson, Kelly identified similarities between the first and second research lessons. She shared that she "felt the same way (not able to use the created questions from the developed lesson plan), that they (the students) had nothing to fall back (lacked prior knowledge) on, so it was very difficult to move forward" (Kelly, Debriefing Session 2, 12/3/19). She also stated during the debriefing session, "I like your bell work; I wrote less is more about the bell work" (Kelly, Debriefing Session 2, 12/3/19); the bell work consisted of one question to get the students thinking about systems of equations. This showed an understanding that intentional questions, even coming from bell work, can make the mathematics more accessible to the students. She also identified that the student presentations did not have a particular order and wrote on her observation notes to "focus on sharing." Kelly identified things that she wanted to try for the next lesson that could support the students through the task. In addition to modifying the bell work from the original lesson, she shared that "the other thing I had was individual think time because I know I didn't do that…would it help…I might try it" (Kelly, Debriefing Session 2, 12/3/19). She also acknowledged that Jessie assigned groups ahead of time and asked, “how did you pick your groups?” (Kelly, Debriefing Session 2, 12/3/19).

After Kelly posed her questions about the implementation of the lesson, she shared her concerns about the next lesson.

> Kelly: What would happen if no one has an answer?
>
> Dr. Lasky: Well, hopefully, somebody wrote something down, and we can use whatever that is. So, if they just wrote 5x, we can start with that.
>
> Kelly: Okay.
>
> Dr. Lasky: And we can ask them (the students), what does x represent? What does the 5 represent? And getting them to think about what those values represent, so that’s just an example. But having that discussion about what those represent doesn’t really give the problem away or take away the productive struggle that’s going to happen, but it helps them think through the task. (Debriefing Session 2, 12/3/19)

After Kelly had the opportunity to watch Jessie teach the research lesson, she posed questions about the implementation. This change in questioning showed the beginnings of her growth into a productive disposition. She acknowledged similar struggles as Jessie and also stated that she might try individual think time in the next lesson. Even though Kelly shared that she was concerned about the outcome of the student solutions, she learned that the teacher can still provide learning opportunities for the students. This was a significant step in her growth towards a productive disposition.

Stage 3: Kelly started to understand the benefits of perseverance and experience the joys of mathematics sense making.

By the closing of the LS, Kelly showed more confidence and was willing to try new things in her classroom. She shared her views with an explanation by sharing, "I thought it (the lesson) went better…I felt like they (the students) were problem solving and it might have been because the goal (of the lesson) was to persevere in problem solving" (Kelly, Debriefing Session 3, 12/11/19). During the closing of the lesson, Kelly tried to promote relationships of the solution pathways, by asking "would you say the way you started was similar to the way the prior group started? (referencing that both groups started with guess and check)" (Kelly, Research Lesson 3, 12/11/19).

Dr. Lasky asked Kelly for clarification, "In terms of the presentations, what was your rationale for the order?" Kelly stated that "I was trying to start with guess and check and then move up from there. The problem was that some students in the same group had different methods written down and I didn't see them both" during the final debriefing session (Kelly, Debriefing Session 3, 12/11/19). However, she acknowledged the difficultly of supporting a student when "I have no idea what she's talking about (explanation of student work); I don't even know what to say right now, and I don't want to make her feel bad" (Kelly, Debriefing Session 3, 12/11/19). Because she wants to improve her teaching and wants to support student learning, she did not hesitate to seek advice from her peers by asking, "what do you do when you have no idea what they're talking about?" (Kelly, Debriefing Session 3, 12/11/19). Dr. Lasky responded with a few different options "1. you can ask them (the student) to clarify; 2. you can ask the students in the class to clarify, or the best way is to 3. turn and talk to their neighbor. That buys you time to kind of think through it, but also a student might be able to explain it in a way that makes everybody understand" (Dr. Lasky, Debriefing Session 3, 12/11/19). Kelly elaborated during the final interview that Dr. Lasky provided methods of how to support students through productive struggle and shared that "they (the students) need to take responsibility of their learning; and it's my responsibility to make sure that they can make those connections" (Kelly, Final Interview, 12/18/19).

Through LS, Kelly has developed an understanding of the benefits of perseverance. Her goal as a teacher has been to promote the students' understanding of mathematics. Kelly shared how she felt at the start of the study, that "in the beginning, I had a lot of self-doubt and wasn't sure if what I was doing was good enough" (Kelly, Final Interview, 12/18/19). Many of her statements in phase one contained uncertain statements, and she struggled with helping students understand the mathematics. In the final lesson, a student stated, "that's why I was trying to figure out this way (elimination method) because when the numbers get bigger, you don't want to use guess and check" (Research Lesson 3, 12/5/19). This illustrated that the student was actively involved in making sense of the mathematics. In the final interview, Kelly shared that she was excited that a student said that they need to do more tasks. The student made this statement when Kelly made closing remarks about problem solving and persevering through a task.

Kelly: Did we like trying to work through stuff like this (referencing the task)?

Student: Yeah, it was a little challenge.

Kelly: It was a little challenging. Did we persevere in problem solving?

Student: Yeah.

Kelly: We did. Some of you were like, I don't know how to do this, but you kept thinking about it, and you got some stuff out of it.

Student: We need to do more tasks like this. (Research lesson 3, 12/5/19)

Since the study, Kelly has been actively looking for more tasks to promote problem solving in the classroom. She acknowledged that "there's a lot that they (the students) can learn from one problem, from each other, from me, and from thinking about their prior knowledge" (Final Interview, 12/18/19). In the final interview, she also shared that she struggled with the concept of productive struggle but realized from the experience that "they need to struggle in order to really cement the ideas" (Final Interview, 12/18,19). Furthermore, Kelly shared that through this process, she has been thinking "about mathematics teaching less of I show you and you do, but more of let's work it out" (Final Interview, 12/18/19). This experience has helped Kelly to understand the importance and meanings of productive struggle in the learning of mathematics. However, she still struggles with implementing effective ways of supporting students' learning.

Research Question 2: How does LS help a novice teacher develop cooperative relationships with other teachers?

Cooperative relationships refer to a supportive environment that contributes to the learning of the novice teacher and eventually fosters student learning. The nature of the conversations can impact the learning for students and teachers. Congenial conversations are the polite sharing of teaching strategies that avoid conflict or constructive criticism, whereas collegial conversations investigate the effects and factors of teaching and learning. This requires the PLC members to ask critical questions and learn reflective practices to properly examine current goings-on within the classroom, which contributes to the examination of teaching practices to understand how they impact student learning.

Stage 1: PLC was introduced to collegial conversations

Before the planning meetings, Kelly shared her initial thoughts on the benefits and obstacles of a PLC. She wrote in her first journal entry that an effective PLC could:

> benefit both teachers and students. Teachers can collaborate with one another and share lesson plans, ideas, activities, failures, and the like. Teachers can feel supported, and newer teachers have a jumping-off point. Students benefit from a productive PLC in that their teacher is also seeking to grow and learn to best meet their learning needs. (Kelly, Journal Entry 1)

Whereas the obstacles of a PLC would be seen

> If teachers do not feel supported in their PLC or if they are not willing to share their wins and losses, then the PLC suffers. If teachers let pride or ego get in the way and forget why we are all here, to begin with, then obstacles will be created within a PLC. (Kelly, Journal Entry 1)

Based on Kelly's statements, she seems to want to go beyond the superficial sharing of ideas and discuss what supports effective teaching and student learning. Therefore, she is open to collegial conversations. However, many of her PLC members simply share materials and strategies without inquiring about their ideas. During Kelly's initial interview, she shared her opinion of the purpose of a PLC:

> So the purpose of the PLC, in my opinion, would be so that everyone teaching the same thing is on the same page; we share resources like a bunch of us will leave out our worksheets for the week or our activities for the week, and we'll just go around and take what everybody has and see how we can use it. Everybody's very supportive and giving as far as any of their lessons; we can kind of compare how students perform on our unit assessments and see…oh, well, your kids did really good on that, so my kids did not, how did you teach that…so that kind of thing. (Kelly, Interview 1, 10/21/19)

She further shared that the teachers direct the PLC to appropriate materials to utilize for their lessons:

> So, the two teachers that have taught it before will say: okay, the book is good for this; outside materials are better for this, or we did this in two days last year, so we can aim for that this year. So, it's kind of timing and what you're going to teach, not necessarily how you're going to teach it. (Kelly, Interview 1, 10/21/19)

The four planning meetings were used to understand the Mathematical Teaching Practices and designing a research lesson in which Kelly would teach the first research lesson. With Kelly being assigned the PLC lead and teaching the first lesson, she took ownership of being prepared for the meetings.

Dr. Lasky was the invited knowledgeable other to the LS and facilitated the meetings. By facilitating the meetings, he guided the teachers towards collegial conversations about teaching and learning. The first meeting introduced the teaching practices. The second meeting provided more examples of the practices and identified the lesson's mathematical objectives. Meetings three and four focused on choosing the task and writing a detailed lesson plan. His objective was for the teachers to think about these goals more deeply and posed deep questions to meet that objective. This was seen in the first meeting after he introduced the teaching practices; he stated:

> I think the first thing we can think about with these practices (MTPs) is: where are strengths; what are we doing already in our classroom associated with these practices; and then maybe what's an area that we want to continue to work to improve on. (Dr. Lasky, Planning Meeting 1, 10/29/19)

Dr. Lasky asked the teachers to reflect on their practices, which initiated the dialog towards the improvement of teaching and learning. Kelly shared her fears and concerns by stating: "I don't know how to build their (the students') confidence in a way so that they're not afraid to take chances," then she would follow her concerns with a question, "how do we break out of that (providing repetitive worksheets) to get to the deeper meaning?" (Kelly, Planning Meeting 1, 10/29/19). Her questions typically asked for advice to improve her teaching practice, which promoted deep conversation. When Kelly realized that she struggles with letting the students struggle, Dr. Lasky pursued this as the goal for the lesson study. He shared what lesson study is and how the group was expected to progress:

> Lesson study is a cycle. It starts with planning…then one person will teach it while the others observe in some capacity, and then afterwards, we reflect upon

> that lesson… We'll talk about the lesson: how can we structure the lesson in a different way; what other questions can we ask them, or how can we rework the task a little bit; or whatever it may be…it's about the lesson. And then we'll revise that lesson based on those recommendations…We're all going to share our experiences and our backgrounds here, and through that, we gain an understanding of how to reflect upon a lesson. (Dr. Lasky, Planning Meeting 1, 10/29/19)

Dr. Lasky shared some ideas to support productive struggle in the learning of mathematics.

> Some of that can come before the lesson even starts…it's kind of setting the norms of your classroom. What you can do is you can actually talk to your students about perseverance, like what does it mean to persevere…so if I were to walk into a room and students were struggling productively, what would I hear? What do you think? (Dr. Lasky, Planning Meeting 2, 10/31/19)

He encouraged the teachers to think about the learning environment and the expectations they may have for the students. Once the teachers discussed the classroom environment, they moved the conversation towards choosing mathematical objectives. Kelly provided everyone with a copy of the skills and standards of systems of equations. In deciding which standards would be appropriate for the study, Kelly asked, "They (the students) should know how to graph it (linear equations) already, right?" (Kelly, Planning Meeting 2, 10/31/19). Then the teachers shared potential tasks, which kept to congenial conversations:

Brian: Something I tried last year was I introduced systems in a jigsaw lesson.

Kelly: Yes, I remember you saying that.

Brian: They struggled at first, but they got to research it on their own. So, they had to look it up and then teach each other what they found, and then we talked about it.

Kelly: Did you give them specific questions to look up?

Brian: Well, yes, and no. I gave each group a specific method to look up.

Kelly: Got it. (Planning Meeting 2, 10/31/19)

From this exchange, Kelly was observed asking technical questions about Brian's approach. Critical questions would include how his approach impacted the students' understanding.

In the next meeting, Kelly brought a variety of tasks and said, "I don't know what the is best one to use" (Kelly, Planning Meeting 3, 11/7/19). Dr. Lasky facilitated the next steps of the meeting, "It might make sense if everybody got one (pass out the different tasks) and kind of dissected it and then shared." (Dr. Lasky, Planning Meeting 3, 11/7/19). He encouraged the teachers to examine each of the tasks to assist in selecting an appropriate task. He reminded the teachers to consider the lesson study goals and mathematical goals when choosing a task.

The teachers finished the lesson plan together during the final meeting, without Dr. Lasky. However, Dr. Lasky sent an email to Kelly with some comments, which helped initiate the conversation of the meeting towards being collegial. These suggestions were designed to drive the discussions towards considering how the students would understand the task. The teachers were encouraged to make decisions that would best help students meet the mathematical goals. Kelly shared that

> Dr. Lasky's feedback was about what solution paths do we anticipate and consider making the total cost (in the task) whole numbers, so that guess and check is possible…what I'm asking you is what would be some good questions for this (task) and what solution paths do you think the students will use? (Kelly, Planning Meeting 4, 11/14/19)

Kelly also shared potential questions that she had written to pose to students as they work through the task. These questions are: 1. Can you write a function for each shopping order? 2. How many variables will you use? 3. What do the variables mean? 4. What methods can you use to solve the problem? 5. What does the solution to each function mean? After sharing Dr. Lasky's comments and sharing her questions, she looked to her peers for additional suggestions for the research lesson.

> Kelly: I wrote some questions that are not very deep questions, but…
>
> Jessie: Asking them what the variables mean makes them go deeper than they normally would.
>
> Kelly: Okay.
>
> Jessie: At least for my kids.
>
> Kelly: Okay
>
> Jessie: And asking what they mean is good.
>
> Kelly: Okay.

Brian: I think the second question (How many variables will you use?) helps with number 1 (Can you write a function for each shopping order?); I mean, if they can't write a function, then they can't move on to the next question.

Kelly: Right, okay.

Brian: I mean, if they can't write a function

Kelly: Yeah. (Planning Meeting 4, 11/14/19)

This dialog showed how the conversation was pulled towards congenial as Jessie shared her opinion of Kelly's questions but moved towards collegial as Brian was examining the relationship of two of the questions. Once those questions were discussed, Kelly reminded them that they needed to discuss other solution paths and focused on listing different methods.

Kelly: How else do you think they're going to try to solve this?

Jessie: There might be some that graph it, or they could graph it and make a table, maybe?

Kelly: So, make a table and plug things in.

Jessie: mm-hmm

Kelly: How do you think they would graph it with the two variables in it? What would they try to do?

Brian: I'm hoping they would create a linear equation.

Kelly: So, solve it for y?

Jessie: Ideally, they would know that it would have to be $y = mx + b$.

Kelly: Okay.

Jessie: Maybe that could be something that we remind them of?

Kelly: Yeah. So, could we incorporate that into the bell work?

Lisa: Well, how would…

Kelly: So, my thought for the first one, I would say $5x + 4y =$ the total, and then they could solve for y and then put it in the calculator; that's what I was thinking they would do.

Lisa: My thought, I always use the letters of the things.

Kelly: Okay, yeah.

Lisa: So, 's' and 's,' so I was thinking that we should change the snacks to chips.

Kelly: Okay, yeah.

Lisa: So that they could have different letters.

Kelly: Okay, that's good. So, they could use 's' and 'c,' good, that works.

(Planning Meeting 4, 11/14/19)

The teachers discussed an obstacle the students may have been faced with if the task remained as finding the cost of soda and snacks.

Kelly also tried to get guidance on the starter problem for the first research lesson. She initiated the conversation with a claim that she does not like her bell work. Starting with a claim pushed the conversation towards seeking approval (congenial), which Brian did. Kelly followed Brian's statement with a question designed to investigate how the bell work was related to the task.

Kelly: What do you think of the (bell) work…I don't like what I have. What would be a good problem? I have the emojis, and they (the students) would solve it…it doesn't hit everything I want it to.

Brian: But it doesn't have to hit everything. It's just to get them thinking.

Kelly: Yeah…so, in the bell work, what would the emphasis be that would lead to the task? How would I make the connection (from the bell work to the task)?

Brian: Well, that's substitution, which is one of the methods.

Kelly: Okay. (Planning Meeting 4, 11/14/19)

Kelly posed questions to the PLC that invited perspectives from her peers. These questions opened opportunities to discuss teaching and learning around the bell work. However, the responses to the questions kept the conversation at a congenial level.

Kelly took this lesson and taught it to her students. After the teachers watched the lesson, they met to reflect on the lesson. The debriefing meeting started with the teachers sharing what they noticed: "I will say that I noticed that they (the students) were way more engaged with that smiley face (emoji starter problem, see Figure 12) than the other problems" (Lisa, Debriefing Session 1, 11/20/19). The conversation shifted from sharing what was noticed to examining what students were doing:

Lisa: There were kids that were multiplying by twelve because there are twelve sodas, and there's thirty bags of chips in the case; are there thirty bags? Where did they get thirty bags of chips; why are they adding extra numbers?

Kelly: Well, I had said…they're asking what's a case of chips, like a bag? No, I'm like a box of thirty; and then they took the thirty and ran with it. I never should have said thirty.

Lisa: You could say those snack-size packs. (Debriefing Session 1, 11/20/19)

After the teachers shared what they noticed about the lesson, Dr. Lasky shifted the conversation towards the revisions of the lesson by starting with the bell work, and to make sure "that it's intentional and to get students to think in ways that we want them to, to lead into the task" (Dr. Lasky, Debriefing Session 1, 11/20/19). His suggestion was to "pick one of these (one of the four starter problems), maybe the first one. What do you think?" By following the suggestion with the question, he invited the teachers to provide their perspectives.

When the PLC collaborated, their conversations typically focused on merely sharing their experience in the classroom. This type of conversation is classified as congenial. However, with Dr. Lasky's facilitation, the teachers started to explore collegial conversations during this first stage. This occurred because he guided the teachers through reflective practices and encouraged the teachers to provide their perspectives.

Stage 2: Collegial conversations emerged from the examination of the lesson

This stage is documented by focusing on the second debriefing meeting. Like the previous meeting, Dr. Lasky had the instructor of the research lesson share their thoughts on the lesson. This meeting had Jessie share first, "I was thinking about the questions, I tried to use the questions that we came up with (questions from the developed lesson plan), but sometimes they didn't work" (Jessie, Debriefing Session 2, 12/3/19). Kelly followed these statements by acknowledging the difficulty of using the questions: "I felt the same way (not able to use the created questions from the developed lesson plan), that they (the students) had nothing to fall back (lacked prior knowledge) on, so it was very difficult to move forward" (Kelly, Debriefing Session 2, 12/3/19). Sharing her feelings kept the conversation at a congenial level. She shared things she liked about the lesson that she will try to implement in the final lesson:

> I liked your clock.
>
> I liked that you handed out the task, so everybody had it instead of just putting it on the screen.
>
> I liked your bell work; I wrote less is more about your bell work.

She also asked a technical question: "how did you pick your groups" (Kelly Debriefing Session 2, 12/3/19). Kelly also asked questions about the structure of the lesson: "the other thing I had was individual think time because I know I didn't do that…would it help…I might try it" (Kelly, Debriefing Session 2, 12/3/19). Asking about individual think time pushed the teachers to think about how the structure may affect the students. As Kelly was asking about the structure of the lesson, she still had her concerns about the final research lesson, "I'm hoping when I do this again (teach the third research lesson) on Thursday, we will have at least been through solving systems by graphing and elimination. So, I'm hoping they'll (the students) have more to build on" (Kelly, Debriefing Session 2, 12/3/19). Kelly shared this concern with the group and looked for guidance on how to proceed with the lesson.

Kelly: What would happen if no one has an answer?

Dr. Lasky: Well, hopefully, somebody wrote something down, and we can use whatever that is. So, if they just wrote 5x, we can start with that.

Kelly: Okay.

Dr. Lasky: And we can ask them (the students), what does x represent? What does the 5 represent? And getting them to think about what those values represent, so that's just an example. But having that discussion about what those represent doesn't really give the problem away or take away the productive struggle that's going to happen, but it helps them think through the task. (Debriefing Session 2, 12/3/19)

Dr. Lasky responded to Kelly's question with strategies that would encourage student understanding. By exploring the different strategies pushed the conversation towards collegial.

Brian focused his comments on the structure of the lesson. He asked a technical question related to the allotted time provided to the students.

Brian: Did you give them 20 minutes to work on it (the task) and then 5 minutes for the poster?

Jessie: That's kind of how it worked.

Brian: Okay, I liked that you're going to work on it (the task) for this amount of time, and now you're going to make your poster.

Jessie: The original intention was you had 20 minutes to figure something out and put it on the poster; that worked in my third period.

Brian: I like that…now you're going to write it on paper, and now we're going to stop and put it on the poster. (Debriefing Session 2, 12/3/19)

In addition to asking questions about the lesson, the debriefing sessions can be a time for teachers to share their teaching experiences. Linda, another member of the group, shared her experience with the task. She shared that the students were able to solve the task within twenty minutes. This showed the group that solving the task was manageable in the allotted time. Dr. Lasky asked about the students achieving the goals: "Your students were able to set up an equation?... They understood what the solution meant?" (Dr. Lasky, Debriefing Session 2, 12/3/19). Dr. Lasky asked Linda questions to show the teachers that they could achieve the intended mathematical goals.

Dr. Lasky: Because that was our goal, was to write the system from a real-world context and understand the solution in the real-world context, right. Those were our two main goals: how they got from one to the other, right. So, if they were able to do that…

Linda: That was the only thing I changed with mine; I didn't have them write the system first. I just wanted to see them find the answer; I just wanted to see if they could solve it. And I told them at the end, hey; you just solved a system of equations. I wanted to show them that they had the background knowledge to apply. (Debriefing Session 2, 12/3/19)

After Linda shared her experience, Dr. Lasky redirected the teachers to

think about the lesson moving forward is the structure of it, so really thinking through time…like how much time are we going to give them for individual think

> time, how much time are we going to give them for group discussion, and then let's consider the cycle between small and whole-group discussion, so like if they're struggling for like four or five minutes or so, let's pause the class and have that whole group discussion about either something that one group did or something that you noticed… and then okay now let's go back to our groups and see if we can take what we've discussed, take what we've learned and apply it somehow. (Debriefing Session 2, 12/3/19)

By this stage, the teachers were willing to ask questions about the choices in the classroom. However, many of these questions were classified as technical questions. These are questions that keep the conversation classified as congenial because they do not inquire about the effects of student understanding. The teachers utilized this debriefing session to share their experiences in implementing the task. As experiences were shared, Dr. Lasky inquired about Linda's implementation to illustrate that the students could meet the mathematical goals. His inquiry demonstrated to the group that probing questions can gain a deeper understanding of the instructional choices.

Stage 3: The PLC members play a significant role in collegial conversations.

This stage focused on the third debriefing meeting and started with Kelly sharing her views of the lesson. She stated that:

> I thought it (the research lesson) went better. When I was just looking over the kids' work, there were different methods. I felt like they were thinking more this time. I felt like they were problem solving, and it might have been because the goal was to persevere in problem solving, so I don't know if that got them

thinking…I felt like they were more willing to do that (problem solving). (Kelly, Debriefing Session 3, 12/11/19).

These comments showed that Kelly was thinking about why she believed the lesson was an improvement. The other members of the PLC made similar statements about what went well:

> I think it helped with timing by having one representative come to the ELMO. I liked that you didn't actually tell them if they were right or wrong and used that as a discussion…So from the previous lesson to this one, there was a definite improvement. (Brian, Debriefing Session 3, 12/11/19)

When Lisa shared her views of the lesson, she started by probing about Kelly's opinion on the students' understanding. The teachers speculated that the students might have been more comfortable with equations, or the choice of numbers may have contributed to the students' success.

> Lisa: Do you feel like they (the students) automatically wrote equations?
>
> Kelly: I feel like it was a lot faster this time.
>
> Lisa: I don't know if having the equation gave them something to guess and check with. I really loved it when student A explained to student B what she did, and he was like, I like what you did there, but we need to know how to do it this way.
>
> Kelly: That class, as a whole, is very compassionate and helpful, so I think that has a lot to do with it.
>
> Dr. Lasky: It could also be some of the smaller numbers that were used. It may have helped with the guess and check. That kind of helped them to make sense of

it, and you told them that it was only integers or whole numbers. (Debriefing Session 3, 12/11/19)

Lisa also shared her opinion of what was missing from the bell work. The only method that was highlighted during the bell work was the elimination method. Even though Lisa made a statement of what she felt was missing, Dr. Lasky provided suggestions on how to push student thinking with fake student work.

Lisa: It might have been cool if you could have had somebody's work that did it by graphing and somebody that did it by elimination and show it under the ELMO.

Kelly: I don't think anybody tried to graph it. They're avoiding graphing, like crazy, but yeah.

Lisa: I really wanted to see that they did it this way and then discuss.

Kelly: Nobody graphed the bell work.

Dr. Lasky: And one way you can get around that is to put student work up there and have some fake student work, that's a student in another class, but doesn't really have to be. But a student in another class did it this way. What did they do; how did they do that; what does this mean, and have some questions around this. So, you could always have some fake student work that, I mean, they don't know that it's yours.

Kelly: I love it!

Dr. Lasky: But if you want to bring those ideas up, then we can ensure that happens by doing that. So, that's just an idea. So, I'm glad you brought that up. (Debriefing Session 3, 12/11/19)

The teachers progressed through the depth of their conversations as they collaborated during the three phases of the study. Initially, the teachers engaged in congenial conversations as they identified what was noticed in the research lessons. When the teachers shared what they noticed, they did it without probing about the instructional choices. By the final meeting, the teachers continued to share what they noticed, but the teachers included statements that showed they considered what contributed to the changes within the lesson. Those statements indicated that the teachers were examining and reflecting on the instructional practices. By adding the additional statements helped to move the conversations toward collegial conversations.

Research Question 3: How does LS help a novice teacher develop MKT?

This question references identifying the changes in Kelly's knowledge in each of the domains within MKT. However, the data shows changes in two of the domains: Knowledge of Content and Teaching and Knowledge of Content and Students. The answers to this question are described through three stages to describe the novice teacher's development of these domains within MKT.

Stage 1: Kelly focused on the portrayal of content

The initial interview with Kelly revealed that she struggled with pedagogical content knowledge. The specific domains within MKT that she struggled with were Knowledge of Content and Teaching and Knowledge of Content and Students. In fact, her statements focused on the need to complete a planned lesson during a class period to be effective.

> I felt like we (the observed class before the lesson study) were getting there (objectives of the lesson) slower, and I didn't end at the point I had wanted to end at, so I couldn't pull it all together. So, I felt like I left them hanging because today I did the same lesson (in a different class), and we were able to get to the ending point where I wanted to be, and it made a lot more sense. (Kelly, interview 1, 10/21/19).

She did not make statements related to student understanding. Because Kelly lacked Knowledge of Content and Students (KCS), she did not understand what the students needed to succeed.

The lesson study started with the four planning meetings. Throughout these meetings, Kelly looked to her peers for advice, "how do we break out of that (providing repetitive worksheets) to get to the deeper meaning?" (Kelly, Planning Meeting 1, 10/29/19). The responses to this question helped Kelly to gain pedagogical content knowledge. Brian responded with, "you need to get them to tell you how they got their answer," and shared that he "answers things wrong" (Planning Meeting 1, 10/29/19). Dr. Lasky clarified that what Brian was describing was to "have them critique the reasoning of others, including you." These statements explained how a lesson could be structured by having students critique the reasoning of others.

Kelly taught the first research lesson, and the structure of the lesson consisted of the starter problem directly to group work, followed by the students presenting their work. The presentations did not consist of a purposeful structure but instead chose to call on volunteers to present their work. Throughout this task, Kelly struggled to identify what the students would find difficult.

The students worked on the bell work as she was taking attendance. When she finished taking attendance, she proceeded to discuss each of the starter problems. At the end of the discussion of the starter problems, Kelly asks the class, "any questions on this?" and then moves to the task, "alright, I want you to think about this when I put up a problem" (Kelly, Research Lesson 1, 11/18/19). She had a student read the task and tried to clarify information on the task by saying, "so when we're talking about the sodas it's like a 12-pack of cans; and cases of chips, I'm thinking like those Frito-Lay cases with like thirty of them in there." The students used the additional information about the number of cans and chips as they worked through the task. This was something Kelly did not anticipate. Once she finished describing what was meant by cases of soda and cases of chips from the task, she informed the students that "I'm not going to tell you how you're going to do it, but think about everything you've learned to this point to answer: How much does each case of soda cost and how much does each case of chips cost." This information was meant to encourage and motivate the students to persevere through the task. Following these statements, the students worked in their groups. She circulated the room to check on the students' progress. She would encourage the students to check their solutions and to create equations by saying: "see if that works. How could you check to see if that works?" or "so, can you come up with an equation to represent that?" (Kelly, Research Lesson 1, 11/18/19). Kelly then had each of the groups present their work, and the lesson closed with Kelly graphing the equations derived from the task and then had the students write responses to the meaning of the variables. She would ask similar questions to each group, which did not advance the students' thinking through the task.

During the debriefing session, the lesson structure was discussed, as well as recommendations for the next lesson. However, when Kelly shared her initial thoughts of the lesson, she made statements that further showed her lack of pedagogical content knowledge.

> I felt good about the lesson…I was disappointed that there weren't that many solution paths…I would say (to the students), think about how we can make this is into an equation or how many equations do we need; then I would come back, and there would be no equations. So, what else could I have said? (Kelly, Debriefing Session 1, 11/20/19)

Throughout this stage, many of Kelly's statements focused on the quantity of material presented to the students during a lesson. That was shown in her initial interview as she discussed finishing the lesson and again during the debriefing session as she asked about additional statements to share with the students to improve their understanding. Kelly had an initial misconception that providing more information to the students equates to a better and more informative lesson. Dr. Lasky suggested simplifying the bell work to provide some scaffolding to the students. Kelly shared that her intention was "to incorporate the different methods (of solving systems) so hopefully, they (the students) would pick something to fall back on, but that didn't work" (Kelly, Debriefing Session 1, 11/20/19).

This first stage showed that Kelly struggled with pedagogical content knowledge, specifically knowledge of content and students and knowledge of content and teaching. She struggled with understanding what students needed to be successful. Her lessons consisted of the topics from the mathematical standards and may contain many examples. Kelly did not consider how the students would react to having so many examples within one lesson.

Stage 2: Kelly integrated content and pedagogy

Jessie taught the second lesson and incorporated Dr. Lasky's suggestion of simplifying the starter problem. After teaching the lesson, Jessie shared her struggle with asking appropriate questions when students presented unanticipated work in the classroom. Kelly acknowledged her statement and shared that she felt the same and proceeded to share things she liked: "I liked the bell work; I wrote less is more about the bell work." The fewer questions on the bell work were purposeful and helped to scaffold the task and created an effective way to transition into the task for the students. She saw Dr. Lasky's suggestion in action helped Kelly understand that lessons are not about the quantity of material presented in a lesson. Kelly also reflected on the structure of the lesson and asked if individual think time would be helpful. The debriefing session closed with Kelly restating to the group the changes she will consider for the final research lesson; the changes included: "the bell work, individual think time, an individual handout for the task, small to whole group cycle, and setting up the goal to persevere in problem-solving."

During this stage, Kelly made reflective statements that showed she was reflecting on the design and structure of the lesson. By acknowledging the choice of a purposeful starter problem and asking about individual think time showed she was reflecting on the structure of the lesson.

Stage 3: Kelly focused on student understanding

Kelly started the final lesson by introducing the goal for the class: to persevere in problem-solving. She asked the class, "what does persevere mean?" (Research Lesson 3, 12/5/19). After the students provided some ideas, Kelly clarified that it means "to keep going; to not give up" (Research Lesson 3, 12/5/19). Kelly used this goal to encourage the students to productively struggle through the task. The students then worked on their bell work to solve one system. In the final debriefing session, Kelly shared that "I remember saying this at the last meeting, less is more. So, with the bell work, I had a lot less bell work. I felt like I made the point faster, and they got it when we were done instead of dragging it out" (Kelly, Debriefing Session 3, 12/11/19). This enactment showed that the structure of the lesson had an impact on student learning.

> Kelly: This is a system, so, when we have a system, how can we solve for x and y? We can graph them, or we can use elimination. What does a system mean again?
>
> Student 1: It's a, umm…
>
> Kelly: It's made up of one thing, many things, which one?
>
> Student 1: It's the input and output.
>
> Kelly: Okay, not quite.

Student 2: It's two or more equations.

Kelly: Yeah, so we got a couple of things going on in this system, right. These two equations make up a system. And remember, when we solve for systems, we used graphing, and we used elimination, okay. Was anybody able to do that here? Was anybody able to put it in the calculator?

Student: No, that's a way?

Kelly: Well, that's one of the ways, graphing. You can graph in your calculators. So, when I look at this, what do I notice about the y's?

Student: They're the same.

Student: They're opposite.

After the solution to the bell work was discussed, she presented the task to the students:

Kelly: Okay, so here's our task. Here's the problem we need to solve (reads the task). The price of the tacos and the price of the sides are whole numbers. So, what does that mean when we're talking about price?

Student: There's no decimal.

Kelly: There's no decimals; there's no change. Using any method you wish, I need you to determine the cost of each taco and the cost of each side. So, our goal is to determine how much the tacos cost per taco and how much the sides cost per side. I'm going to hand out…everybody's going to get their own paper, and I'm going to give you about five to eight minutes, individually, to think about how you might want to do this, okay. Write down some ideas, and then you're going to share your ideas with your group. (Research Lesson 3, 12/5/19)

By asking for clarification about the price, Kelly encouraged the students to make sense of the task. She considered the knowledge the students would need to be successful as they work through the task (KCS). Kelly provided clear expectations about the class structure when she informed the students they would work individually first. She shared her expectation for the teaching sequence and structure of the class (KCT). Kelly circulated the class; when she stopped at a group, here's the dialog:

> Kelly: I like that you have two equations and two variables; that's good. Something happened here; you've got a good start. You added those, but did anything eliminate?
>
> Student: No.
>
> Kelly: No, so how can you make something eliminate? What did we do?
>
> (Research Lesson 3, 12/5/19)

This pattern of questioning helped the students to complete their work through the elimination method.

During the presentations, Kelly tried to reiterate the need to make equations to complete the task.

> Group 3: So, we made equations.
>
> Kelly: Hold on, she made what?
>
> Group 3: Equations
>
> Kelly: She made an equation, with how many variables?
>
> Group3: With two.

> Kelly: With two variables, and how many equations? (Research Lesson 3, 12/5/19)

The final group came to the ELMO and stated: “I’m going to explain where I got lost.” This was an opportunity to discuss and critique the reasoning of others. As the students shared their confusion, this was an opportunity for Kelly to develop KCS by learning about misconceptions.

The final research lesson structure differed from the first lesson in that it included individual think time. This time allowed the students to think about the task independently and contribute ideas when collaborating with their assigned group. Kelly purposefully sequenced instruction to allow individual think time. She shared during the debriefing session that “I felt like that (structure of the lesson to go from individual to group to the whole class) made a big difference” (Kelly, Debriefing Session 3, 12/11/19). She also explained her thoughts during the group presentations. She intended to sequence their work purposefully.

> I was trying to start with the guess and check and then move up from there. The problem is that some students in the same group had different methods written down, and I didn’t see them both; I just saw one. So then when they got up here and presented, they presented two different things, and I was like, oh, I didn’t see that other one. (Kelly, Debriefing Session 3, 12/11/19)

Kelly shared that she was not aware of every students’ work. For her to sequence in a way she anticipated, she needed to be specific about whose work to bring to the ELMO.

During the final interview, Kelly reflected on the LS and shared what she learned from the experience. She started by sharing her thoughts on lesson planning.

> I focus less on the material and more on how the students are going to respond to the material and their likely answers, and how I can guide their thinking. So, when I first started planning lessons, it would be like, okay, here's the material I need to present, here's how I'm going to present it, and I really didn't think too much about how the students were going to receive it. Now I think more about what they're going to think about it, their likely answers, and where I think they'll go wrong. (Final Interview, 12/18/19)

She further shared her thoughts on the quantity of the material presented to the students and shared that she learned about

> the amount of material I try to cram into a lesson. So I've learned that less is more; I've learned that…and my colleagues taught me that, so when I had my first bell work, it had four different things on it, and then Jessie's just had one thing, one problem and that was way more effective than my four things, so I've learned that. And I've also learned that I can buy myself some time by having the students turn and talk because I don't always know…I can't always anticipate, having not taught this before, what the students are going to come up with and that turn and talk will give me some time to figure out where I want to go next with the lesson instead of just keep going and floundering around. (Final Interview, 12/18/19)

Another thing that had an impact on Kelly was to consider the students' knowledge. She further explained that

> I honestly never thought about thinking about what the students were going to think, I just thought about the end goal, like they need to learn this, and I never thought about what roadblocks they would hit along the way; what things didn't make sense. I also never thought about if they could solve some of these things a little differently than I would, so I never kind of took that into consideration when I was planning a lesson, and now it's helpful; it makes sense. (Final Interview, 12/18/19)

During this stage, Kelly considered the students' needs. She started to realize the importance of how the students may react to the lesson.

Through participation in LS, Kelly developed MKT. Initially, Kelly focused on the pacing guide to make her planning decisions. She would present many examples that would illustrate each mathematical goal. Through this process, she realized that she does not need to give many examples to be effective. Kelly also shared that planning a lesson with the students' understanding in mind makes sense. However, with being a new teacher, she struggles with knowing what to anticipate. She realized that she needs to be prepared to use the teaching strategy, turn and talk, to alleviate this issue. By having the students turn and talk, Kelly will be able to listen to the students and learn how they experience the lesson.

Research Question 4: What are the key factors supporting or hindering a novice teacher's learning through LS?

This question refers to relevant factors that may have influenced the development of the novice teacher. To identify potential factors, the researcher gathered data throughout the different phases of the study, as stated in Table 3. These factors may have hindered or supported her growth during LS. Potential factors that may have impacted the novice teacher's growth through the study include: a knowledgeable other, multiple cycles of LS, teacher attitudes, and the understanding of the process and materials. Kelly had a supportive team that contributed to her learning through LS. Her team consisted of her PLC members and the knowledgeable other.

This study observed a first-year teacher during interactions with her PLC as they collaborated to develop and improve a lesson and observed her teach the lesson. The design of this study created the opportunity for the researcher to obtain an in-depth understanding of the novice teacher as she progressed through LS, which assisted in capturing key factors. The following sections will describe the supporting and hindering factors.

Hindering Factors

Many novice teachers feel stressed as they transition into the classroom (Lewis, 2014). Like many novice teachers, Kelly felt stressed. She voiced her feelings of being overwhelmed at the start of the study. Because Kelly was an alternative route first-year teacher, she was also attending classes at the local university. As she was participating in this study, she was completing coursework and preparing for her first observation. Kelly was also assigned the role of the PLC leader. The collaborative meetings occurred during the PLC's common planning period, which added concern for Kelly because she was unsure how the study would impact the PLC meetings (Field Notes).

Furthermore, the PLC members voiced concerns that they were sacrificing their planning time to participate in the study. They were concerned that they would not achieve their goals because they were meeting for the study and not planning their courses. These initial concerns may have contributed to Kelly's stress because they were also voiced to her. Future studies need to consider teacher buy-in because a novice teacher benefits from having a supportive team to alleviate stress (Lewis, 2014). Furthermore, time was a constraint. The researcher considered this factor and utilized video as a tool to overcome teachers needing to take time off to observe. However, this required the teachers to commit time to watch the video and take notes. In fact, Lisa, Kelly's mentor, shared her views of the PLC,

> I felt like some of the members of the PLC weren't really committed to the lesson study at the beginning. I feel like if everyone were invested from the beginning, then the first lesson would have gone better and Kelly wouldn't have been so stressed at the beginning, but I do feel like the lesson study brought the PLC together." (Lisa, 12/11/19)

The study started with the PLC members reading a few chapters from *Taking Action: Implementing Effective Mathematics Teaching Practices in Grades 9-12* (Boston et al., 2017). Many of the teachers did not complete the reading. Kelly read through the book and took notes but found the reading overwhelming. Even though the reading contained information about the teaching practices, Dr. Lasky came to the first meeting with materials to thoroughly discuss the teaching practices.

During this study, the PLC considered student learning and the structure of a lesson as they developed the lesson plan using the TTLP (Appendix E) but failed to provide detail through the different sections of the template (as seen in Figure 27).

Anticipated Solutions and Instructional Supports	
What are the various ways that students might complete the activity? Be sure to include correct, incorrect, and incomplete solutions. What questions might you ask students that will support their exploration of the activity and bridge what they did and what you want them to learn? These questions should assess what a student currently knows and advance her or him toward the goals of the lesson. Be sure to consider questions that you will ask students who cannot begin as well as students who finish early.	
Correct and Incomplete Solutions	**Instructional Supports (Assessing and Advancing Questions)**
Guess and check Table/graph	Is there a more efficient way we can organize the data? Which variable is dependent, and which is independent? Does it matter? Was this the best method? How else can we solve this?
Possible Errors and Misconceptions	**Instructional Supports (Assessing and Advancing Questions)**
Determining which variable to solve for.	How can you solve for both variables?

Figure 27. A portion of the developed lesson with the use of the TTLP

This portion of the TTLP was completed during Planning Meeting 4 when Kelly asked, “How else do you think they’re going to try to solve this” (11/4/19). This dialog was classified as congenial because they treated the template as a checklist to fill out instead of using the template to gain a deeper understanding of student learning. The TTLP is designed to encourage teachers “to move beyond the structural components often associated with lesson planning to a deeper consideration of how to advance students’ mathematical understanding during the lesson” (Smith et al., 2008, p. 137). Therefore, more discussion around this template needs to occur to best promote collegial conversations within the PLC.

Supporting Factors

PLCs consist of collaborative teams that work towards achieving essential learning for all students and are committed to their own learning (DuFour et al., 2006). The PLC in this study consisted of a supportive environment. Kelly shared during her first interview that "Everyone's very supportive" (10/21/19). Kelly reiterated these statements during her final interview.

> I feel that this process (the lesson study) has made everyone in the PLC a little more open to listening to everybody else's ideas. It's not a competition like I never felt threatened by them or felt that they wanted to see me fail. I feel like I can turn to my PLC members and say, that was terrible; what can I do differently; what did you do? All the feedback was helpful, and I feel like even the teachers that have taught longer than I have even learned something. (12/18/19)

Through the use of iterative cycles of LS, the researcher was able to identify changes of the novice teacher. Each cycle showed growth, as described in the prior questions. This study also utilized a knowledgeable other; Dr. Lasky was the knowledgeable other for this study, and he assisted in the facilitation of the study. He posed questions that the teachers may not have considered without him and encouraged collegial conversations. By the final cycle, the PLC members were examining and reflecting on the instructional practices. The debriefing sessions contributed to the growth of Kelly. Dr. Lasky guided the PLC to engage in collaborative learning to improve their practice. The knowledgeable other encouraged Kelly to have an active role within the PLC by posing questions directly to her during the meetings. Typically, the mentor controls the level of participation and the pace of progression to a full member (Wenger, 1998) of the PLC. Kelly shared her views of Dr. Lasky's role during her final interview:

> He was a good facilitator. He gave us good questions to help guide our thinking and posed what-if questions. He never made anybody feel bad. He made me feel like an important part of the team even though I had the least experience. He was there to help facilitate, and he let us run with ideas, like a teacher should. He was a role model; that's funny; he showed us how teachers should be in the classroom. (12/18/19)

A new teacher needs a supportive environment that encourages the development of their teaching practices. This study provided Kelly with effective guidance that helped her reflect on her teaching practices.

Summary of Teacher Growth

Kelly has demonstrated improvements through participation in LS, as seen in Table 10. She made changes to her disposition by shifting towards productive beliefs and believes she can rely on her PLC for effective feedback. Within her PLC, the conversations started to shift towards collegial conversations with the assistance of the knowledgeable other. Her MKT improved through the process of reflection and enactment.

Table 10

Summary of Changes

Change	Description
Disposition	Kelly understands the importance of productive struggle and believes that "It's okay to not do the traditional drilling" (Kelly, final interview, 12/18/19).
Cooperative Relationships	Kelly initially looked to her PLC as a support group that shares resources, and that shifted to a group that can provide helpful feedback to improve the lesson.
MKT	KCT: improvement of the structure of the lesson by providing a purposeful starter problem and including private think time
	KCS: Kelly now attempts to anticipate student misconceptions

Further detail of Kelly's growth through each phase of the growth model follows.

Patterns of Change

The growth of the novice teacher can be observed through the LS cycle with the assistance of the Extended Interconnected Growth Model (Coenders & Terlouw, 2015). The growth model connects the development phase and the class enactment phase. The development phases consist of designing and improving a lesson. The class enactment phase is the enactment of the designed lesson. The model was adapted to illustrate and interpret the growth of the novice teacher (Figure 28).

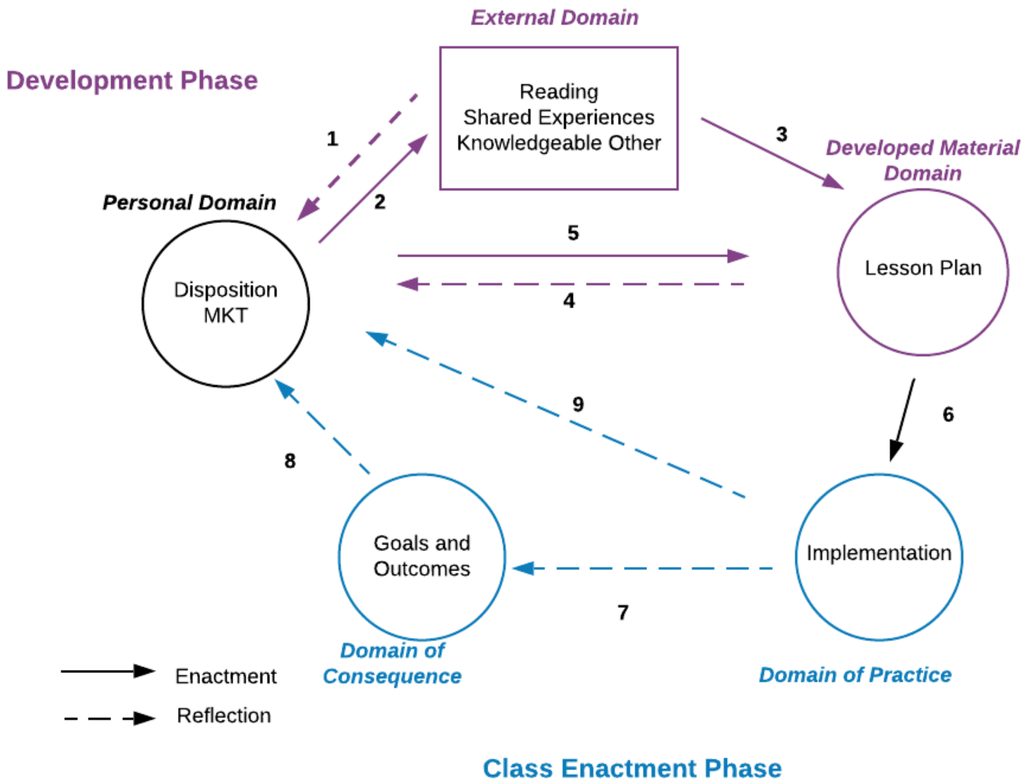


Figure 28. Kelly's Growth Network (Adapted from Coenders & Terlouw, 2015)

The development of the novice teacher occurred through practice and reflection during the different phases. Changes of the novice teacher were identified during interactions by analyzing the reflective journals, research lessons, planning, and debriefing sessions. The researcher also collected artifacts such as student work and the lesson plans. The experience impacted her personal domain that included disposition and the different domains of MKT.

Planning Sessions. Kelly's journey starts with the planning sessions. These planning sessions are the development phase (Figure 29). During this phase, her participation was at first legitimately peripheral. She was observed taking notes as she listened to Dr. Lasky and her peers. Kelly would share her thoughts when questions or statements were directed to her. This was observed when Dr. Lasky asked the group to share their experiences once he provided information about the mathematical practices. Lisa shared information about Kelly, “Kelly, haven’t you used number eight: elicit and use evidence of student thinking, as the students worked in groups at stations around the room” (Planning Meeting 1, 10/29/19). Now that Kelly was brought into the conversation, she stated that “one of the biggest things in trying to get the kids to make connections is fear” and further shared, “I don’t know how to build their confidence in a way so that they’re not afraid to take chances” (Planning Meeting 1, 10/29/19).

This phase consisted of four planning meetings to develop the lesson plan. Kelly was often seen taking notes as Dr. Lasky provided information about the mathematical teaching practices during these meetings. He provided the PLC with handouts that consisted of a self-assessment and an example of a task. The information provided by Dr. Lasky was classified within the external domain. Dr. Lasky had the teachers reflect on the information he provided (Arrow 1) as they filled out the self-assessment. The self-assessment required that the teachers reflect on information from the external domain while filling out the continuum to best represent their teaching practice. The enactment from the personal domain to the external domain (Arrow 2) was observed when Kelly chose to respond to Dr. Lasky’s question, “what might be something you would like to continue to work on” (Planning Meeting 1, 10/29/19). Kelly acknowledged her struggle and chose to share with the group, “I struggle with letting them (the students) struggle”

(Planning Meeting 1, 10/29/19). This statement led to the groups' LS goal (Arrow 3): to develop problem solvers who persevere when faced with challenges.

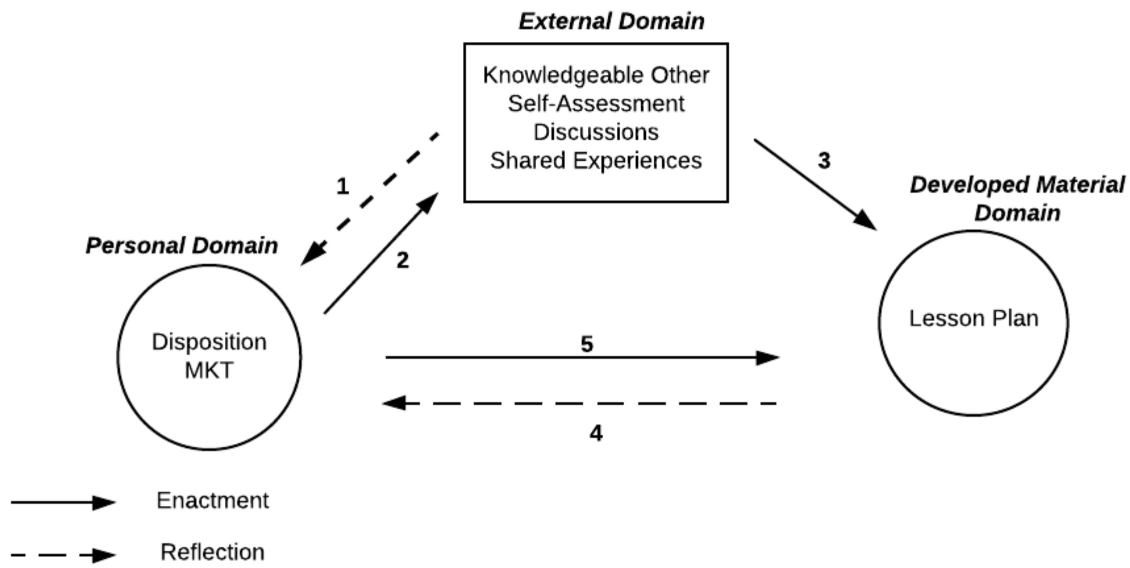


Figure 29. Adapted Development Phase

The next meetings were focused on developing a lesson plan for the first research lesson. Kelly brought a variety of tasks in the hopes of selecting an appropriate task for the lesson. In order to choose an appropriate task, the teachers needed to consider if the task would contribute to the development of problem solvers. They also needed to establish whether the task would meet the mathematical goals: set up a system of equations in context and understand the solution to the system in context. The group decided on a task and filled out the lesson plan template (Arrow 3). Kelly would read what needs to be filled out on the template, and she would write down what she hears.

Kelly: Okay, we've got learning goals; we've got the task. Prior knowledge, what prior knowledge and experience will students draw on in their work on this task?

Brian: Knowledge of standard form; knowledge of slope-intercept form; identifying variables.

Kelly: I got it; I'm writing it; keep talking. (Planning Meeting 3, 11/7/19)

Kelly had her doubts about the lesson and made some changes to the task before meeting 4 (Arrows 4, 5). She presented her changes to the group and asked for their input. She specifically asked for their feedback on the questions and starter problem.

During these meetings, Kelly felt uncertain about teaching and learning. She noticed that the template had parts for her to fill out that she had not considered. Kelly had not considered anticipating what students would think about the task. Not knowing what the students would think or which task to choose, showed her lack of KCS and KCT.

Research Lesson 1. After meeting four, Kelly implemented the lesson the group created (Figure 30). The learning goal was for the students to set up a system of equations in context and solve. The goal was written with the expectation that Kelly would see equations. As Kelly circulated the class, she looked for equations (Arrow 6). During the lesson, Kelly even reiterated what a student said: "did you hear what he said? He said you got to make an equation" (Research Lesson 1, 11/18/19). Through the implementation, conclusions were made about the preparation of the lesson plan to get the best work from students. These conclusions impacted her belief in her ability (Arrow 7). She felt uncertain, and she did not understand how to support students through productive struggle.

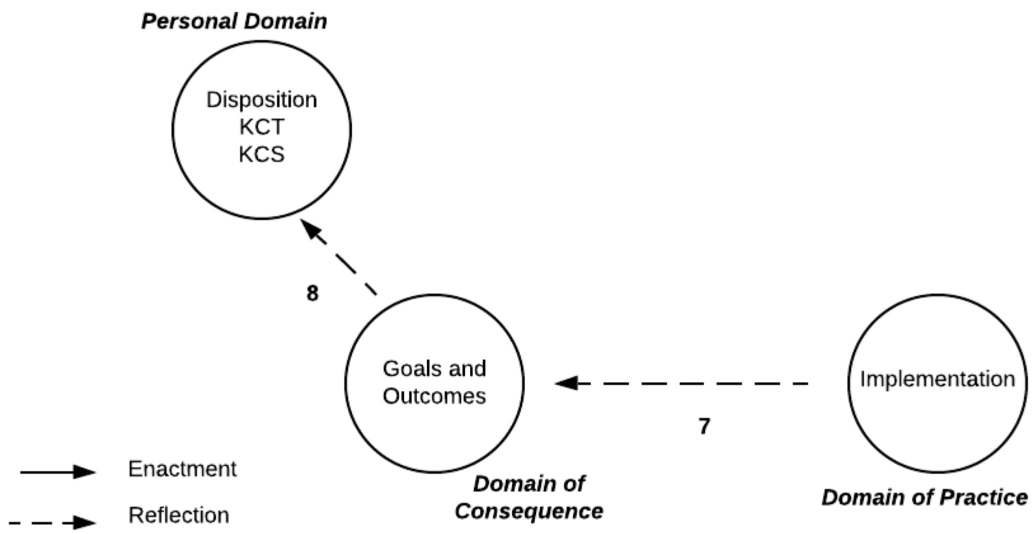


Figure 30. Research Lesson 1

Debriefing Session 1. After the lesson, the teachers debriefed. This was an opportunity for the teachers to make adjustments to the lesson. As the teachers improved the lesson, they re-entered the development phase (Figure 29). The session started with Kelly sharing her experience and views during the debriefing session (Arrow 2). Kelly reflected on her practice: “I wonder if it was my questioning…was I not giving them something to think about that could help them to move to a solution path…what else could I have said?” (Kelly, Debriefing Session 1, 11/20/19). As the other members shared what they noticed, Kelly listened to their suggestions and took notes (Arrow 1). The input from everyone impacted how the lesson plan should change (Arrows 3, 5). The takeaways from this meeting to improve the lesson were to minimize the bell work and change the wording in the task from “cases of chips” to “packs of chips.”

Research Lesson 2. Kelly observed Jessie’s implementation of the research lesson (Figure 31). As she reflected on the lesson, Kelly focused on the structure of the lesson. She identified things she liked from the lesson, such as having a timer and providing each student with a copy of the task. Kelly also liked the purposeful starter problem and described it as “less is more” (Debriefing Session 2, 12/3/19). This reflection did not reference student understanding.

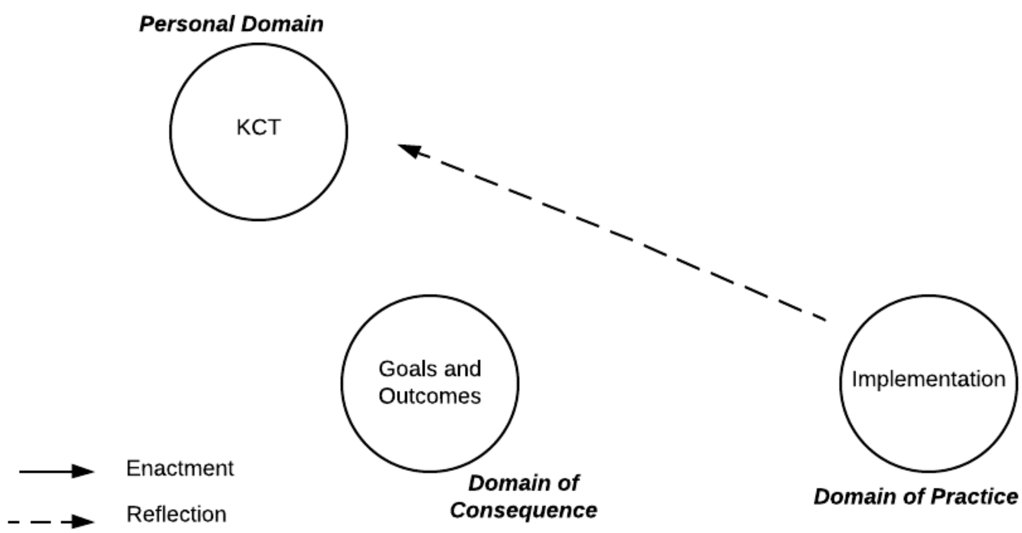


Figure 31. Jessie's Implemented Lesson

Debriefing Session 2. During the second debriefing session (Figure 29), Kelly shared her notes of the lesson (Arrow 2) and listened to other’s observations (Arrow 1). Kelly took notes as the group members shared. The meeting closed with suggestions to the structure of the lesson by including individual think time and a purposeful starter problem (Arrows 3, 5). Kelly would use their suggestions to improve the lesson in preparation for the final implementation.

Research Lesson 3. Kelly taught the final research lesson (Figure 32), and she reflected on the structure of the lesson (Arrow 8). The lesson structure consisted of bell work, the introduction of the task, individual think time, group, and then whole-class discussion. The bell work consisted of one question that led to the task.

Prior to the lesson, Kelly still had doubts about the success of the lesson. During the lesson, she observed the students working together to find a solution (Arrow 6). As the students were working in their groups, she checked on their progress. Kelly reflected on the students' outcomes, and that affected her personal domain (Arrow 7).

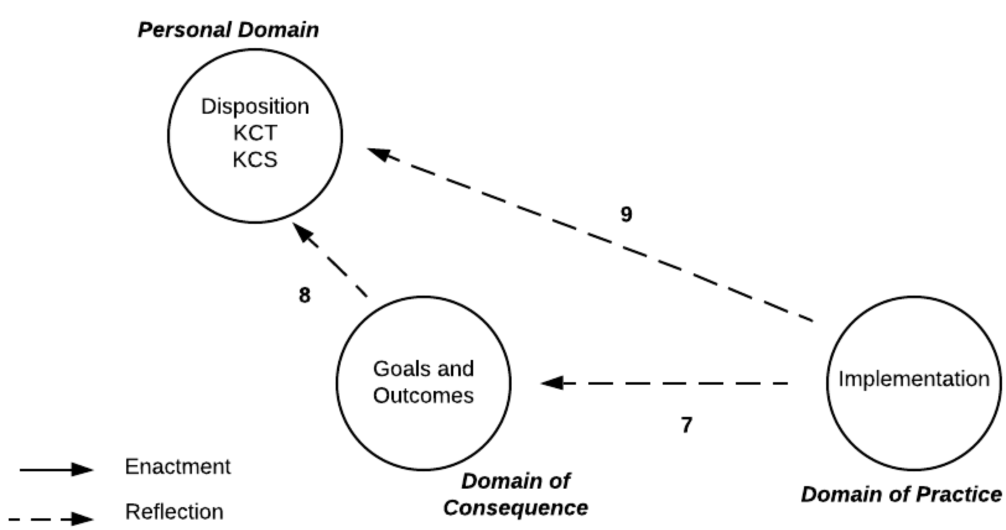


Figure 32. Lesson 3

Debriefing Session 3. Kelly's reflections prepared her for the final debriefing session (Figure 29). The debriefing session started with Kelly sharing her views of the lesson (Arrow 2). She shared that she believed the structure had a positive impact on the lesson. She shared that she did not know what to do when unsure what a student was saying. Dr. Lasky suggested that it was an opportunity to use turn and talk (Arrow 1). In addition to turn and talk, Dr. Lasky shared that fake student work provides opportunities for different ideas to be put into a lesson (Arrow 3). Kelly reflected on these suggestions and has considered these for future lessons. Through this process, Kelly now considers how the students may react to the lesson (Arrow 4).

Summary of Changes

The LS started with the planning meetings. Dr. Lasky, the knowledgeable other, facilitated the meetings. He presented information and questions that the teachers may not have considered (External Domain). As he posed questions and new information, Kelly reflected on the information (Arrow 1) and asked questions based on the presented material (Arrow 2). This information impacted how the teachers write their lesson (Arrows 3, 5). Kelly saw information on the TTLP (Appendix E) that she had not considered (i.e., Anticipated Solutions) (Arrow 4). By writing the lesson plan with her colleagues, Kelly was introduced to ideas that she had not considered. The new ideas impacted her Personal Domain. Once the lesson plan was created, she used the created lesson in her class (Arrow 6). As she taught the lesson, she reflected on her teaching (Arrow 7) and reflected on the student outcomes (Arrow 8). After the first research lesson, she felt like a bad teacher (Personal Domain) (Field Notes). Some of her reflections from teaching the lesson were shared with the PLC during the debriefing session (Arrow 2). During the debriefing session, Kelly shared that “it flustered me that no one was coming up with anything” (Debriefing Session 1, 11/20/19). The knowledgeable other provided information for the teachers to consider that would help the students to progress. This provided Kelly with information for future lessons (Arrow 1). After adjustments were made to the lesson, Jessie taught it to her class. Kelly observed the implemented lesson and reflected on the lesson (Arrow 9). Kelly shared her observations (Arrow 2), which included a purposeful starter problem and providing each student with a tangible copy of the task. Seeing another teacher implement the same lesson positively impacted Kelly because she noticed similar struggles. After improvements were made to the lesson, Kelly taught the final research lesson (Arrow 6) and reflected on her teaching (Arrow 7) and the outcomes (Arrow 8). Kelly asked, “what do you do when you have no idea what they’re (the students) are talking about?” (Debriefing 3, 12/11/19). The knowledgeable other provided a suggestion of using the teaching strategy: turn and talk. When Kelly was faced with this uncertainty during the lesson, she let the student continue to share. Kelly struggled with providing feedback to students when she sees something she is not familiar with, which is why there are no enactment arrows during the class enactment phase in Figure 28. She acknowledged positive changes in the lesson (Arrow 9) after private think time was included.

The research lessons followed the same structure: launching the task, implementing the task, and discussing the task. However, each portion of the final lesson was more purposeful. The novice teacher acknowledged “less is more,” meaning having specific problems to work through can be more powerful of a learning experience than having many problems to practice. In the final lesson, the launching of the task consisted of one part instead of four; this allowed the start of the class to be purposeful and directly related to the task. Specifically, solving a system of equations was made visible using the elimination method and assisted in directing the students to this methodology. Lesson 1 Debriefing and Lesson 2 Debriefing assisted in these changes by reflecting on the goals of the lesson and how to alter the starter problem to assist in scaffolding the task. The teacher also incorporated private think time in the final lesson. This change allowed the students to provide different solution paths within their groups to discuss. The first debriefing session emphasized the structure of the lesson: purposeful starter problem; private think time (this allows the students to make sense of the problem individually and to create a solution pathway to share with the group); and sequencing of the presentations in order to make connections to the different groups. The novice teacher considered these ideas during the implementation of the final lesson. Having a purposeful starter problem provided the necessary scaffolding to the students to persevere through the task. The teacher intended to sequence the class discussion by starting with guess and check and then moving towards the more complex solution paths, but this did not go as planned due to having a variety of methods within the same group. During the closing of the lesson, as the students shared their work, the teacher was faced with an unanticipated solution path, which also brought up a teaching strategy during the final debriefing session of turn and talk. The interviews and journals revealed that the novice teacher benefited from participating in LS as follows: (1) knowledge about content and students: anticipated student solutions and misconceptions can assist with the sequence of instruction when planning out a lesson; turn and talk promotes meaningful discourse; (2) knowledge of content and teaching: incorporating private think time into the structure of the lesson. Furthermore, all three phases of LS—development, class enactment, and intermediate—resulted in mathematical knowledge for teaching development, as seen in Figure 33.

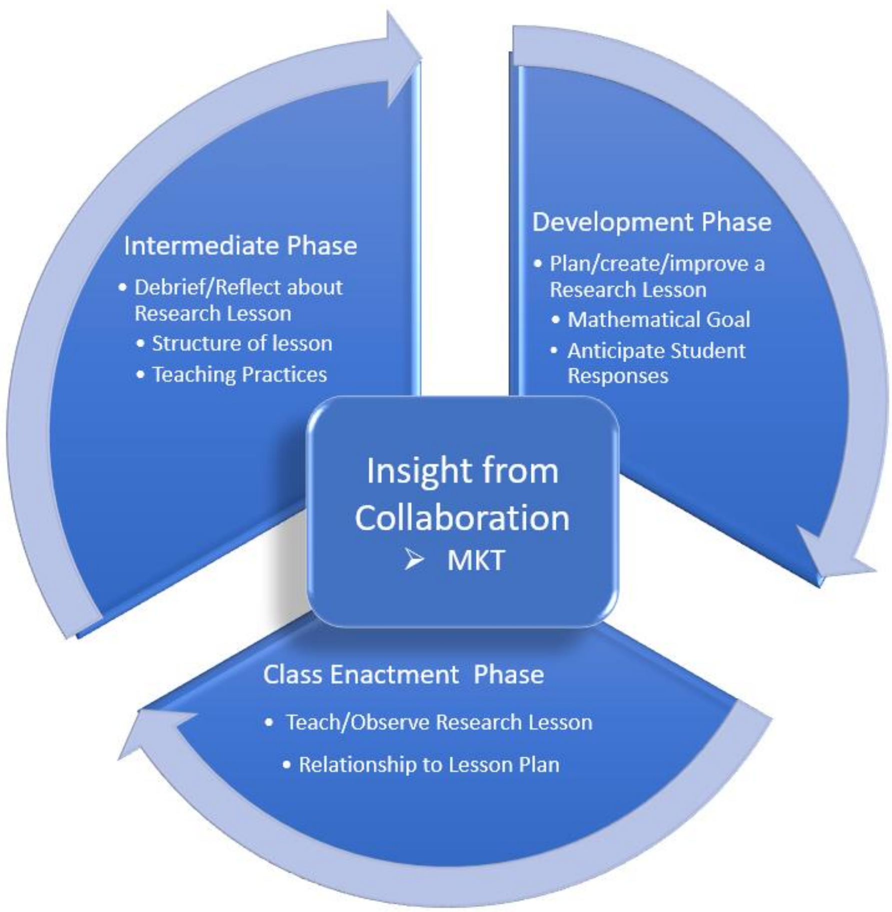


Figure 33. Phases of Lesson Study

Chapter Summary

The chapter provided detailed accounts of Kelly's experience through LS. The researcher analyzed the data to identify specific changes of the novice teacher with respect to her mathematical knowledge for teaching, disposition, and cooperative relationships. Kelly's personal domain improved through each iteration of LS. Kelly needed the opportunity to teach a second time to notice improvements in her teaching. Having the opportunity to observe another classroom provided Kelly with the understanding that teachers can have similar struggles. Furthermore, each implemented lesson provided Kelly with additional MKT. When she implemented the lessons, her reflections were focused on her teaching (KCS). When she had the opportunity to observe another classroom, Kelly focused on the structure of the lesson (KCT). The knowledgeable other was also vital to Kelly's improvement as he provided suggestions that assisted in the advancement of Kelly's personal domain. By engaging in a collaboratively designed lesson plan, the novice teacher was provided an opportunity to develop cooperative relationships. The PLC improved on their dialog by moving their conversations towards collegial conversations. The following chapter summarizes the study and discusses the results and recommendations for future research.

CHAPTER V: DISCUSSION AND CONCLUSION

Introduction

Induction programs are commonly used to support novice teachers during the first three to five years of teaching. They are professional development programs designed for the novice teacher to improve professional knowledge. LS is a specific form of professional development in which the participants are actively engaged in meaningful discussion, collaborative planning, and the enactment and discussion of lessons (Lewis et al., 2009). The positive effects of LS have been described in the literature (e.g., Huang et al., 2014; Huang & Shimizu, 2016; Lewis, 2016; Lewis et al., 2009; Obara & Bikai, 2019) (i.e., developing MKT, teaching practices, collaborative communities, and disposition, see Chapter II in detail) and provide a rationale for teachers to participate in LS. Yet, there is a lack of studies specifically related to the development and growth of the novice teacher.

This qualitative study explored how LS can contribute to the development and growth of the novice teacher. This chapter summarizes the findings of the study, discusses the contribution, and draws conclusions from the findings from this study presented in the previous chapter. Then a discussion of the implications for mathematics teacher education will be presented, followed by recommendations for further research inspired by this study.

Summary of Study

Novice teachers are new to the teaching profession and may not have the specialized skills and knowledge needed to teach mathematics effectively. Mathematics teaching should help students improve their conceptual understanding and implement Common Core State Standards in Mathematics (CSSM; Common Core State Standards Initiative [CCSSI], 2010). Novice teachers need proper support when transitioning to full-time teachers because they do not hold all the necessary knowledge and skill to be successful (Ingersoll & Strong, 2011); therefore, induction programs should be utilized in the transition of pre-service teachers to competent in-service teachers (Morris, Hiebert, & Spitzer, 2009). Pre-service teachers participate in teacher preparation programs where they are provided with opportunities to learn how to teach, then transition to the classroom to practice and implement what they learned from the programs (Wang & Odell, 2002), but they need further support. Many new teachers feel stressed and overwhelmed when they enter the teaching profession. Having a support system can help ease the stress for new teachers (Ingersoll & Strong, 2011). However, some novice teachers do not enter the teaching profession through this route. The alternative route allows individuals to obtain a teaching certification without participating in traditional teacher education programs, and these programs have been criticized for the lack of teacher pedagogical preparation (Wayman et al., 2003). Induction programs are designed to assist all novice teachers during their early years of teaching by providing the necessary support, tools, and knowledge at the start of their careers (Ingersoll & Strong, 2011; Ingersoll, 2012; Kearney, 2014; Wong, 2004).

A single-case study (Yin, 2018) was used for this study to explore LS can be used as an essential component of an induction program to acclimate a novice teacher into the teaching profession and to develop the novice teacher’s mathematical knowledge for teaching (Ball et al., 2008), disposition, and cooperative relationships with other teachers. To achieve this goal, a novice teacher was selected to participate in one LS cycle with three iterations of the research lesson. The LS group consisted of the novice teacher's PLC. For this study, the novice teacher was a first-year mathematics teacher starting the alternative route for a practitioner license. Multiple data sources were collected before, during, and after the LS to corroborate evidence and achieve triangulation (Patton, 2015; Creswell, 2007). Detailed descriptions of the single case were provided, and changes of the participant were identified throughout the LS process. Her experience was analyzed, and changes were identified through different stages of the LS cycle. The results were described through each research question and presented in terms of three stages. Then an analysis of the changes was presented through the growth network.

The novice teacher, Kelly, made changes concerning her disposition, MKT, and cooperative relationships with her peers. Kelly demonstrated that she developed a productive disposition through this study. At the start of the study, she was conflicted with what constituted effective teaching practices. Through the progression of the study, she learned the importance of teaching through problem solving to promote productive struggle in the learning of mathematics. As the teachers collaborated in the development of the lesson plan and during the debriefing sessions, the nature of their conversations shifted. Their conversations were typically classified as congenial conversations and gradually shifted towards collegial conversations during the study. Throughout the study, the teachers would simply share what they noticed within the observed lessons. However, by the end of the study, the PLC members demonstrated collegial conversations by including what may have contributed to what was observed in the lessons. Through the participation in LS, Kelly developed MKT. Initially, Kelly focused on the pacing guide to make her planning decisions. She would present many examples that would illustrate each mathematical goal. Through this process, she realized that she does not need to give many examples to be effective. Multiple iterations of the research lesson contributed to Kelly's progress. Kelly gained confidence after each iteration. Initially, she had doubts about her teaching ability and finished the study feeling confident about student learning during the final research lesson. Having a knowledgeable other present during the study also contributed to Kelly's growth. He provided valuable input that Kelly did not consider on her own.

The Extended Interconnected Model of Teacher Professional Growth (Coenders & Terlouw, 2015) was adapted (see Figure 34) to describe the growth of the novice teacher as she progressed through LS. Three phases of teacher growth make up this model: the development phase, class enactment phase, and the intermediate phase. The development phase consists of the PLC developing the research lesson. Having the PLC be the LS group allowed the researcher to examine the cooperative relationships during this phase. Following this phase was the class enactment phase. This phase consists of the teacher implementing the research lesson and observing classroom teaching. The class enactment phase did not have enactment arrows because Kelly demonstrated that she was unsure how to respond to students. The students presented solutions that Kelly did not anticipate; however, this was an opportunity for Kelly to learn through the enactment within the classroom. Kelly reflected on these unanticipated solution pathways and posed questions during the debriefing sessions. Even though Kelly was unsure how to respond to the students, she learned about different teaching strategies. The different teaching strategies were discussed during the debriefing sessions or the intermediate phase. After the teachers reflected on the lesson, they entered the development phase to discuss improvements to the lesson. This demonstrated that Kelly learned from the different environments, and learning occurred through the interaction with the individuals in the different environments: either with her PLC members in the development phase or through the observation of classroom teaching during the class enactment phase.

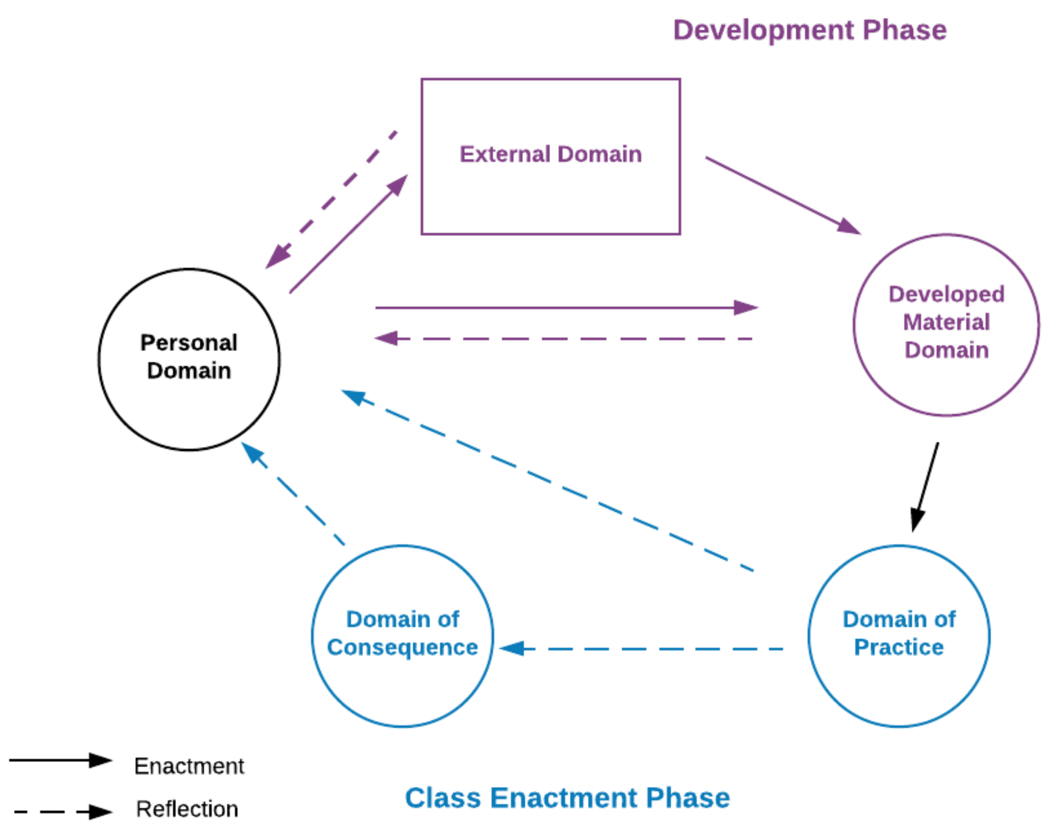


Figure 34. Extended Interconnected Model of Teacher Professional Growth of a Novice Teacher. Adapted from Coenders & Terlouw, 2015

Discussion of Results

Prior to data collection, permission was obtained from the school district and school principal. The novice teacher's mentor was an active member of the PLC who was also teaching the same subject and grade level. The knowledgeable other, the district's high school mathematics specialist, is an experienced subject matter expert with seven years of teaching experience. The design of the study purposefully considered the recommended characteristics of an effective induction program. The novice teacher collaborated with her PLC members to create a lesson plan. During the LS, her class was observed, and she observed another class. Through this collaborative process, many positive outcomes occurred for the novice teacher and the participating PLC members. These teachers progressed towards more meaningful dialog by shifting their conversations towards collegial and away from congenial.

This study illustrates the compatibility of LS with characteristics of effective induction programs, as summarized in Table 11, and justifies support of LS as a component for induction. The results of this study further support and add new insights to existing theory, research, and practice, which will be explained in greater depth in subsequent sections of this chapter. This study makes contributions in the following aspects: demonstrating a relationship between LS and effective induction programs, the importance of a knowledgeable other, and the use of EIMPG. Adopting LS as a component for induction may help overcome the weaknesses of induction that have been identified as being disjointed or lacking proper support. The discussion points described in the paragraphs that follow have both theoretical and practical significance.

Table 11

Comparison of Effective Induction Programs and LS to Kelly's Experience

A comparison of characteristics of effective Induction and Lesson Study to Kelly's Experience		
Induction	LS	Kelly's Experience
Experienced Mentor in the same subject and grade level	Knowledgeable others	Dr. Lasky, Lisa
Collaboration with other teachers	Collaboration with other teachers	PLC
Support from Principal/administration	Support from Principal/administration	Support from Principal
Observe mentor and/or veteran teachers	Observe teachers within LS	Observed Jessie
Be observed while teaching by a mentor or expert teachers	Be observed while teaching by LS group	PLC and Dr. Lasky observed Kelly

A situative perspective approaches learning as situated and constructed through participation in socially organized activities (e.g., Greeno, 2003; Lave & Wenger, 1991). In this study, Kelly collaborated with teachers from her school who taught the same subject at the same grade level. As these teachers collaborated, they could make the discussions applicable to their needs by making their conversations pertinent to their classroom; these discussions include mathematical content to teach and the pedagogy being used to teach the content. Kelly started this study as a legitimate peripheral participant. She would take notes during meetings as she listened to her peers (Arrow 1) (see Figure 35). However, due to her participation in LS and being assigned the PLC lead, she gained more responsibility and was assigned a central role. Situative learning theorists would argue learning occurs through authentic contexts, settings, and situations (Lave & Wenger, 1991) in order to gain an understanding of teaching strategies. Through the participation in LS and the support of the PLC members, Kelly was willing to try new practices within the classroom. The situative perspective can be used to capture the learning of the novice teacher as she progressed through the study.

Throughout the study, Dr. Lasky contributed to Kelly's growth. He posed questions that helped the teachers reflect on their practice, which impacted Kelly's growth and assisted in the change in the dialog of the PLC. He demonstrated that he was an essential component of the external domain. Dr. Lasky provided suggestions to the structure of the lesson, but some of his comments were not observed until the final research lesson. For example, Dr. Lasky discussed private think time during the first LS meeting and was not implemented until the final research lesson. He helped the teachers to reflect on the learning goals throughout the LS. Teachers need to have clear learning goals for students and need to consider how best to help them meet the goals. Therefore, the results of this study support that knowledgeable others contribute to the success of lesson studies (i.e., Huang et al., 2017; Takahashi, 2014; Takahashi & McDougal, 2016).

Although this study could have utilized the Interconnected Growth Model of teacher change (Clarke & Hollingsworth, 2002), it instead uses the Extended Interconnected Model of Teacher Professional Growth (Coenders & Terlouw, 2015). This study adds to the literature base on how this model can be used to interpret teacher growth by discussing the changes of Kelly through two phases: Development Phase and the Class Enactment Phases. Like Coenders and Terlouw's study (2015), the teachers discussed the logistics of cooperative learning. In addition to gaining PCK knowledge, this study reveals how the growth model could model a novice teacher in the development of her productive disposition. Furthermore, this model utilized two distinct phases of teacher growth: the development phase, followed by the class enactment phase. This study expands on the use of the development phase to model the development of cooperative relationships. The external domain consisted of the discussions and shared experiences that were provided by the PLC. These discussions shifted towards collegial conversations and positively impacted the overall research lesson (Arrow 3). The lesson plan template (Appendix E) provided questions for the PLC to consider when developing the lesson plan (i.e., What will students say, do, or produce that will give evidence of their understandings?) and how they responded to these questions could have encouraged collegial conversations. The resources and conversations (external domain) directly impact the lesson plan and teacher learning.

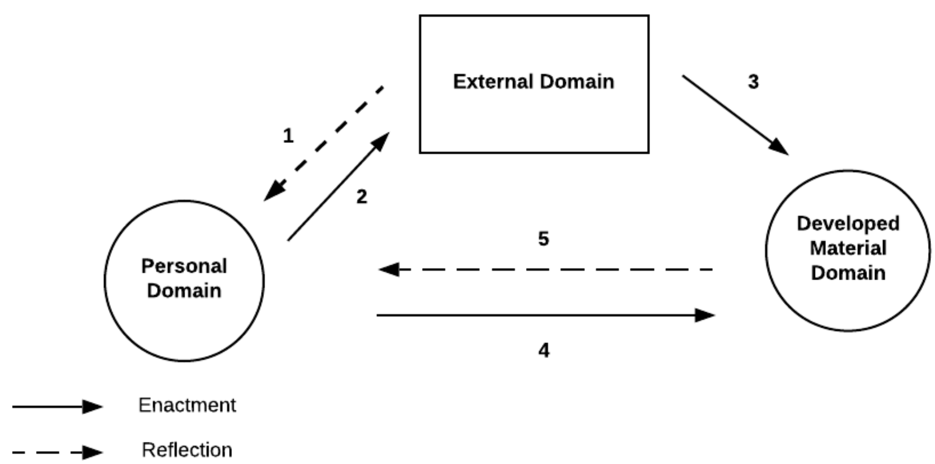


Figure 35. Development Phase

Coenders and Terlouw (2015) described the transition between the two phases (development phases and class enactment phase) as the intermediate phase (Figure 3; Arrows 7, 8). They explained these phases to be connected through the developed material domain and the domain of practice (as seen in Figure 36 with Arrow 6). This arrow describes the novice teacher deciding to use the developed lesson plan. However, the researcher connected the class enactment to the development phase through the personal domain, as seen with Arrows 8 and 9. The researcher suggested that the novice teacher acquired knowledge through the class enactment phase. The novice teacher reflected on the outcomes (Arrow 8) and reflected on the lesson (Arrow 9) before changes were made to the lesson plan. Once the changes were made, the lesson was enacted in the classroom (Arrow 6).

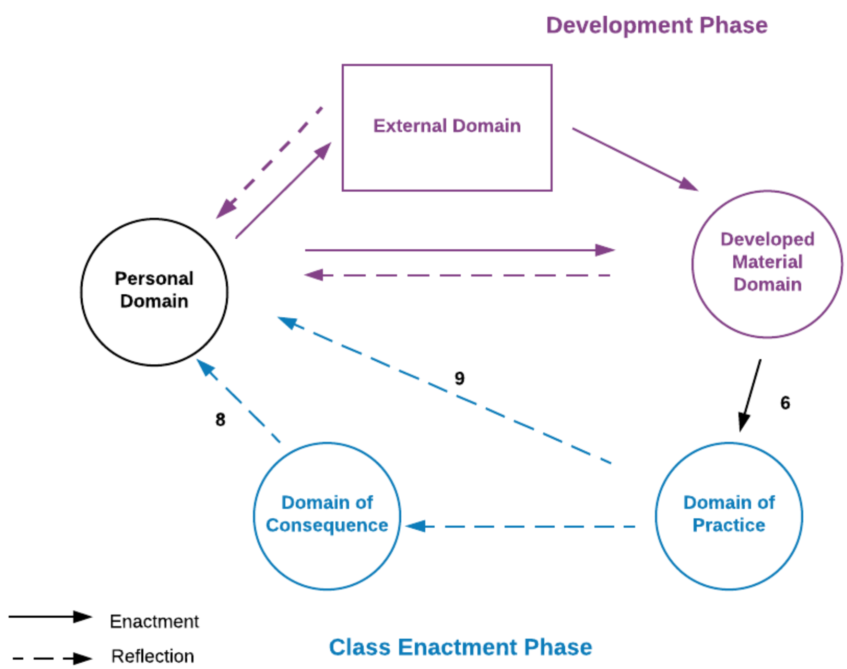


Figure 36. Extended Interconnected Model of Teacher Professional Growth Identifying the Transitions between the Two Phases

This study expands on this model by revealing additional growth patterns that lead to changes in the personal domain. Induction programs should provide support and tools that help new teachers improve their knowledge and skills at the start of their career. This study demonstrates that LS contains the core features of an effective induction program. It also reveals that LS provided the support that Kelly needed as a novice teacher while also establishing that it can provide the necessary structure and collaborative opportunities necessary to assist a novice teacher during the induction year. This study contributes to LS research by showing how LS can support a first-year teacher.

Implications

Implications for mathematics teacher education that arise from this study include instructors seeking certification through the alternative licensure route. The prevalence of alternative licensure routes creates a potential need for more LS with this expanding demographic to supplement the current research literature. In addition, expanding the focus of future LS to include other groups of educators would provide additional context and justification for inclusion within teacher induction programs. By creating the conditions for increased and improved collegial teacher communications with one another, engendering increased levels of trust within the LS group, and encouraging self-reflective practice, this study also contributes to the practices of professional learning communities and professional development programs.

Induction programs are designed for teachers during their beginning years of teaching to support and train new teachers towards becoming lifelong learners (Wong, 2004). Even though teacher induction programs have been widely researched, a specific plan to support novice teachers through induction has not been suggested. Effective induction programs should consist of: (1) an experienced mentor; (2) collaboration with other teachers; (3) sustained professional development; (4) support from principal; (5) observe others teaching; and (6) be observed (McBride, 2010; Wang, 2004). This study demonstrated that LS contains many of these elements. The results of this study provide information about how participation in LS can provide novice teachers with the necessary components of induction. Adopting LS as a component for induction may help overcome the weaknesses of induction that have been identified as being disjointed or lacking proper support. Therefore, LS should be considered as an additional component for teacher induction programs.

Supportive interactions with colleagues are important for a novice teacher. This study had the participation of a first-year teacher and the members assigned to her PLC. The school's scheduling included a shared planning period for all members of her PLC, which allowed for more frequent collegial interactions embedded within the school schedule. The district's mathematics specialist, who also happened to be experienced with LS, served as the knowledgeable other. Providing an introductory LS facilitator training would be necessary for future knowledgeable others who did not have previous LS exposure. The novice teacher collaborated with individuals with whom she already had a working relationship and improved their collaborative relationship through this experience. Therefore, PLCs should consider adopting LS to improve their collaborative interactions.

Recommendations for Future Research

This study focuses on the growth of one non-traditional novice teacher through participation in LS. Findings from this study demonstrate teacher growth through LS and provided opportunities to collaborate and discuss lessons with colleagues. Growth was identified in the novice teacher through the implementation of multiple iterations to plan and enact the lesson. Since there was only one participant in this study, the researcher can only draw conclusions from the novice teacher's experience. Even though valuable information was gathered from this study, further information needs to be collected from the participation of more novice teachers. This would include traditional and non-traditional participants and their associated PLCs. More participants would better equip districts and school officials with information to effectively acclimate novice teachers into the schools and collaborate with their associated PLCs. Furthermore, to fully gauge the change in MKT, another instrument would need to be used to measure a teacher's growth in different aspects of MKT (i.e., growth of content knowledge through participation in LS). Future researchers may consider quantitative data to gauge student achievement.

Even though this study illustrates the compatibility of LS with induction programs, sustainability needs to be considered to guarantee that new teachers are continued to be supported. Overall, this study demonstrates components of an effective induction program; but further investigation of sustainability is required to establish the impact of retention. This study adds to the literature base on the effectiveness of LS with novice teachers in the US, which is crucial because there are many ineffective induction programs within the US (Wong et al., 2005).

Chapter Summary

Many novice teachers start their teaching careers by being part of an induction program. New teachers need guidance with both creating effective lesson plans and effectively implementing the lessons within their classrooms. LS presents a promising approach in providing the necessary guidance as it is situated in the classroom (Lewis et al., 2009) and creates opportunities to reflect upon practice, promoting effective lesson plans, and effectively implementing the lessons.

Having an effective induction program is essential to providing the necessary support to novice teachers. Effective induction programs can help teachers improve their knowledge and skill in their new environment. This study utilized the PLC as the LS group and had no scheduling conflicts for the duration of the study because the teachers utilized their common planning period to collaborate. The teachers watched recorded lessons, which aided in the avoidance of scheduling conflicts. Induction programs should not add stress to teachers' schedules, and this study worked with their schedules. The results of this study reveal the effectiveness of lesson study for a novice teacher, as the participant developed productive disposition, cooperative relationships, and MKT.

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APPENDICES

APPENDIX A: Effective Teaching Look Fors Observation Protocol

Instructions: Select Teaching Practice(s) and record specific teacher moves or actions that demonstrate that Practice.

Teaching Practice (NCTM, 2014) Look Fors	***Evidenc e***
Establish mathematics goals to focus learning. ☐ Goals are appropriate, challenging, and attainable. ☐ Goals are specific to the lesson and clear to students. ☐ Goals are connected to other mathematics. ☐ Goals are revisited throughout the lesson.	
Implement tasks that promote reasoning and problem-solving. ☐ Chooses engaging, high-cognitive-demand tasks with multiple solution pathways. ☐ Chooses tasks that arise from home, community, and society. ☐ Uses how, why, and when questions to prompt students to reflect on their reasoning.	
Use and connect mathematical representations. ☐ Uses tasks that lend themselves to multiple representations. ☐ Selects representations that bring new mathematical insights. ☐ Gives students time to select, use, and compare representations. ☐ Connects representations to mathematics concepts.	
Facilitate meaningful mathematical discourse. ☐ Helps students share, listen, honor, and critique each other's ideas. ☐ Helps students consider and discuss each other's thinking. ☐ Strategically sequences and uses student responses to highlight mathematical ideas and language.	
Pose purposeful questions. ☐ Questions make the mathematics visible. ☐ Questions solidify and extend student thinking. ☐ Questions elicit student comparison of ideas and strategies. ☐ Strategies are used to ensure every child is thinking of answers.	
Build procedural fluency from conceptual understanding. ☐ Gives students time to think about different ways to approach a problem. ☐ Encourages students to use their own strategies and methods. ☐ Asks students to compare different methods. ☐ Asks why a strategy is a good choice.	
Support productive struggle in learning mathematics. ☐ Provides ample wait time. ☐ Talks about the value of making multiple attempts and persistence. ☐ Facilitates discussion on mathematical error(s), misconception(s), or struggle(s) and how to overcome them.	
Elicit and use evidence of student thinking. ☐ Identifies strategies or representations that are important to look for as evidence of student understanding. ☐ Makes just-in-time decisions based on observations, student responses to questions, and written work. ☐ Uses questions or prompts that probe, scaffold, or extend students' understanding.	

APPENDIX B: Comments Form

1. To what extent did the lesson tasks, activities, and/or discussion support the lesson objectives?

2. What representations/strategies/approaches did students use to solve problems and demonstrate their understanding? Which ones may need more attention going forward?

3. What questioning and discourse went well, and what was challenging?

4. In what ways did you see students making connections (between concepts and procedures; between representations; to previously learned concepts; to the real world)?

5. In what ways were students asked to grapple with mathematics? How effective were your strategies to support their struggle without taking away students' thinking?

6. To what extent were you able to determine whether each student learned the objectives?

7. What do you feel were the most successful aspects of this lesson?

8. What are you learning that you would like to remember when you teach this lesson again?

APPENDIX C: Mathematics Teaching Practices

1. Effective mathematics goals to focus learning

2. Implement tasks that promote reasoning and problem solving

3. Use and connect mathematical representations

4. Facilitate meaningful mathematical discourse

5. Pose purposeful questions

6. Build procedural fluency from conceptual understanding

7. Support productive struggle in learning mathematics

8. Elicit and use evidence of student thinking

APPENDIX D: Teaching and Learning Beliefs Survey

SD = Strongly Disagree D = Disagree A = Agree SA = Strongly Agree

Belief	SD	D	A	SA
1. Mathematics learning should focus on practicing procedures and memorizing basic number combinations.				
2. The role of the teacher is to tell students exactly what definitions, formulas, and rules they should know and demonstrate how to use this information to solve mathematics problems.				
3. All students need to have a range of strategies and approaches from which to choose in solving problems, including, but not limited to, general methods, standard algorithms, and procedures.				
4. The role of the teacher is to engage students in tasks that promote reasoning and problem solving and facilitate discourse that moves students toward a shared understanding of mathematics.				
5. Mathematics learning should focus on developing understanding of concepts and procedures through problem solving, reasoning, and discourse.				
6. An effective teacher makes the mathematics easy for students by guiding them step by step through problem solving to ensure that they are not frustrated or confused.				
7. Students can learn to apply mathematics only after they have mastered the basic skills.				
8. Students can learn mathematics through exploring and solving contextual and mathematical problems.				
9. An effective teacher provides students with appropriate challenge, encourages perseverance in solving problems, and supports productive struggle in learning mathematics.				
10. The role of the student is to memorize information that is presented and then use it to solve routine problems on homework, quizzes, and tests.				
11. The role of the student is to be actively involved in making sense of mathematics tasks by using varied strategies and representations, justifying solutions, making connections to prior knowledge or familiar contexts and experiences, and considering the reasoning of others.				
12. Students need only to learn and use the same standard computational algorithms and the same prescribed methods to solve algebraic problems.				

APPENDIX E: Thinking through a Lesson Protocol (TTLP) Planning Template

Learning Goals What understandings will students take away from this lesson?	**Evidence** What will students say, do, or produce that will give evidence of their understandings?
Task What is the main activity that students will be working on in this lesson?	**Instructional Support – Tools, Resources, Materials** What tools or resources will be available to give students entry to – and help them reason through – the activity?
Prior Knowledge What prior knowledge and experience will students draw on in their work on this task? **Essential Questions** What are the essential questions that I want students to be able to answer over the course of the lesson?	**Task Launch** How will you introduce and set up the task to ensure that students understand the task and can begin productive work, without diminishing the cognitive demand of the task?

<table>
<tr><th colspan="2">Anticipated Solutions and Instructional Supports</th></tr>
<tr><td colspan="2">What are the various ways that students might complete the activity? Be sure to include correct, incorrect, and incomplete solutions.
What questions might you ask students that will support their exploration of the activity and bridge what they did and what you want them to learn? These questions should assess what a student currently knows and advance her or him toward the goals of the lesson. Be sure to consider questions that you will ask students who cannot begin as well as students who finish early.</td></tr>
<tr><td>Correct and Incomplete Solutions</td><td>Instructional Supports (Assessing and Advancing Questions)</td></tr>
<tr><td>Possible Errors and Misconceptions</td><td>Instructional Supports (Assessing and Advancing Questions)</td></tr>
<tr><td colspan="2">Sharing and Discussing the Task</td></tr>
<tr><td>Selecting and Sequencing
Which solutions do you want students to share during class?</td><td>Connecting Responses
What specific questions will you ask so that students:
• Make sense of the mathematical ideas that you want them to learn
• Make connections among the different strategies and solutions that are presented?</td></tr>
<tr><td colspan="2">Homework/Assessment</td></tr>
</table>

Monitoring Tool

(Green – complete prior to lesson; white – complete during the lesson)

Anticipated Solutions	Instructional Support		Who/What	Order
	Assessing Questions	Advancing Questions		
Unanticipated Solutions				

APPENDIX F: Self-Reflection Journal Questions

Self-reflection Journal 1

R1. Regarding the lesson I observed, what are the most exciting moments? Why?

R2. Regarding the lesson I observed, are there some things you are not satisfied with? Why?

R3. If you have an opportunity to re-teach the lesson, what will you do differently?

R4. Can you describe what a favorite lesson looks like?

R5. Regarding the PLC I observed, what part do you like most? Why?

R6. What part do you not feel is beneficial? Why?

R7. What are the benefits of a PLC?

R8. What are the obstacles of a PLC?

Self-reflection Journal 2

R9. Pick 2 or 3 Mathematics Teaching Practices that you believe are the most difficult to implement. Explain why you believe this.

Self-reflection Journal 3

Reflecting on the strengths and weaknesses of the lesson taught:

R10. Do you feel you achieved the overall goals of the lesson?

R11. What are the most exciting moments?

R12. Are there anything you would like to change if you teach this lesson again?

R13. What have you learned from reviewing your own teaching and reflecting on the lesson?

R14. What have you learned from the feedback of other PLC members?

Self-reflection Journal 4

Reflecting on the strengths and weaknesses of the lesson taught:

R15. Do you feel you observed the achieved the overall goals of the lesson?

R16. What are the most exciting moments?

R17. Are there anything you would like to change if you teach this lesson again?

R18. What have you learned from reviewing your own teaching and reflecting on the lesson?

R19. What have you learned from the feedback of other PLC members?

Self-reflection Journal 5

Reflecting on the strengths and weaknesses of the lesson taught:

R20. Do you feel you achieved the overall goals of the lesson?

R21. What are the most exciting moments?

R22. Are there anything you would like to change if you teach this lesson again?

R23. What have you learned from reviewing your own teaching and reflecting on the lesson?

R24. What have you learned from the feedback of other PLC members?

APPENDIX G: Before Lesson Study Interview

B1. Describe what teachers should be doing during a lesson.

B2. Describe what students should be doing during a lesson.

B3. How do you think the lesson/class went? What worked?

B4. What is your perspective on the teaching and learning of mathematics?

B5. Was the instructional objective met? How do you know students learned what was intended?
When you are teaching, describe what you observe that you consider evidence of student learning. (What do you look for so you know students have learned?)
How do you use that evidence? (How do you know when you can move to the next topic?)

B6. Were the students productively engaged? How do you know?

B7. How do you prepare for a lesson?

B8. Did you deviate from the plan during the lesson? Why?

B9. What additional assistance, support, and/or resources would have further enhanced the lesson?

B10. If you had the opportunity to teach the lesson again to the same group, would you do anything differently? Why?

B11. Describe how you and your colleagues collaborate. This may include planning to teach, discussing a lesson that has already been taught, or discussing a unit that will be taught. How often do you collaborate?

B12. What is the purpose of the PLC?

B13. Were the goals met of the PLC meeting?

APPENDIX H: During Lesson Study Interview

D1. How do you think the lesson/class went? What worked?

D2. Reflecting on the observed lesson, what aspects of the lesson do you feel did not go as well as they could have?

D3. Based on what you observed, what suggestions do you have for the lesson?

D4. Were the students productively engaged? How do you know?

D5. What were your take-aways from observing the lesson?

APPENDIX I: After Lesson Study Interview

A1. Describe how lesson study has influenced how you and your colleagues collaborate. This may include planning to teach, discussing a lesson that has already been taught, or discussing a unit that will be taught.

A2. Tell me how you plan a lesson when you are preparing without your colleagues. Are there things that you consider now as you make your plans that you did not consider before this experience in lesson study?

A3. When you are teaching, describe what you observed that you consider evidence of student learning. What do you look for so you know students have learned?

A4. What did you learn while participating in lesson study? This could be many things: mathematics content, how students think mathematically, how your colleagues view some aspect of teaching different from your own view, how you interpret standards or curriculum, etc.

A5. Describe any contributions of the knowledgeable other. This may be about the enactment of a lesson, the mathematics of the lesson, etc. How did the contributions influence what you learned?

A6. As you think about the things we focused on in lesson study, how might this experience influence how you examine practice, either your own or another colleague's? You may want to describe how you may have "looked" at the practice of teaching before lesson study and how you may "look" at it now.

A7. Reflecting on lesson study, what have you learned, or what have you thought about differently due to our conversations and work? (collaboration, mathematics, pedagogy, expectations for students, evidence of student learning, etc.)

A8. Did you, at any time, during lesson study, plan or instruct or even think about mathematics teaching and mathematics learning differently because of something we did or discussed during lesson study?

A9. What things have we discussed during lesson study that you had not thought of before or that were surprising to you or that you disagreed with?

A10. What have you tried because of our work in lesson study in your classroom, outside of the lesson we planned together?

A11. What do you see as the role of the knowledgeable other in lesson study?