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Using Student and Teacher Thinking to Improve Teaching and Learning

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This research project examined how a teacher and an instructional coach can use formative assessment data on student thinking to improve the teaching and learning in a mathematics classroom. Two research questions guided the project and from them three instructional strategies emerged. The first strategy was the use of formative assessment data collected on student thinking from a previous lesson to plan for the learning in future lessons. The second strategy was the use of formative assessment data collected on student thinking during a lesson to make decisions about how to proceed with the lesson. The third strategy was the creation of a student-centered learning environment based on the Sociomathematical Norms where student thinking is made available to the teacher. The research suggest that mathematics teachers who elicit student thinking through formative assessment and then use that thinking to plan and implement math lessons create a stronger leaning environment.

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This research project examined how a teacher and an instructional coach can use formative assessment data on student thinking to improve the teaching and learning in a mathematics classroom. Two research questions guided the project and from them three instructional strategies emerged. The first strategy was the use of formative assessment data collected on student thinking from a previous lesson to plan for the learning in future lessons. The second strategy was the use of formative assessment data collected on student thinking during a lesson to make decisions about how to proceed with the lesson. The third strategy was the creation of a student-centered learning environment based on the Sociomathematical Norms where student thinking is made available to the teacher. The research suggest that mathematics teachers who elicit student thinking through formative assessment and then use that thinking to plan and implement math lessons create a stronger leaning environment.

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Chapter 1

Introduction

Research Questions

- How does a teacher improve the teaching and learning in the classroom by using formative assessment data to make adjustments in a current lesson as well as plan future lessons?
- How does an instructional coach use information gathered from classroom observations and student responses to assessment problems to improve the coaching of teachers?

This study is an action research project on how a teacher uses formative assessment data to inform lesson planning and how an instructional coach can be supportive in this endeavor. The study is based on the coplanning of mathematics lessons, observations of instructional practices that elicit information on student thinking, and the reflective discussions between the coach and the teacher on how the lesson affected student thinking on the content standard being addressed. This first chapter of the dissertation introduces the reader to the context of the study as well as the problem the study will be addressing. The importance of the study and an overview of the methodology will also be presented.

Context of the Study

In this study, I will present the work of an instructional coach as an embedded form of professional development. I will also discuss a teacher's use of formative assessments to generate data that can be used to plan future classroom lessons as well as make adjustments to a current lesson. Finally, I will examine the instructional coach's use of formative assessment data in coaching as a path to improve a teacher's use of formative assessment data in teaching.

Data is information (Erickson, 1985; Maxwell, 2013). It may be quantitative and evaluated by statistics, or it may be qualitative and evaluated by interpretive inquiry (Lincoln, 1995). The formative assessment data I will be referring to in this study is qualitative and will be generated by a teacher's observations of students interacting with each other through the content as well as from evaluating student responses to written assessment prompts. Qualitative data is as much about the thinking a student demonstrates as he or she creates the response to the prompt as it is the correctness of the response (Lincoln, 1995). The information gathered from these two sources can then be used by the teacher to target instruction towards improving how students think about the ideas and understandings associated with the prompt (Duckor, 2014; Tomlinson, 2014; Ritchhart, 2015).

Instructional coaching is also about collecting information. However, the work of the coach is to gather and assess teacher thinking as the teacher is facilitating a lesson as well as evaluating students' responses to written assessment prompts. By evaluating the thinking a teacher uses to make planning decisions, both during the class period as well as between class periods, the instructional coach can target the coaching to the instructional needs of the teacher.

This study will also be looking at the data, or information, an instructional coach gathers to use in improving the instructional practices of the teachers being coached. Just as formative data is used by a teacher to inform their instruction, the information a coach gathers on what teachers are thinking about as they teach and assess is used to inform their coaching.

Instructional coaching as an embedded form of professional development. My approach as an instructional coach has been to serve the teachers I work with by establishing myself as the lead-learner (West & Staub, 2003). As such, I try to position myself as a student in my coaching. Just like the role of the interviewer is to learn from the participant and use their responses to make meaning of the issues being studied, the role of a coach is to listen to and make meaning of the instructional questions a teacher is asking (Creswell, 2007; Knight, 2007; Maxwell, 2013).

In this project, my participant and I will coplan lessons, I will observe her teach the lesson, we will then debrief on the effectiveness of the lesson through the student work collected, and coplan next steps for classroom experiences based on the student data. I will be using the reflective cycle to support the participant as we reflect on the effectiveness of a lesson, what the teacher and students did, why this happened, did it meet the needs of the students, and what might be done the same or differently in future lessons (Gibbs, 1988). To drive this conversation, we will be looking at how students perform on assessment tasks and use this information to plan future lessons and how they will be taught (Tomlinson, 2014). We will also be discussing in the moment use of data to make adjustments to the lesson based on what students demonstrate as they are learning (Duckor, 2014).

Using formative assessment data to plan lessons. Formative assessment is an ongoing exchange between teacher and student and has great potential to improve both teaching and learning (Duckor, 2014; Tomlinson, 2014). Formative assessment data can be gathered through short formative assessment problems, evaluated collectively for proficiency using a rubric, and then used to form an awareness of student understanding which can then be used to make decisions about future lessons. By providing insight on a student's current understanding, formative assessment can also assist a teacher in making in the moment adjustments to the lesson so that learning proceeds as intended (Duckor, 2014). When used as a bridge between the beginning and the end of the lesson or between today's and tomorrow's lesson, formative assessment data becomes a mechanism for increasing student understanding leading to higher scores on classroom, district, or state assessments (Bambrick-Santoyo & Peiser, 2012; Duckor, 2014; Dufour & Eaker, 1998; Tomlinson, 2014).

The effectiveness of a lesson is not about how it was taught; rather it is about whether the students learned what was taught (Bambrick-Santoyo & Peiser, 2012; Boston & Smith 2009).

By focusing on the learning, teachers can see beyond their efforts to the results of their efforts when they use student work formatively to decide what to teach next and how to teach it (Dufour & Eaker, 1998; Goodwin & Hein, 2016). Using formative assessment data in this capacity can support teachers to more effectively target their planning and teaching as they create student-centered classrooms to meet the needs of their students (Duckor, 2014; Goodwin & Hine, 2016; Kazemi & Stipek, 2001).

The use of formative assessment data in coaching to improve a teacher's use of formative assessment data in teaching. Student-centered classrooms promote a learning environment where the focus is on the student's learning, and teacher-centered coaching promotes a learning environment where the focus is on the teacher's learning (Duckor, 2014; Tomlinson, 2014). Just as a teacher needs to focus on student thinking gathered through formative assessments, an instructional coach also needs to focus on teacher thinking through planning sessions, classroom observations, and debriefing meetings (Carpenter, Fennema, Franke, Levi, & Empson, 2000; Knight, 2014). In gathering and using information through classrooms observations and debrief discussions an instructional coach can target the needs of a teacher in gathering formative assessment data on his or her students.

Problem Statement

Creating strong learning environments, which draw out the mathematical understandings students need to be proficient on standards, can be difficult, but using formative assessment data gleaned from both observing students as they learn as well as from collected assessment items can assist the teacher in creating lessons which target the needs of students (Duckor, 2014; Tomlinson, 2014). The difficulty of using formative assessment data to improve the learning environment in the classroom has led me to ask the following research question:

- How does a teacher improve the teaching and learning in the classroom by using formative assessment data to make adjustments in a current lesson as well as plan future lessons?

In a similar way, creating a strong learning environment which draws out the instructional understandings a teacher needs to be proficient in creating a strong learning environment for students is also difficult (Bay-Williams, McGatha, Kobett, & Wray, 2014; Knight, 2007). Using information gleaned from classroom observations as well as discussions of student mathematical understandings from collected work can assist the instructional coach in targeting the needs of teachers. The difficulty of using formative assessment data to create a strong coaching environment has led me to ask this second research question:

- How can an instructional coach use information gathered from classroom observations and student responses to assessment problems to improve the coaching of teachers?

The goal of this study is to research the strategies a coach uses to gather and assess a teacher's thinking on how formative assessment data can be used to improve instructional practices. This study will address a teacher's ability to use formative assessment data to improve their teaching as a measure of the effectiveness of coaching strategies.

My beliefs that undergird this study are:

1. Effective teaching requires the use of formative assessment data to target the educational needs of students.
2. Effective instructional coaching improves teachers' instructional practices.
3. Effective coaching requires the ability to gather and use information on teachers' instructional practices as well as evaluation of student work to target the instructional needs of a teacher. This will improve the effectiveness of the coaching, which in turn will improve the instructional practices of the teacher being coached.

Over the course of this study, I found three instructional strategies emerge as important to answering the two questions of this study. The first strategy was planning lessons based on the understandings students bring from previous lessons. The second strategy was using student thinking generated during the lesson to make in the moment decisions about how to proceed with the lesson. The third strategy was creating a classroom environment based on the Sociomathematical Norms where student collaboration promotes the mathematical understanding of every student in the classroom (Yackel & Cobb, 1996)

Importance of This Study

This research will use what is known about using formative assessment data to target the needs of students and take this understanding to see how an instructional coach can use teacher thinking to target the need of teachers. By looking at formative assessment data on two levels, data gleaned by the math teacher on what her students are learning about math and data gathered by an instructional coach on what his teacher is learning about teaching and learning, this study will give a comprehensive analysis of the use of formative assessment data on two levels.

Methodology

In this section I will give an overview of the methodology I will use in this study. I will give a short description of the case study approach to inquiry and present the stages used to gather the data for the study. I will also describe the coach/teacher relationship and how this study will provide opportunity for the participant and I to work closely on important issues in teaching and learning.

The value of choosing a case study for a qualitative inquiry. The case study method will be employed because it provides the opportunity to engage in action research with one participant by describing a phenomenon in context. This is based on a constructivist paradigm which allows for the creation of meaning (Baxter & Jack, 2008). Flyvbjerg (2006) supports the belief that case study plays a significant role in understanding human learning because case study is a context-dependent approach which allows the researcher to progress from novice to expert. In the study of human affairs, all knowledge is context-dependent. In contrast, people tend to remain at the novice level when they are trained through context-independent methods.

Stages used to gather data. There will be four stages used to collect data as I work with my participant. First, we will coplan the main lesson from the district-approved resource using the Launch-Explore-Summary planning model (Van de Wall, 2007). Second, as my participant teaches the main lesson, I will observe and script the instructional decisions made to gather and collect data as well as the decisions made on how to use the data during the lesson. Third, we will meet to debrief the effectiveness of the main lesson based on the evidence of student learning from my observations as well as collected student work. We will also plan the reteach lesson during the debrief stage based on the data for student thinking from the teaching stage. Fourth, I will observe and script the instructional decisions the teacher makes in the reteach lesson based on the data analysis from the debrief of the main lesson. These planning and debrief stages will be audio recorded and the teaching and reteaching stages will be video recorded. The researcher will transcribe and analyze the recordings and use that data to determine how the participant is taking on the facilitation strategies that give students the opportunities to share their thinking. The researcher will then analyze how the participant uses that student thinking to plan and implement mathematics lessons. In this study, I will repeat this cycle of planning, teaching, debriefing, and reteaching three times during the Fall semester of 2017. A more detailed description of these three cycles will be provided in chapter 3 of this dissertation.

Bias in the study. I have worked with the participant as her instructional coach for 18 months. In this time, I have come to know her as a strong learner who is willing to try on new ideas and approaches to forming a learning environment in her classroom. As an established coach in the school building and the researcher of this investigation, I am placed in a unique position to engage in this action research study. I must consider throughout the course of the study how my close work with this one teacher affects my relationship with the other 12 math teachers whom I also coach. I also need to validate the history I have already established with my participant in order to minimize its effects on the interpretations I make as I collect and analyze the data. Finally, I need to consider what all these relationships look like after the study concludes because I will need to continue to work with these people once this study has concluded.

Introductions

The Research Participant. The research participant in this study, whom I will refer to as Amy, is a white middle class math teacher beginning her fifth year in the profession. She has been working at the same middle school for the last three years. She graduated from college in 2012 with a degree in elementary education and went back to get her highly qualified status in secondary mathematics. Amy recalls that as a student math ideas came easier to her than to her peers, and at times keeps her from appreciating the struggle some of her students have with math. In school, Amy liked learning math at her own pace and so avoided advanced track classes where students were pressured to perform at levels she was not interested in. I have been Amy's instructional math coach for the last 18 months, primarily supporting her in creating student-centered mathematics classrooms. Amy is learning how to use students to support other students as she facilitates the discussions using the student-centered instructional practices she and I have been working on.

Whereas Amy's classroom will comfortably hold up to 30 students, all her class sizes this school year are in the mid-20s. She has an interactive white board on one wall, which is mainly used to project problems for her students to work on. However, she does use the graphing and transformations features with her interactive board as well as switching between the projector and the visualizer to show and discuss examples of student responses to problems. On the opposite wall are two large regular white boards that Amy uses to post the learning outcome(s) for the day as well as space for students to solve problems publically for the class.

As her coach for the last 18 months, I have found Amy to be a risk taker who is willing to try on new ideas to improve her teaching. I believe that Amy will be a strong participant for this case study approach because she is early in her career, eager to learn, and she is open to feedback on her instructional practices. We have also formed a solid relationship over the last 18 months allowing us to press each other in taking on new ideas about teaching and learning. Her characteristics as a professional make her an ideal participant for this study, and I consider myself fortunate that she has agreed to join me in this research project.

The Researcher. I am an instructional math coach working at an urban middle school of over 1000 students in a department of twelve math teachers and three special education teachers. This is my third year at this middle school, however I have been an instructional coach for the past nine years and have worked across the district at most of the middle schools and all of the high schools. Before I was a coach, I worked at both the high school and middle school level as a math and science classroom teacher. This is my 29th year as an educator, and they have all been spent in the same school district.

As a veteran math teacher and coach, I bring a wealth of experiences, knowledge, and understanding to the work of developing classroom instructional practices. My goal in this position is to serve the teachers and administrators I work with, and my hope is that I will leave the position with established understandings about how to use student data to improve planning and teaching. My belief is that better planning and teaching creates better opportunities for more students to achieve in the classroom and beyond.

I believe that knowledge is socially constructed (Crawford &Witte, 1999; Kazemi & Stipek, 2001; Yackel & Cobb, 1996). As her instructional coach, I will need to continually check in with my participant to ensure that we have common understandings in how we are making sense of the work we are doing. This does not necessarily mean that we have formed a single truth, but rather provides for reflection on the complexity of the process. These check-ins will occur through the act of coreflection throughout the study.

Definition of Terms

In this section, I will provide definitions of the primary terms used to describe and answer the research questions posed.

Classroom Discourse: A facilitated classroom conversation where all members have the opportunity to engage authentically in each other's thinking (Frykholm & Pittman, 2001). Discourse is a key agent of education because it gives evidence about whether anticipated learning has occurred (Wagner, Herbal-Eisenmann, & Choppin, 2012).

Formative Assessment: The process of a classroom teacher gathering and using information on student understanding specifically to target their teaching to the academic needs of the student (Duckor, 2014).

Instructional Coaching: The work of a full-time on site professional developer who unpacks teacher's instructional goals to help them realize their professional aspirations (Knight, 2007).

Problem-Based Teaching: An approach to instruction where learners probe deeply into problems or issues searching for connections and exploring with complexity before they receive formal instruction (Stephien & Gallagher, 1993). This will also be referred to as reformed or progressive teaching.

Sociomathematical Norms: normative aspects of mathematical discussions that are specific to students' mathematical activity and understanding (Yackel & Cobb, 1996).

Summary

Planning mathematics lessons is a critical component to creating a learning environment where students think like mathematicians as they solve math problems (Boston, & Smith, 2009). The difficulties teachers have with collecting, analyzing, and using formative assessment data to improve planning mathematics lessons has prompted my interest in studying the ways to support teachers in using data to inform their both their lesson planning and instruction (Bambrick-Santoyo & Peiser, 2012; Duckor, 2014; Tomlinson, 2014) . Instructional coaches also have difficulties collecting, analyzing, and using formative assessment data to improve the instructional practices of the teachers they are coaching (Bay-Williams et al., 2014; Knight, 2007). To study these issues, I have chosen to engage in an action research study with one fifth year math teacher where I can observe the use of formative assessment data as a tool to both improve a teacher's planning and teaching as well as coach's planning and coaching.

This chapter outlined the various components of my study, the background of the study, and why I find the study to be important. I have stated the problem I wish to address as well as an overview of the methodology I will be using to research the problem as I search for solutions. The next four chapters will include a review of the literature as it pertains to collecting student data and using it to plan lessons, a detailed description of the research methodology I will employ, an analysis of the data collected, and a discussion generalizing the conclusions drawn from the study.

Chapter 2

Literature Review

Research Questions

- How does a teacher improve the teaching and learning in the classroom by using formative assessment data to make adjustments in a current lesson as well as plan future lessons?
- How does an instructional coach use information gathered from classroom observations and student responses to assessment problems to improve the coaching of teachers?

This chapter includes a literature review on the current state of educational reform in mathematics as well as how gathering and using formative assessment data can improve teaching and learning in our nation's classrooms. A description of how teachers use formative assessment data as well as how instructional coaches use teacher thinking will be made. This literature review will reveal that while there is much known about the need to gather and use formative assessment data in the classroom, how this can be supported by an instructional coach through the collection of formative assessment data on teacher thinking is not well understood in the literature.

Taking Action

Teachers need to know they are a part of a larger struggle to promote a strong community (Cochran-Smith, 1991). Whereas a teachers' primary responsibility is to his or her classroom, teaching is fundamentally a political activity that extends beyond the walls of the schoolhouse (Cochran-Smith, 1991). The fundamental role of education is to prepare the next generation of citizens to be critical thinkers who can solve the next generation of societal problems; for it is through education that society defines its purposes and organizes the means and resources to achieve them (Dewey, 1897). This approach to educating children requires the teacher to see their own lives and the conditions of their realities in relation to the perspectives of other’s (Gutstein, 2003). It is by accessing the perspectives and understandings of their students that teachers can then target their instruction to meet the needs of their pupils (Shepard, 2005).

Reformed instructional practices look at the role teachers play in society by creating a student-centered culture of thinking across a school (Ritchhart, 2015). Student-centered teaching places the student at the center of the learning environment where he or she has opportunities to engage in inquiry as part of a community of learners (Brown & Walden, 1976; Staples, 2007). The value of engaging students in reformed instructional practices, which create student-centered classrooms, is in creating equitable learning environments. These will then support mathematical understanding at the conceptual level (Staples, 2007). Van de Walle (2007) describes student-centered teaching as student-to-student dialogue facilitated by the teacher where one student asks another to clarify or justify an idea. Because correct responses to problems do not necessarily represent correct student thinking, the teacher in a student-centered classroom should not validate answers as right or wrong (Lannin, Barker, & Townsend, 2007). Instead, the teacher should turn the ideas back to the class for the students to evaluate the reasonableness of the responses (Van De Walle, 2007). Finally, student-centered teaching promotes students forming mathematical arguments and entering into debate with those ideas to justify why the math works. Selecting student work with various computational strategies as well as different answers, and making this work public for the class to evaluate, can promote classroom debate leading to understandings critical to a strong learning environment (Smith, Hughes, Engle & Stein, 2009; Yackel & Cobb, 1996). Creating a student-centered classroom requires instruction that uses student understanding to generate new understandings.

The National Council of Teachers of Mathematics (NCTM) has created a set of principles and standards to define reformed mathematic teaching because there is a need for a common foundation of math to be understood by all citizens (NCTM, 2000). The goal of reformed math instruction is not to simply teach the ideas but also to ensure that all students engage in the critical thinking necessary to learn and make sense of the ideas (Ritchhart, 2015). This is important because the professions of the 21st century need the independent thinking and problem solving developed in student-centered classrooms (Rotherham & Willimgham, 2009). Accomplishing this task requires promoting access to rigorous mathematics for all with the expectations that our students can achieve high levels of mathematical understanding. This can be accomplished by creating a coherent plan focused on important mathematics articulated both across the school year and through the grades. In this plan, teachers understand what students need to learn and can challenge them, with the necessary supports, to achieve it (NCTM, 2000). This is a progressive approach to the teaching and learning of mathematics because traditionally the emphasis has been on just getting correct answers. In a reformed math program, answers maintain their importance, but by requiring that students make sense of the math, the goal of instruction becomes more than just answers (Ritchhart, 2015). Learning how to teach reformed mathematics using research based instruction is a daunting task and requires embedded professional development through the use of instructional coaching (Knight, 2007).

Using Assessment Data to Improve Instruction.

Data is information and it may be qualitative in nature and evaluated through interpretive inquiry, or it may be quantitative in nature and evaluated through statistics (Erickson, 1985; Lincoln, 1995; Maxwell, 2013). The data I refer to in this study is qualitative and will be generated through the teacher's evaluation of student work as well as the students' interactions with each other during the lesson. Qualitative data in this context is about the correctness of the response as well as the thinking the students engaged in as they solve the problem (Lincoln, 1995; Ritchhart, 2015). Teachers can then target their instruction towards improving the students' response to a prompt based on how they have responded in the past (Duckor, 2014; Ritchhart, 2015; Tomlinson, 2014).

The two types of written assessments used in schools are summative and formative (Eberle Center for Teaching Excellence, n.d.). The purpose of summative assessment is to evaluate student learning at the end of a unit or school year and compare scores against a statistical standard. Due to the objective nature of summative assessment, the scores are usually used to give quantitative measures of a student's ability as compared to other students (Eberle Center for Teaching Excellence, n.d.; Marzano, 2006). Formative assessment, on the other hand, is designed to monitor student learning and provide teachers with ongoing feedback useful in improving the learning environment of the classroom. Due to the subjective nature of formative assessment, the data gives a qualitative measure of a student's ability based on the criterion defined in both the content standards and the scoring rubric (Eberle Center for Teaching Excellence, n.d.; Marzano, 2006). Since qualitative measures give teachers a richer set of information upon which to create lessons, this study will focus on formative assessment and the qualitative data gleaned from it (Maxwell, 2013; Lincoln, 1995; Tomlinson, 2014).

An indication of a quality assessment is how well it provides encouraging feedback to a student on how to improve (Marzano, 2006). Typical math assessments scored for the correctness of the numerical answers can be discouraging because when children work on closed questions, which have right or wrong answers, and they get the wrong answers, they tend to take on a low opinion of their abilities (Boaler, 2013). Open-ended questions allow students to describe the procedures they used and why those procedures work. This offers better opportunities for students to evaluate their understanding and gives them information they can use to improve their understanding (Boaler, 2013). Open-ended responses also give teachers better insights into their students thinking allowing them to use the responses to target future instruction (Boaler 2013; Marzano, 2006.

Using formative assessment to plan lessons. The purpose of gathering and analyzing formative assessment data on student's mathematical understandings is to use the information from student thinking to make instructional decisions. Whereas teachers have a great deal of intuitive knowledge about the mathematical thinking their students engage in, the thinking is often fragmented and usually does not play a significant role in the instructional decisions teachers make (Carpenter et al., 2000). Improved planning and teaching leading to improved student learning includes making decisions based on evaluating student thinking during classroom exploration as well as on written assessments (Carpenter et al., 2000; Duckor, 2014; Tomlinson, 2014). Teachers who conceptualize their instruction grounded on student thinking, plan their instruction based on a framework of deeper understanding, and continually reflect on and modify the framework based on what they hear and see from their students (Carpenter, et al., 2000).

Formative assessment, also called assessment for learning, can lead to improved student achievement because it can identify areas of strength and weakness in student understanding. Formative assessment is an ongoing exchange between teacher and student and has great potential to improve both teaching and learning (Duckor, 2014; Tomlinson, 2014). The data gleaned from formative assessment helps a teacher form an understanding of what the students need in either the current lesson or in future lessons (Bay-Williams, et al., 2014). Data gathered through short formative assessment problems, evaluated collectively for proficiency using a rubric, and then used to form an awareness of student understanding can assist teachers in making decisions about how to target instruction towards increasing student understanding in the content (Andrade, 2000). By providing insight on a student's in-class understanding, formative assessment can also assist a teacher in making in the moment adjustments to the lesson so that learning proceeds as it should (Duckor, 2014). When used as a bridge between the beginning and the end of the lesson or between today's and tomorrow's lesson, formative assessment data becomes a mechanism for doing more than just raising the end of the year scores on classroom, district, or state assessments (Tomlinson, 2014).

Collecting data formatively is a complex endeavor that requires the teacher to observe conversations in groups, listen closely to responses to conferring questions, and scan the room for students sitting quietly looking confused (Bay-Williams et al., 2014). To maneuverer through this complexity, Bay-Williams et al. (2014) presents strategies for effectively using formative assessment in the classroom. Effective teachers share and clarify the learning goal for the day, plan effective tasks that elicit evidence of student understanding, and provide feedback that moves the learning forward as students take on new ideas (Bay-Williams et al., 2014).

There are two kinds of formative assessment found to be beneficial for informing teachers as to what their students know and can do (Gusky, 2003). They are tasks that help a teacher make decisions about future lessons and tasks that are designed to give teachers in the moment understanding about what the students comprehend as the lesson unfolds during the class period (Tomlinson, 2014). Posing rigorous problems and conferring with students using focusing questions such as "why is that true", "can you prove that idea", and "how does that make sense to you" can give teachers useful data for making in the moment decisions about how to proceed through that day's lesson (Franke & Kazemi, 2001; Herbal-Eisenmann & Breyfogle, 2005; Kazemi, 1998). Watching and listening to students as they interact with the ideas of the lesson and looking for clues about their developing understandings will give teachers information about what to do next (Guskey, 2003). Questioning is a powerful assessment tool that focuses the student on justifying why they performed a particular procedure and/or why the procedure worked (Herbal-Eisenmann & Breyfogle, 2005).

In addition, the teacher should provide the class with a short assessment problem to be given during the class period, assessed outside of class, and then used to plan future lessons (Tomlinson, 2014). These assessment problems need to be generated and evaluated by teachers collectively to develop a shared understanding of proficient responses to problems based on both the answer and the thinking used to arrive at the answer (Bambrick-Santoyo & Peiser, 2012). When reviewing student data in collected work samples, teachers need to look for patterns in what has been mastered, what has not, and what needs to be done about it (DuFour & Eaker, 1998; Tomlinson, 2014). The goal is to look for clusters of students who need similar things and group them based on these needs (Tomlinson, 2014). Using data to group students based on the needs demonstrated through the assessment can be very powerful. For example, many math teachers run a mini lesson at the beginning of the class period where concerns that surfaced through the analysis of the student work are addressed. This can be a perfect time for organizing students into differentiated groups based on what the data from these lessons suggest. However, these groups need to be disbanded for the main lesson so as minimize status in the room and give all students access to each other during the new learning of the day (Boaler, 2011; Kohn, 1998; Oakes, 1986). In this way the teacher can avoid creating new holes in students' understandings by limiting them to a reduced curriculum.

For both types of formative assessment, choosing rigorous problems that cause students to demonstrate their thinking is imperative. Creating mathematics lessons which support higher order thinking is more engaging for the students and leads to thinking about the math rather than just doing the work (Brookhart, 2016; Ritchhart, 2015). Rigorous mathematics lessons where students are provided the opportunity to think deeply about ideas and concepts begin with open-ended questions where students are required to find more than just numerical answers to problems. Usually these types of problems require the student to justify why an answer is correct or why a procedure works (Boston & Smith 2009). As a result, there can be multiple correct answers for the students to form arguments from and use in classroom debate (Yackel & Cobb, 1996). The arguments posed by students then become the formative assessment data a teacher uses to make decisions about the rest of the current lesson or lessons to create in the future.

Gathering formative assessment data as an instructional coach is similar to that of a classroom teacher. Just like an effective 7th grade teacher will listen to students as they share ideas and observe them as they take on new ideas, an effective coach will listen to the teacher he or she is coaching and observe them as they take on the ideas from the coaching sessions. By observing teachers as they facilitate lessons and listening to teachers as they share their struggles and successes, the coach can make decisions about what coaching moves to use next (Knight, 2007). Gathering this formative data and then using it to target the next set of coaching moves can result in the desired changes in instructional practices (Bay-Williams et al., 2014; Knight, 2007). This will be discussed more in the next section on coaching.

Using formative assessment to teach lessons. Because large-scale state assessments are used for rank-ordering schools and districts, they are not good instruments for helping teachers improve their instruction (Guskey, 2003). Assessments best suited for this purpose are formative because they are created and administered for the purpose of learning what the students currently understand. However, for these assessments to be useful in improving instruction, teachers need to change their view of what an assessment is and their interpretation of the results (Guskey, 2003). Mathematics assessments that only require numerical answers do not give the teacher the information they need to assess the thinking a student is engaging in as they solve the problems (Boston & Smith 2009; Hiltabidel, 2012). When the assessments are scored, the data is primarily used for assigning grades to their students instead of assessing understanding (Wiggins & McTighe, 2005). For assessment data to be used formatively, teachers need to change their approach to assessment in three important ways: make assessments useful, follow assessments with corrective action, and give students second chances to demonstrate success (Guskey, 2003).

The effectiveness of a lesson is not about how it was taught. Rather, it is about whether the students learned what was taught (Bambrick-Santoyo & Peiser, 2012; Boston & Smith 2009). When teachers use student work formatively, they can see beyond their own efforts in the classroom to the results of those efforts in the learning taken on by the students (Dufour & Eaker, 1998; Goodwin & Hein, 2016). By using formative assessment data in this capacity, teachers can more effectively target their planning and teaching to meet the needs of their students (Duckor, 2014; Goodwin and Hein, 2016).

Making assessments useful. When a student studies hard preparing for a mathematics test only to discover that the material on the test is different than what was studied, the student learns that hard work and effort does not pay off. This is the opposite of what educators want students to believe about their academic endeavors. The data gleaned from this negative experience is also not useful for revealing to the teacher the effectiveness of the lesson. To make an assessment useful to the student and the teacher, it needs to be tightly aligned to what was taught (Guskey, 2003).

Whereas students need to have access to the problems based on the experiences in the classroom, assessments “tightly aligned” could be interpreted as using the same problems on the test that were used in class. This is a concern because an indication of mastery is being able to apply and transfer knowledge and understanding from classroom experiences to other contexts (Wiggins & McTighe, 2005). Additionally, “tightly aligned” may mean that the problem allows the student to pull from what the teacher has said rather than from what the student understands.

At issue here is whether students do well on the assessment due to their understandings or the teacher's (Boston & Smith, 2009). This can be alleviated somewhat by regular classwork and homework experiences where students are given new and unique problems to solve without the teacher's assistance (Boston & Smith, 2009). This can help the student to see that the expectations are to make approximations to problems and justify why their reasoning makes sense (Cambourne, Handy & Scown, 1988; Forman, 2012).

Useful classroom assessments help teachers gather important data on student proficiency (Guskey, 2003). By simply tallying how many students succeeded or failed to meet certain criterion on the assessment items, teachers can gather critical information for what is and what is not working in their instruction. However, just as the student responses on the assessment need to be evaluated for proficiency, the quality of the assessment itself also needs to be evaluated for how it provides opportunities for students to demonstrate proficiency (Boston & Smith, 2009; Marzano, 2006). Once it is determined that the assessment adequately required proficient responses and students still did not respond accurately, the attention needs to redirected to the instruction used to present the ideas (Guskey, 2003). When instructional issues are discussed collectively, teachers' egos can be bruised. It is difficult to reflect on the idea that if students did not learn, then the idea has not yet been adequately taught. Whereas it is true that students have a role in their own learning, if the teacher is not reaching the students in the class, then the teacher's method of instruction needs to improve (Dweck, 2006; Guskey, 2003).

Teachers also need to be clear about what they are looking for in proficient work. Using a rubric, which defines proficiency, and posting students' work to make an understanding of proficiency available to the class is critical to this clarity (Guskey, 2005). In this way, assessments can serve as a meaningful source of information that does not surprise students.

They see the assessment as a fair measure of what they know and are able to do, and can use the results to evaluate how they are progressing towards learning goals (Guskey, 2003**).**

The use of assessment also needs to build students' beliefs in themselves and their ability to learn. When students see assessment as a grade rather than an opportunity to learn, they either shut down or put their focus in the wrong place (Dweck, 2006; Resnick, 2003). Therefore, most assessment should be used formatively to help students analyze their own work for proficiency (Tomlinson, 2014). Moving the focus of the work off of the grade and onto the learning needs to be a daily effort in school (Dweck, 2006; Resnick, 2003).

Quality assessments are created from what students need to know, understand, and are able to do (Wiggins & McTighe, 2005). These set the groundwork for preassessment and the ongoing formative assessment throughout the unit of study (Tomlinson, 2014). They do not need to be comprehensive, but they should be rigorous opportunities for students to demonstrate where they stand in relation to the outcomes for the unit (Boston & Smith, 2009). Asking good questions as students are working on their assignments in their groups can also give teachers good information about what students are thinking in the moment. The teacher can then use this assessment data to make decisions about the next step in the lesson for that day or later in the week (Duckor, 2014).

Useful formative assessment builds flexibility into how students can respond to the prompt (Tomlinson, 2014). For instance, a justification for a response to a math problem might take the form of a picture, sentence, and /or table. Many times a simple calculation is not adequate. When a teacher seeks to know whether the student understands why a calculation works, the opportunity for the student to respond in a flexible manner is critical. Significant wait time, even to the point of being uncomfortable, can be necessary for students to form justifying statements (Dukor, 2014; Foreman, 2012). Then, as students begin to respond in whole class or small group, the teacher can facilitate the discussion by having students revoice each other's ideas to create a shared understanding of the concepts (Yackel & Cobb, 1996)

Follow Assessments with Corrective Action. Since formative assessments provide information for what still needs to be learned, they cannot mark the end of learning. Instead, they need to be followed by high quality corrective instruction involving different strategies than what were used initially (Bambrick-Santoyo & Peiser, 2012; Guskey, 2003). These alternate strategies should be considered at the beginning of the school year so that teachers have a toolbox of approaches to use both with the initial as well as with the corrective instructional sessions. Collaborative grade level planning can be very beneficial for looking at student work and choosing strategies to use during corrective instruction because the strategies and the results of the strategies can be evaluated collectively (Bambrick-Santoyo & Peiser, 2012; DuFour et al., 2010).

There is a tension between the time taken to allow for corrective instruction and staying on pace to ensure students get a year's worth of experiences. Using excessive amounts of time for corrective instruction because a gap has been found in a student's understandings can keep a teacher from getting to experiences with critical material. This can form new holes in understanding (Guskey, 2003). Teachers need to make sure they are not creating new gaps in understanding by filling old gaps. Effort needs to be made to convince the students that corrective instruction is in their best interest so they will engage in it and use the time and opportunity afforded them to meet standards (Guskey, 2003).

Whereas formative assessment should rarely be graded, it needs to be used to give students useful feedback (Tomlinson, 2014). Quips such as "nice job" or "needs work" do not help learners understand what they were or were not able to demonstrate in their response (Dweck, 2006; Kohn, 2001). Praise such as "You're so smart," though intended to motivate, many times sends a message defining a person's ability as inherent rather than fluid and can keep a person from engaging in a challenging task where such praise may not come (Dweck, 2006; Ritchhart, 2015). Activities where students evaluate their own work and the work of others based on a standard of proficiency allows students to internalize what was done well and what needs to be improved (Foreman, 2012). However, students need to be taught how to thoughtfully examine both teacher and peer feedback, and use it to develop plans for their own academic growth.

The effort to make sense of feedback needs to be facilitated by a teacher who has a clear sense of what challenges the student needs to engage with (Tomlinson, 2014). Too little feedback or too much feedback can leave a student with a fixed mindset (Dweck, 2006). Feedback becomes powerful when it motivates students to increase their desire to learn and grow in their understandings and it becomes detrimental when it causes students to believe that knowledge is inherent and fixed. The repercussions of feedback can be detrimental because individuals with a fixed mindset are more likely to avoid difficult situations, cheat if they are coerced into them, and finish the task with a decreased belief in their own ability (Dweck, 2006; Ritchhart, 2015).

Give Second Chances. Implied in the use of corrective action is the need to give students second chances to learn the material at a proficient level (Guskey, 2003). Math teachers over the years have been reluctant to provide additional chances for students to pass assessments, and if these were afforded, then there were even more difficulties with assigning the same grade to a student who passed it the second time around as a student who passed it the first time (Brant, 1992). One argument given by many teachers is that life does not give us second chances. Contrary to this belief, making approximations is a necessary component to learning new material or learning how to apply established ideas into new contexts (Cambourne, et al., 1988).

Even adults regularly need several opportunities to make approximations in how to solve a problem or complete a project, and students in our public schools need to be afforded the same chances.

Becoming a lifelong learner requires developing learning-to-learn skills and a critical component to this is making mistakes and learning from them (Brant, 1992). Showing students the mistakes they made on an assessment and then not allowing them to correct those mistakes, keeps them from seeing the benefits of being a lifelong learner. Since successful students know how to take corrective action on their own, educators need to teach all students how to do this so that all can be successful (Guskey, 2003).

This section on using assessment data to improve instruction has shown that qualitative data on student thinking can be collected and used to target instruction in future lessons. The information on student thinking can also be collected and used during the lesson to target the needs of students during the same class period. The next section will discuss adult learning theory and how an instructional coaching model can engage teachers in improving their instruction.

Embedded and Sustained Professional Development

Currently there is a uniquely high level of interest in improving the instructional practices in schools across the country. Over the last few decades, the educational community has discovered that one-shot professional development usually fails to have any significant impact on teachers' instructional practices (Knight, 2007). One-on-one or group based embedded professional development with an instructional coach is demonstrating itself to be a more effective venue for creating the changes needed in how educators approach teaching. The primary goal of instructional coaching is to use this venue to support teachers in implementing scientifically proven instructional practices that lead to a strong learning environment in the classroom (Knight, 2007).

Adult learning Theory. Just as with young children and adolescents, adult learning that fosters inquiry, individualization of the learner, and independence in pursuing knowledge will increase the motivation of the learner. Integrating theory about how adults learn with the practice of professional development is critical in the creation of a strong learning environment for professionals seeking to improve their understandings in the field (Merriam, 2001).

Current learning theory presented by Donovan, Bransford, & Pellegrino (1999) describes three critical components to the creation of a strong learning environment:

1. Students come to class with preconceptions about how the world works. The Instructor must validate these preconceptions for any new concepts to be understood.
2. Students must connect facts and ideas onto a conceptual framework to create a deep understanding of what the facts and ideas mean so they can be retrieved in future applications.
3. Students must be taught to take control of their own learning by metacognitively defining their learning goals and monitoring their progress.

This design framework assumes that the learners are children or adolescents, but the same components are critical in adult learning as well (Donovan et al., 1999). A goal of coaching as embedded professional development is to create a school wide learning culture where adult learning is learner-centered, knowledge-centered, assessment-centered, and community-centered (Donovan et al., 1999). Creating powerful professional development requires formative assessment data designed to target the knowledge and skills a teacher needs (Knight, 2007). This approach places the teacher at the center of the effort with the instructional coach as a consistent support for teachers as they incorporate ideas into their teaching.

However, adults carry different kinds of experiences into the learning environment than children and these need to be validated as well. Adult learners generally bring an independent self-concept allowing them to direct and reflect on their own learning (Merriam, 2001). Adults are problem centered, desire immediate application of the leaning, and are motivated by internal as opposed to external factors. They also bring a reservoir of rich life experiences that need to be assessed, validated, and used by the coach to create learning experiences targeted to their needs (Merriam, 2001). Instructional coaching needs to bridge adult learning theory with the practice of improving teacher's instruction. Teacher-centered instructional coaching will be addressed later in this chapter.

Instructional coaching. Instructional coaching pulls from an array of coaching models and methods to create a comprehensive approach to improving teachers' understanding of effective instruction. One model is the Coactive approach in which the coach-teacher relationship involves the whole life of the teacher (Whitworth, Kimsey-House, & Sandahl, 1998). For example, a coactive coach might find that teachers come for personal as well as professional needs. The goal of coactive coaching in an educational setting is to first support the classroom teacher in living a more fulfilled, balanced, and effective life where the coach and teacher work collaboratively in designing an alliance which meets his or her needs. Coactive coaches are inquisitive, instinctive, and authentic listeners who earn and then respect their teacher's confidentiality by creating space for nonjudgmental conversation (Knight, 2007).

Another model, Cognitive Coaching, is more prescriptive than the Coactive model by laying out a process for enhancing a teacher's professional learning. It describes useful communication and relationship building tools to be employed by the coach in order to create a coherent theoretical foundation (Knight, 2007). The assumption in the cognitive coaching approach is that behaviors change beliefs. The coach's role is therefore to change the teacher's perceptions as they construct meaning by engaging and reflecting on new experiences (Costa & Garmston, 2002). Cognitive coaching always involves the three interrelated elements of a planning conversation, the event planned for, and the reflecting conversation (Knight, 2007).

The last coaching model to explore is Instructional Coaching. An instructional coach is a full-time on-site professional developer who unpacks teachers' instructional goals to help them realize their professional aspirations (Knight, 2007). Instructional coaches incorporate the coactive approach by empathizing, listening, and building trust with the teachers. They also integrate the reflective practices of cognitive coaching through coplanning and coteaching along with reflecting on the results in student learning. In addition, instructional coaches are cognizant of a large number of scientifically proven instructional practices and are experienced in methods for supporting teachers in how to practice them (Bay-Williams et al., 2014; Knight, 2007).

A Systemic Approach to Professional Development. It is this integrative work of an instructional coach that allows him or her to bring the systemic changes needed to transform our schools into thinking institutions (Crow, 2008; Ritchhart, 2015). The educational system needs to develop a clearer sense of what educators do and how this work connects to the larger community in which it serves (Crow, 2008). Since most of the skills and understandings a teacher needs to acquire are not learned in college level teacher preparatory courses, instructional leaders must have strong embedded professional development to ensure that teachers get systematically better at their work. This can occur when teachers know how and why they do what they do as educators (Knight, 2007). Today there is a great deal known about how people learn (Bransford, Brown, & Cocking, 1999). The educational community needs to implement these understandings in the creation of strong effective learning environments (Crow, 2008). The educational community cannot be casual about how to organize for quality instruction. Instructional coaching is an effective model for intentionally supporting teachers as they practice with the use of research based instructional tools (Crow, 2008; Van Driel & Berry, 2012).

The intentionality of instructional coaching is designed to help teachers both understand and embrace the research-based instructional practices shown to create strong learning environments (Driscoll, 2008). Effective professional development needs to improve teachers' content knowledge, provide access to the research-based instructional strategies which bring inquiry into the classroom along with opportunities to reflect on their benefits, as well as build teachers' capacity for using assessment to monitor student learning and achievement (Driscoll, 2008).

The phrase "professional development" implies that those facilitating the learning as well as those engaged in the ideas being facilitated are professionals. Wiggins & McTighe (2006) have given four characteristics of a professional which need to be considered if the professional development is going to be effective at systematically changing the way teachers engage with their students. Professionals (a) act on the most current knowledge defining their field; (b) adapt to meet the individual needs of their teachers; (c) are results orientated; and (d) uphold the standards of their profession through peer review. Facilitators acting professionally will ensure that each of the four components of professionalism are part of any training or series of trainings, and teachers acting professionally will engage in each component as they work to improve their educational practice (Crow, 2008; Wiggins & McTighe, 2006).

When an instructional coach incorporates the components of adult learning theory the professional development of a teacher can be powerful (Donovan et al., 1999; Knight, 2007). In the next section, we will see that just as a teacher can gather and use information on student thinking to target instruction an instructional coach can gathering and using information on teacher thinking to target coaching.

Using Formative Assessment Data to Improve Coaching.

This research project will also be looking at the data, or information, an instructional coach gathers to use in improving the instructional practices of the teachers being coached. Just as formative data is used by a teacher to inform their instruction, the information a coach gathers on what teachers are thinking about as they teach and assess is used to inform their coaching (Knight, 2007).

Instructional coaching is also about collecting information. However, the work of the coach is to gather, assess, and support teacher thinking before, during, and after the lesson. By evaluating the thinking a teacher uses to make planning decisions both during the class period as well as between class periods, the instructional coach can target the coaching to the instructional needs of the teacher.

The use of formative assessment data to improve the work of an instructional coach focuses the coach on the ability to adapt coaching strategies to the individual needs of the teacher being served. An instructional coach will collect and analyze formative assessment data on teachers to conceptualize the teacher's thinking in regards to their instruction (Carpenter, et al., 2000; Knight; 2007). A coach can collect data on teacher thinking in two different ways.

First, the coach needs to be a good listener. Humans naturally are drawn to what they agree with and withdraw from what they disagree with (Knight, 2007). To gather accurate information during coaching sessions a coach needs to listen carefully to the teacher's thinking and not project their own opinions into what the teacher says as they are saying it (Aguilar, 2013; Knight, 2007). Coaches need to enter conversations with teachers as learners where the focus is to understand the teacher and their struggles in the classroom. Effective listening, which leads to an understanding of teacher thinking, comes from being attentive to the verbal and nonverbal messages being sent from the teacher. A coach who is able to press a teacher into considering and then taking on new ideas in the classroom must first honestly want to know what the teacher has to say and why he or she needs to say it (Knight, 2007). Coaches need to also listen and respond to teachers with empathy and respect. An effective coach must know the person he or she is working with both emotionally as well as intellectually in order to take that teacher into places they may not even know need to be explored (Aguilar, 2013).

Second, an effective coach needs to be a good observer. Rather than acting as an evaluator, a coach needs to be a second set of eyes in the classroom to watch for the use of critical teaching behaviors (Knight, 2007). The teaching behaviors a coach needs to be looking for are the instructional practices research has shown to be effective in creating a strong learning environment (Crow, 2008; Forman, 2012). The coach has the role of both bringing these practices to the classroom as well as observing teachers making approximations on how to use them effectively. While instructional practices such as conferring with students or facilitating student-to-student discourse allows teachers to gather formative assessment data on student learning (Duckor, 2014; Kazemi, 1998), observing the teacher gather this information gives the coach information which informs him or her about what to do in the moment or what to plan for in future coaching sessions (Knight, 2007).

A difficult part of coaching is supporting teachers as they practice the art of selecting instructional practices in a lesson to form a strong classroom learning community (Foreman, 2012). It is the weaving of these scientifically demonstrated instructional practices into a seamless lesson, which meets the needs of the students through the formative assessment data, that make for an effective teacher (Carolan & Guinn, 2007). In the same way, it is the weaving of the various coaching moves into a unified approach to improving teaching and learning in the classroom, which makes for an effective instructional coach (Aguilar, 2013). In both cases, it is the practicing of instructional and coaching moves that brings out the artist in the teacher and the coach.

Collecting and analyzing information on teacher effectiveness. The instructional coach should collect data during the lesson through classroom observations. Opportunity to collect information on both student and teacher thinking begins at the start of the class period. When an instructional coach visits a classroom, the environment is set for him or her to collect data that can be used to improve a teacher's instructional skills. Walk throughs and informal observations are two types of classroom observations a coach can use to note a teacher using formative assessment data with their students (Guskey, 2003; Jackson, 2008).

Walkthroughs are a quick five to seven minute snapshot of a teacher's individual practice and are one method for a coach to collect data on how to approach a teacher in a coaching meeting (Jackson, 2008). The coach needs to determine ahead of time what instructional behaviors to look for in order to find trends in these behaviors over the course of a school year and/or across the grade level planning team. These quick drop-ins can give a coach a broad picture over time as to how well a teacher is taking on the ideas discussed in the coaching meetings (Jackson, 2008).

Informal observations are similar to walkthroughs except they are longer in duration, giving the coach the opportunity to also look for clarity in the learning objective. Because of the longer time spent in the classroom, the coach needs to be careful to record what is actually seen rather than what is perceived as might be going on in the lesson (City, Elmore, Fiarman, & Teitel, 2010). A teacher's desire to improve can be documented over the course of the year or by comparing how each teacher in a planning team progresses compared to each other. The coach has the role to build the growth mindset of teachers to promote the desire to improve their instructional practice (Jackson, 2008). Documentation over time can provide a wealth of information to be used by the coach to inform the decisions about how best to press and support the teacher into taking on the next instructional challenge. Walkthroughs and informal observations should be the only types of observations an instructional coach is part of. Since coaching and evaluation should be intentionally distinct, a coach should never be involved in a formal observation (Aguilar, 2013; Knight, 2007).

An instructional coach can also collect information about teacher thinking by evaluating student responses to written assessment problems with the teacher (Guskey, 2003; Knight, 2007). Determining a teacher's ability to identify a proficient response, using it to ascertain proficiency of individual students as well as the class as a whole, then taking this information to plan future lessons is a significant role of the instructional coach (Guskey, 2003; Knight, 2007). The main purpose of working with achievement data is to determine if the teacher is using the data formatively. The coach needs to determine if the teacher has a clear goal for the assessment being used to collect achievement data as well as verifying whether the teacher is using the data to decide if students are progressing towards mastery at an acceptable rate (Jackson, 2008). The coach also needs to see if the teacher implements instructional practices necessary to create opportunities to assess students informally, and then whether the teacher uses the data to diagnose and treat misunderstandings in the lesson. Finally, the coach needs to determine, if by addressing the needs found in the data, the teacher does not press the class into the new learning aligned with the grade level being taught (Kazemi, 1998).

Building trust between the teacher and the coach. Trust is a feeling of confidence between two or more people; it is established in a coaching relationship when the coach demonstrates that he or she has the skills, abilities, attitudes, and knowledge to do the things they say they can do (Aguilar, 2013). Due to the complexity of interpersonal relationships, trust is something that must be practiced as an art. Whereas trust is something that is often taken for granted, it does not happen by accident or in the moment (Bay-Williams et al. 2014). Trust takes time to build though the intentional effort of the coach to make appropriate, honest connections with teachers. Trust comes through by being both transparent in communication as well as maintaining confidentiality (Bay-Williams et al. 2014). An effective coach needs a high level of emotional intelligence to demonstrate to teachers the ability to read verbal and nonverbal cues as well as the subtle shifts in the emotional state of the teachers he or she is working with (Aguilar, 2013).

Assessment and scaffolding. Whether it is a teacher gathering information on student thinking or a coach gathering information on teacher thinking, the purpose of the data is to create insights about a learner's current understanding so that appropriate scaffolding can be put into place to get them to the next level of understanding (Shepard, 2005). Scaffolding which supports a learning culture must allow the learner to both access and be pressed into the ideas being developed (Ritchhart, 2015). Vytogsky (1978) calls this space between the actual level of independent problem solving and the desired level the Zone of Proximal Development (ZPD). The ZPD is the place where learning occurs as long as the scaffolds, which place a learner in this space, do not remove the challenge associated with productive struggle (Shepard, 2005; Vygotsky, 1978). Productive struggle is created by the disequilibrium that occurs when new ideas confront existing ideas and it must occur for authentic learning to arise (Burns, 1992; Foreman 2012). Good teaching and good coaching both create the productive struggle necessary to create a learning environment. More on this will be presented in the next section on teacher-centered instructional coaching.

Formative assessment and the data gathered through the process will not be effective unless it is a part of a larger cultural shift in how educators view teaching and learning (Shepard, 2005). Reformed teaching is primarily designed to place the student at the center of the teaching in which the teacher structures the discourse to minimize status in the lesson and confers with students as they discuss their ideas to uncover understandings as well as struggles and misconceptions (Foreman, 2012; Kazemi 1998). The teacher can then use the information revealed through the conferring to select and sequence the ideas during the full class summary (Franke & Kazemi, 2001; Smith, et al., 2009).

Teacher-centered instructional coaching. As mentioned earlier, effective coaching places teachers at the center of the learning by building an emotional connection with and between teachers to minimize status between teachers (Agular, 2013). In addition, by bringing teachers into visit other teachers' classrooms, the coach can facilitate the collective understandings of the instructional practices being developed. Teacher-centered learning also occurs when the instructional coach confers with teachers to determine what they understand about the instructional ideas being practiced so the coach can make decisions about what the next coaching moves should be.

Collecting and using data to engage in teacher-centered coaching involves the active participation of the teacher and the coach in identifying the problem and determining the solution to instructional challenges. The goal of this approach is to provide support and structures that allow teachers to make their own choices about how to resolve their own instructional challenges and grow as professionals (Jackson, 2008). However, as mentioned earlier in regards to students, teachers also have a ZPD that must be accessed by the coach to provide for the challenges necessary to ensure learning (Vygotsky, 1978). Instructional coaches must have a set of foundational beliefs in order to engage teachers in the productive struggle necessary to improve as educators. First, coaches need to know how to identify good teaching practices and recognize areas for improvement (Jackson, 2008). Second, coaches need to believe that teachers can learn and change the way they organize and run a classroom (Jackson, 2008). Third, coaches must have a shared understanding with the teachers they serve as to what good instruction is (Knight, 2007). Fourth, coaches must agree to remain engaged with teachers when the conversations get difficult (Jackson, 2007). Finally, coaches must be willing to give honest feedback without being offensive (Aguilar, 2013). Understanding the needs of the teacher a coach is working with is critical to acting on these foundational beliefs and using teacher thinking during the coaching sessions gives a coach the necessary data to engage with teachers through these beliefs.

Summary

This chapter included an overview of the literature on the current state of educational reform in mathematics education. The role of the teacher in using formative assessment to gather data that informs a teacher's lesson planning decisions has been developed. The role of the instructional coach in using classroom observations and student achievement data to inform decisions about how best to direct a teacher to the next level of instructional practice has also been established.

The purpose of this study is to research how an instructional coach can use information gathered from collaborative planning meetings, classroom observations, and debriefing sessions to support a teacher in using formative assessment data to improve her teaching. To accomplish this, an instructional coach will work with one 8th grade math teacher in a one-on-one coaching environment. They will coplan lessons, the coach will observe the teacher teach the lesson, and the coach will collect information about teacher thinking during the lesson. The coach and teacher will evaluate the student responses to written assessment problems based on proficiency and use this information to plan future lessons. The desired outcome of this study is first to look at how teachers use formative assessment on student understanding to target their teaching to the needs found in the data. The second outcome is to look at how coaches can use formative assessment on teachers' instructional practices to target their coaching to the needs found in the data. The next chapter will present a description of the methodology to be used in collecting data for this dissertation study.

Chapter 3

Methodology

Research Questions

- How does a teacher improve the teaching and learning in the classroom by using formative assessment data to make adjustments in a current lesson as well as plan future lessons?
- How does an instructional coach use information gathered from classroom observations and student responses to assessment problems to improve the coaching of teachers?

Qualitative Research

In this study, I will conduct a qualitative research project. Qualitative research is a nonlinear inquiry based reflexive process where cause and effect both affect each other (Maxwell 2013). Qualitative research methods are useful in the social sciences because of the nonlinear nature of human interactions where participants shape their own norms, desires, and understandings (Reflexivity, 2016). This is due to the social nature of qualitative inquiry that provides an environment for hearing directly from the participant(s) in the study. Whereas linear approaches to research design provide a model for conducting research, nonlinear approaches provide a model of research, which treat the design as a real entity rather than an abstraction or plan (Maxwell, 2013).

This chapter will begin with a discussion regarding the value of using case study as an approach to inquiry. I will then proceed to describe how the qualitative data gathered will be organized through the transcribing of audio-recorded dialogues, the coding of the recordings, and the organization of the codes into a categorical coding matrix developed by Maxwell (2013). The body of this chapter will include the purpose and rationale for the study and a description of the four stages that will be studied to answer the research questions. The chapter will conclude with the process I will use for analyzing the data, and a statement on how to validate subjectivity in a qualitative study while still maintaining the rigor necessary for the results to be useful.

The Value of Choosing Case Study for a Qualitative Inquiry. A case study approach to qualitative inquiry provides an in depth understanding of a single issue or problem studied within a real-life context where the margins between the issues and the context are not evident (Creswell, 2007; Merriam, 1997). It is an approach in which the researcher explores a real-life issue in a bounded and integrated system over time (Creswell, 2007; Merriam, 1997). A case study entails the identification of a specific case usually involving one or a small group of individuals along with an identified problem or concern that needs to be addressed (Creswell, 2007). Case studies also require an in depth understanding of the issues involved in the case on the part of the researcher both through a review of what the current literature says about the issues as well as through the interviews, observations, and audio recordings provided within the study itself (Creswell, 2007). The goal of a case study is to answer the researcher's questions through the identification of themes or generalities that surface during the study leading to assertions by the researcher based on these themes or generalities (Creswell, 2007).

I will use the case study approach to qualitative inquiry because it provides the opportunity to engage in action research with one participant by describing a phenomenon in context. It is based on a constructivist paradigm that allows for the creation of meaning (Baxter & Jack, 2008). Flyvbjerg (2006) supports the belief that case study plays a significant role in understanding human learning in that case study is a context dependent approach that allows the researcher to take on understandings through the context. The conventional wisdom that research needs to be context independent to maintain a generalizing and theoretical approach has been shown to be insufficient (Flyvbjerg, 2006). Knowledge can actually be more powerful through a context-dependent approach because it resonates with the experiences of the reader that are rooted in context (Merriam, 1997). This approach can develop expertise in both the participant as well as the reader because the knowledge produced by the study is readily useful (Flyvbjerg, 2006; Merriam, 1997). This study is an action research study of one teacher as she works to develop her expertise at teaching adolescent children. It is for this reason that I have chosen the case study approach to inquiry for this study. Flyvbjerg (2006) also addresses other issues regarding case study which I will attend to next.

Flyvbjerg (2006) gives five reasons for using case study to understand human behaviors. First, case study is situated in real-life circumstances because human behavior can only be meaningfully understood through a nuanced view of reality. Since this study occurs in the real-life context of an 8th grade mathematics classroom, conducting a case study allows me to observe the formation of a strong learning environment where I am learning about the participant in a similar fashion to how her students learn about math (Flyvbjerg, 2006). Second, whereas it is argued that large philosophical statements cannot be generalized from one case, there are examples in history where this is exactly what happened (Flyvbjerg, 2006). The goal of my action research project is not necessarily to generalize the findings to other schools or subjects, but knowing that case study allows for this does provide that option. Third, case studies are useful for generating hypothesis throughout the entire research process. This case study will be used to test the validity of the proposition identified in the problem statement of the study by allowing the researcher to make logical deductions within the nonlinear structure of this qualitative inquiry (Flyvbjerg, 2006). Fourth, since bias associated with the case study approach is the same or less than with any other qualitative or quantitative studies, the findings in a case study inquiry are valuable for making decisions (Flyvbjerg, 2006). Fifth, case study, as with all qualitative inquiry, is a good research approach for studies with a large amount of divergent nonlinear data (Flyvbjerg, 2006). Since I expect these issues to be true in this inquiry, I am encouraged that this approach allows for somewhat ambiguous data because this may be more useful and interesting to the practitioner than a generalized theory.

Transcribing the data. Talk is social and the transcribing of an interview needs to reflect the social aspects of the experience. However, teasing out the social roles and relations associated with language through a transcription can be a daunting task (Bird, 2005). Deciding what will make it into the study report and why it is included involves asking the questions about whose story is being told and how it will be told (Bird, 2005). If the researcher has a strong agenda associated with the study, then this may very well play a role in these decisions. This is especially true of qualitative inquiry where the focus is on the intent and context of the language rather than simply the words employed (Bird, 2005).

Constructing understanding towards my research topic through the voice of my participant rather than my own preconceived ideas will be a significant challenge. However, the effort to make this happen by attending to the teacher's thinking is similar to what classroom teachers should consider as they gather information on student thinking. A mathematics teacher needs to be able to get out of the way of the student as he or she is making sense of the math just like the instructional coach needs to get out of the way of the teacher as he or she is making sense of instructional practices. An outcome of this study will be reflecting with my participant about the teacher's role in a classroom activity which both allows and hinders the collection of this information. Likewise, I will be reflecting on my coaching by specifically noticing what I do which either allows or hinders the collection of accurate information on teacher thinking.

Qualitative Inquiry through a Case Study Approach

I am now going to describe how I will carry out this qualitative inquiry through a case study approach. I will start with an overview of the study including the purpose of the study along with the rationale for running the study. This will be followed by a description of each stage in the data collection process.

Purpose of the study.

The purpose of this study is to research how an instructional coach can use information on teacher thinking from collaborative planning meetings, classroom observations, and debriefing sessions to support a teacher in using information on student thinking to improve her teaching. To accomplish this, I will work with one 8th-grade math teacher to plan lessons, observe the instruction through the lessons, collect data on student and teacher thinking, use the data to plan the next teaching move or the next lesson, and reflect on what was learned by both the students and the teacher. The desired outcome of this study is first to look at how teachers use formative assessment on student understanding to target their teaching to the needs found in the data. The second outcome is to look at how coaches can use formative assessment on teachers' instructional practices to target their coaching to the needs found in the data.

Rationale for the study.

Research on the effective use of formative assessment to inform teachers on what students know and are able to do is abundant (Dukor, 2014; Tomlinson, 2014; Shepard, 2005). However, actually gathering information on student understanding and using it to improve the quality of classroom instructional practices has been shown to be difficult for many teachers (DuFour, DuFour, Eaker, Many, 2010; Bambrick-Santoyo & Peiser, 2012). An instructional coach cognizant of the difficulties teachers have in gathering data on student achievement, making sense of the data as an indication of student proficiency, and then using the data to improve classroom practices can be very beneficial in supporting teachers in this endeavor (Bay-Williams, et al. 2014; Knight, 2007). Knowing how to create a formative assessment situation and then using the data gleaned from it to inform the approach to coaching will make an instructional coach more successful at supporting teachers in using the data collected.

The model used by this study to support the use of student data gathered through formative assessment comes from a compilation of research findings including that of Duckor (2014), Guskey (2003), Tomlinson (2014), and Shepard (2005). In these findings are the recommendations for teachers in how to collect, evaluate, and use student achievement data to improve teaching and learning. The model used by this study to support teachers in the use of formative assessment to improve instructional coaching comes from a compilation of research findings including that of Aguilar (2013), Bay-Williams et al. (2014), and Knight (2007). In these are strategies for observing teachers as they facilitate lessons as well as looking at student responses on formative assessments. Documents from The Teachers Development Group (Foreman, 2012) will be accessed for creating the planning and observing tools I will use throughout the study.

Four Stages to the Study

I will be working as the instructional coach in this research study. My participant, Amy (not her real name), is a third year 8th grade mathematics teacher. I have been working with her as her coach for three semesters. There will be four stages used to collect data as I work with Amy in this study. First, I will coplan a lesson with her from the district-approved resource using the Launch, Explore, Summary planning model (Van de Wall, 2007). Second, I will observe her teach the lesson in her 8th grade mathematics class, collect observational data on student and teacher thinking as they engage in the lesson, and use this information to make decisions about the next coaching move to support her next teaching move. We will also collect student work on a preplanned assessment problem to analyze for student proficiency. Third, we will meet to debrief the effectiveness of the lesson based on the evidence of students learning from the collected student work as well as my observation notes. We will also use the student and observational data to make decisions concerning follow-up reteach lessons. Fourth, I will attend one or more of the follow-up lessons to gather information concerning the effectiveness of the follow-up planning. In this study, I will repeat this cycle of planning-observing-debriefing-observing three times during the Fall semester of 2017. Figure 1 is a display of each stage in a cycle and most of this chapter will be devoted to an in depth description of each stage.

Figure 1 **The Components of Each Cycle**

Stage	Duration	Description	Outcome
Stage One Planning	45 minutes	Amy and I will use the Launch-Explore-Summary instructional model to plan a lesson based on inquiry.	The lesson will elicit student mathematical understandings through student-to-student discourse as well as teacher-to-student conferring
Stage Two Observing	60 minutes	I will observe our lesson for how well it brought out student understandings. I will also observe how Amy's instruction in the lesson allowed student to demonstrate what they understand about the mathematics.	I will gather formative data on both student thinking and teacher thinking. This will be the information I bring to the debrief
Stage Three Debriefing	45 minutes	Amy and I will meet to discuss what the students learned as well as how the lesson plan and instruction facilitated the learning that occurred.	Plan the follow -up lesson based on what the data on student thinking tells us the students need. Discuss the instructional practices used to enact the lesson based on how well they promoted and elicited student understanding.
Stage Four Observing	30 minutes	I will observe the follow-up lesson for how well it addressed the student learning needs as determined in the debrief.	Evaluate the effectiveness of the lesson and the instruction used to enact it and use this information in the next cycle.

The school where Amy and I will be working has 100-minute daily math classes. The 100 minutes are broken into a 30 minute reteach lesson for addressing the needs of students as determined in previous lessons, and the remaining 70 minutes is for digging into new ideas based on the grade level standards designed through the Common Core State Standards (CCSSI, 2010a). Whereas the structure is designed to allow most of the class period to be used for engaging students in new content, many teachers find difficulty in keeping the reteach follow-up lesson to the designed 30-minute time frame. By extending the reteach lesson into the portion of the period designed to get at new ideas and concepts, teachers can easily find themselves off pace for teaching the year's allocated standards. The efforts to fill gaps in understanding as demonstrated by the data can create new gaps when the class does not get to the content assigned to a grade level. Strong initial learning can minimize the need for reteaching (NCTM, 2000). So Amy and I will work to ensure that the initial 70 minute lesson takes advantage of the time by engaging students in rich meaningful mathematical experiences. In this study, Amy and I will be working to create strong initial lessons implemented with effective instructional practices. This will be followed by solid reteach lessons designed to give students additional time and opportunity to make sense of the mathematical concepts and procedures being taught from the standards.

Each cycle will include four days. On the first day we will meet to plan the 70 minute lesson on new content. On the second day I will observe the lesson and look for how it elicits information on student thinking. We will also collect student work at this time to evaluate it for proficiency. On the third day, we will meet to debrief the student thinking in the lesson based on the observation notes as well as evaluate the student work collected from the assessment. We will discuss how this information can be used to target instruction in the next day's 30-minute reteach lesson and we will plan that lesson. Finally, on the fourth day I will attend the class where our reteach lesson is enacted to observe its effectiveness in meeting the needs as determined in data from the initial lesson. As mentioned earlier, all four stages make one cycles and each cycle will be repeated three times over the course of the study.

Stage one. On the first day, Amy and I will plan the 70-minute lesson out of the district resource assigned to 8th grade mathematics classes. We will use the three-part lesson framework known as the Launch, Explore, and Summary instructional model to elicit information on student thinking necessary to make instructional decisions during the lesson (Annenberg Foundation, 2016; Van de Walle, 2007).

The components of an effective Launch are to summarize the learning from the previous day by revisiting mathematical experiences, connecting the prior experiences with the learning outcome for the day, and relating the context of problem(s) to the students' lived experiences (Annenberg Foundation, 2016; Van de Walle, 2007). An indication of an effective Launch is when students can explore the challenge(s) of the day's lesson independent of the teacher. The components of an effective Explore are the independent and group time provided to work on the problem(s) of the lesson, structure group discourse, and confer with students as they work to select and sequence student ideas for the Summary (Foreman, 2012; Smith et al., 2009). The components of an effective Summary are to present student understandings based on the teacher's intentional selecting and sequencing of the ideas that surfaced during the Explore portion of the lesson (Smith et al., 2009). A goal of the summary is to solidify the mathematical ideas from the lesson so they can be used in the launch of the next day's lesson (Duckor, 2014; Tomlinson 2014).

Amy and I will be planning for the Launch, the Explore, and the Summary for each of the 70-minute lessons we run. We will be using the planning template displayed in Figure 2 to create lessons where students inquire by making approximations in solving problems, describing the math used, and explaining why the math they used works to find the solution. The next section describes how we will consider each component of an inquiry-based lesson to generate information on student thinking which can be used in the moment as well as in future lessons.

<table>
<tr><td colspan="2">Figure 2 Three-Part Lesson Planning Framework</td></tr>
<tr><td colspan="2">Lesson</td></tr>
<tr><td colspan="2">Learning Outcome: What should students understand and be able to do?
Success Criteria: What will students be doing in the lesson to demonstrate proficiency on the learning outcome?</td></tr>
<tr><td>Launch</td><td>How will this lesson be launched?</td></tr>
<tr><td rowspan="2">Explore</td><td>The student's role- what will the students do in the lesson?</td></tr>
<tr><td>The teacher's role- What will I do in the lesson?
Questions to ask and instructional strategies to implement</td></tr>
<tr><td rowspan="3">Summary</td><td>What solutions/strategies do I anticipate from students?</td></tr>
<tr><td>How will I select and sequence these responses?</td></tr>
<tr><td>What connections will I need to make to create opportunities for understanding?</td></tr>
</table>

Planning for inquiry**.** Inquiry based learning is student-centered where the student grapples with challenging mathematics by using what they bring into the lesson to make sense of the problem and how to solve it. The three-part lesson framework is essential to creating inquiry in the classroom because it helps to define the teacher's role and the student's role in the lesson. A traditional mathematics lesson has the teacher telling the students what they need to know at the beginning of the lesson through a direct instruction model and then the students practicing the procedures demonstrated to them on similar problems. An inquiry based mathematics lesson, on the other hand, has the teacher posing the challenge along with previously developed understandings associated with the challenge to support the problem solving effort.

Through our planning Amy will work to implement an inquiry-based lesson by facilitating the mathematical ideas in the lesson through both group discourse as well as individual problem solving opportunities. As student are discussing the mathematical ideas during the lesson, Amy will use conferring questions like those displayed in Figure 3 and listen closely to the student responses to gather information on student thinking. This information will then be used to select and sequence ideas in the summary of the lesson so students can connect the day's lessons to past lessons (Tomlinson, 2014). The understandings developed in the summary will be accessed in the launch of future lessons to make connections to new ideas associated with this day's ideas. In this way the understanding of student thinking is used to plan for future lessons. The student thinking generated by the summary will also be used by the study to answer the first research question.

Figure 3 **Conferring Questions**

To help students build confidence and rely on their own understanding, ask…

- Why is that true?
- How did you reach that conclusion?
- Does that make sense?

To help students learn to reason mathematically, ask…

- Is that true for all cases? Explain.
- Can you think of a counterexample?
- How would you prove that?
- What assumptions are you making?

To check student progress, ask…

- Can you explain what you have done so far? What else is there to do?
- Is there a more efficient strategy?
- What do you notice when…?
- Why did you decide to organize your results like that?
- Have you thought of all the possibilities? How can you be sure?

To help students collectively make sense of mathematics, ask…

- What do you think about what________said?
- Do you agree? Why or why not?
- Does anyone have the same answer but a different way to explain it?
- Do you understand what________is saying?
- Can you convince the rest of us that your answer makes sense?

To encourage conjecturing, ask…

- What would happen if…? What if not?
- Do you see a pattern? Can you explain the pattern?
- Can you predict the next one? What about the last one?
- What decision do you think he/she should make?

To promote problem solving, ask…

- What do you need to find out?
- What information do you have?
- What strategies are you going to use?
- Will you do it mentally? With pencil and paper? Using a number line?
- Will a calculator help?
- What tools will you need?
- What do you think the answer or result will be?

PBS Teacherline. (n.d.). *Developing mathematical thinking with effective questions*. Retrieved from http://rmpbs.pbslearningmedia.org/

The teacher's role. An understanding of the teacher's role and student's role is essential in creating a strong learning environment in the classroom (Van Zoest, & Enyart, 1998). Amy and I will create an inquiry base classroom by planning lessons where we choose and pose problems that challenge student thinking (Van Zoest, & Enyart, 1998). We will then plan for the discourse, and Amy's support of it, so she can listen closely to student as they engage in the productive struggle associated with solving the problem (Boston & Smith, 2009; Van Zoest, & Enyart, 1998). The lesson will require students to clarify and justify their responses by responding to the conferring questions Amy poses (Foreman, 2012; Van Zoest, & Enyart, 1998). The lesson will also require student to mathematize the problem by decontextualizing and then recontextualizing with models or other mathematical representations.

Using mathematical models and representations will be significant in planning the Explore component of each lesson. Doerr (2006) has provided three principles for effectively using mathematical models and representations and they will be accessed to help students make sense of the mathematics in the lessons. First, we will plan for the Reality Principle by presenting students with worthwhile tasks where students are encouraged to use their personal knowledge and experiences to access and make sense of the problem and its solution (Doerr, 2006; Foreman, 2012). Next, we will plan for the Construction Principle by helping student recognize the need for constructing mathematical models and representations. Students will be pressed into justifying the solution to the problem through the use of the model and/or representation they constructed. The justifications will be evaluated based on how well they reveal the student thinking associated with the problem and the model or representation associated with it (Doerr, 2006). The third principle we will plan for is the Documenting Principle. It is here that students will learn how to make sense of proficiency and use this knowledge to create proficient responses in their work (Doerr, 2006). Specific parts of the class period will be devoted to this task to make the evaluating of work by the students an intentional part of the lesson.

The student's role. The student's role is to bring their mathematical understandings to the lesson and use them to make sense of the ideas presented during class. To do this, students will listen to, respond to, and ask questions of the teacher and each other (Van Zoest & Enyart, 1998). This is not something most students will come to class being able to do so Amy and I will need to plan for the student's role by teaching the students how to question each other and themselves as they are working on the problems. The complexity in the problems will be used to train students how to engage with each other as they struggle with high cognitive demand tasks (Boston & Smith 2009; Kazemi, 1998). We will do this by introducing the sociomathematical norms into the classroom culture as shown in Figure 4. We will also plan for the use of the question set titled, "To help students collectively make sense of mathematics, ask…" as shown in Figure 3. Through these questions and the implementation of the sociomathematical norms students will be facilitated in convincing themselves and each other of the validity of the representations, solutions, and/or conjectures presented in class (Van Zoest & Enyart, 1998). Planning lessons that cause students to engage in the sociomathematical norms is essential to gathering in the moment information on student thinking which can then be used to modify the direction of the lesson to meet the needs of the students.

Figure 4 **Sociomathematical Norms**
1. Students access mathematics as the authority in the classroom in order to engage in mathematical reasoning, justification, and/or understanding. 2. Students go beyond making sense of the math for themselves and contribute to the understandings of others through their explanations of the mathematics. 3. Students make the shift from just solving problems to comparing the solutions of others. By finding the similarities and differences between their approach and results to those of other students can begin to form mathematical arguments. 4. Students reason through the math, form explanations that inform the thinking of others, and evaluate the similarities and differences in other explanations they can then form a

mathematical argument which can be used to engage in mathematical debate and form consensus.
Yackel & Cobb, 1996

A goal of each lesson is to create productive struggle. To do this Amy and I will challenge students with different perspectives or contradictions in thinking and then support them in reconsidering or expanding their understanding (Foreman, 2012). Training students to engage in productive struggle can be accomplished by helping students to see the results of their efforts through new understandings taken on because of their effort (Resnick & Hall, 2003). Amy and I will plan for the use of conjectures formed at the beginning of the lesson and compare them to the new understandings taken on by the end of the lesson. In this way, students can become aware of how much they have learned. These experiences can promote the development of a growth mindset that in turn supports students in engaging in productive struggle (Dweck, 2006). More on conjectures and how they are used to develop a growth mindset will be given later in the Instructional Practices section. Planning lessons that cause students to engage in productive struggle is critical to eliciting the information on student thinking necessary to make in the moment decisions about the direction of the lesson.

Figure 5 **Instructional Practices**

- Structure the discourse
- Confer with students using inquiry-based questions
- Have students post their original work
- Select and sequence the student responses

***Instructional practices*.** Another component of the teacher's role is the instructional practices she brings to the lesson as shown in Figure 5. These are the instructional practices, designed to create a student centered classroom, are the practices Amy and I will be planning for (Foreman, 2012) Amy will work to structure the discourse to promote equity in the conversation and confer with students as they work to determine what understandings they are taking on (Foreman, 2012; Franke & Kazemi, 2001). Amy will also have students create a record of support displaying the ideas they attaining. She will use the information gathered through the discourse, conferring, and posting of student ideas to make decisions about how to best select and sequence the understandings that surface during the Explore component of the lesson. Next is a detailed description of each of the four instructional strategies and how they will be planned for and implemented in the lessons for this study.

First, we will plan for a lesson by choosing which problems students will work on individually, and which problems students will work on collaboratively. Students need private reasoning time to make sense of the math before they share in their groups about how they are making sense of it (Foreman, 2012). For this reason, Amy and I will plan for a problem or part of a problem to be worked on individually before students share their understandings. After time has been given for students to makes sense of the problem, they will write down what they understand about the problem in the form of a conjecture. The conjecture statement can then be revisited after the summary to assist the students in seeing how much they have learned through the class period. This is an instructional strategy used to promote a growth mindset (Dweck, 2006).

Once students have the opportunity to work on the problem individually, and have written a conjecture, Amy will provide opportunities for the student to discuss their individual ideas collectively in collaborative groups. Amy will work to structure the discourse to minimize status within the groups and promote equity throughout the classroom. This will occur by assigning letters and/or colors to individuals in each group which are used to promote one student talking at a time while the rest of the group listens to understand what is shared. Once the student has finished, another student in the group will be given a chance to share while the others listen, clarify and revoice. This structure can occur in pairs, triads, or quads, but is not as useful in group larger than four. Planning for this structure requires a rigorous worthwhile problem aligned with the learning outcome for the day so the conversations can stay rich and varied. Planning also includes deciding whether pairs, triads, or quads will be used in the structuring.

Second, Amy and I will plan for the conferring by first choosing a rigorous problem with opportunities for students to explore with the mathematical concepts and connecting the ideas from previous lessons. We will then choose inquiry-based questions from Figure 3 to confer with students using focusing questions such as “why is that true”, “can you prove that idea”, and “how does that make sense to you” (Herbal-Eisenmann & Breyfogle, 2005). The student responses will give Amy useful data for making in the moment decisions about how to proceed through that day’s lesson (Kazemi, 1998; Franke & Kazemi, 2001; Herbal-Eisenmann & Breyfogle, 2005). Questioning which focus the student on justifying why they performed a particular procedure or why the procedure worked is a powerful assessment tool and the assessment data on student thinking that is gleaned can be used to make both in the moment and future lesson planning decisions (Duckor, 2014; Herbal-Eisenmann & Breyfogle, 2005; Shepard, 2005; Tomlinson, 2014). How Amy creates the opportunities and then uses them to make planning decisions will be data I can gather and use to answer the second research question of the study.

Third, Amy and I will plan for which problems we want students to post on chart paper or on the white board. Amy will select a few groups to post their original work on the problem for the class to consider as the rest of the class is working on the same problem at their tables. In our planning, we will anticipate what students might do with the problem to assist in monitoring for the various solutions and solving strategies the students are using (Smith et al., 2009). Figure 6 has the planning document we will be using to anticipate what students will do with the math and we will select and sequence these ideas.

Figure 6	**Planning for Selecting and Sequencing**			
Strategy or idea	Rationale for the selection	The mathematics of the strategy	Sequence	Conferring questions to draw out the mathematical understandings
Foreman, 2012				

Fourth, the posted solutions, as well as those formed by students at their tables, will be selected by Amy to draw out the ideas in the learning outcome for the day. Correct as well as incorrect solutions will be selected and presented to the class for student to engage in evaluating the correctness of the responses to the problem. Justification for why the correct responses are correct and why the incorrect responses are incorrect will be formed and differences in understanding will be used to create debate across the classroom. In this way, the summary of the lesson flows from anticipating student responses, to monitoring for those responses, to selecting and sequencing the responses in an engaging discussion and/or debate (Smith et a., 2009). Finally, Amy will connect the mathematical ideas of the lesson to each other as well as ideas from previous lessons (Duckor, 2014; Smith et al., 2009; Tomlinson, 2014). Once the summary is concluded Amy will have students go back and look at their conjecture to make any necessary changes based on what they now know and understand regarding the learning outcome of the lesson. The thinking, which Amy engages in to work through these instructional strategies, and how her teaching moves work to generate understanding about student thinking will be data I can gather and use to answer both questions guiding this study.

These four instructional strategies are very effective in soliciting the information in student thinking that teachers need to improve the learning environment in their classroom (Smith et al., 2009). Amy will take advantage of the conversations that occur through the structuring of the discourse, the responses to her conferring questions, and the select and sequence ideas to make decisions about the rest of the ongoing lesson as well as future lessons. Depending on the information, the class gives her regarding their thinking, and the amount of time left in the class period, Amy may have them continue to discuss in their groups or work more individually on the problem.

As Amy and I plan for the Launch, Explore, and Summary of each lesson, I will be audio recording the discussion to analyze the decisions we make and the reasons why we made them. These recordings will then be transcribed and coded to look for insights into the problem being researched as described in the research question. Coding will be based on themes that emerge as I study the transcripts. A more detailed description of how I will organize the codes will be presented later in the chapter. I will also be keeping a research journal with ongoing data analysis and memoing throughout stage one of the study. The lesson plans using the lesson-planning framework as displayed in Figure 2, and the selecting and sequencing document displayed in Figure 6, will be included in the study as an artifact.

Stage two. On the second day, I will attend Amy's class to observe the 70-minute lesson. I will be looking for how Amy's instruction through the Launch, Explore, and Summary provides opportunities for her to generate, gather, and use student thinking to make planning decisions. Student responses to the conferring questions from Figure 3 posed throughout the class period will give Amy information about how to proceed with both the current lesson and with future lessons. I will be looking at how Amy uses this information to make instructional decisions. As her instructional coach, I will also be available to discuss with her what we are seeing and how the lesson might proceed based on the learning that is occurring. However, as mentioned earlier, I want to be careful that my coaching does not get in the way of collecting accurate data on Amy's thinking.

In my observations of Amy's lessons, I will be looking for how she engages students in the following components of an inquiry based learning community. First, I will look for how Amy uses student to student discourse rather than typical student and teacher conversations which generally exclude the rest of class (Van de Walle, 2007). When posed with a question from a student, I will observe how Amy redirects the question to another student, and then how she has a third student describe, explain, or revoice the thoughts or understandings being shared. I will note if Amy helps students notice different solutions in each other's work and how she asks them to consider who may or may not be correct (Smith et al., 2009; Van de Walle, 2007).

Next, I will observe how Amy requires justification to accompany responses so that the request for a justification does not suggest that the response is either correct or incorrect. I will note whether Amy validates or invalidates responses as either representing correct or incorrect thinking since correct answers do not necessarily represent correct thinking and incorrect answer may be due to a simple calculation error (Van de Walle, 2007). By having students explain their thinking Amy will create opportunities to diagnose both the response and the conceptual understanding that supports it and I will observe how Amy takes advantage of these opportunities. This will assist Amy in gathering the information on student thinking she can use to make in the moment decisions about the direction of the rest of the lesson (Duckor, 2014; Van de Walle, 2007). As her instructional coach I may offer assistance in these decisions. By having students provide justifications for their responses I plan to observe how well the students are taking on the idea that math is more than just answers; it requires making sense, justifying, and generalizing with the math to demonstrate understanding (Foreman, 2012).

I will observe how Amy calls on quiet students in both large and small group settings to draw them into the learning community, and I will observe how Amy boost her students' confidence by expressing how much value their work will bring to the class' understanding of the concept(s) (Dweck, 2006; Van de Walle, 2007). However, shy students need opportunities to formulate their response before being called on (Van de Walle, 2007). So, I will first observe how Amy notices what the student is doing with the mathematical ideas in the lesson, then how she gives them advanced warning that they will be called on in the whole class discussion to share an idea, and finally how she encourages the student to practice sharing thee response within his or her small group before they share in the large group (Van de Walle, 2007). I will look for opportunities in the lesson for Amy to engage her quieter students, and take note of what she does with the opportunities.

Next, as students are exploring with the math, I will observe how Amy looks for correct as well as incorrect responses to problems that can be drawn out in the summary (Smith et al., 2009). I will be looking for how Amy validates these answers as the students are exploring, and how she waits to expose the differences through the selecting and sequencing of student ideas in the summary. I will be using the planning form found in Figure 6 to record what was selected, how it was sequenced, and how Amy's facilitation of the discussion allowed her students to evaluate each other's work. Creating an engaging summary comes from drawing out these differences and using them to form a mathematical argument across the classroom (Smith et al., 2009; Van de Walle, 2007).

Through these instructional moves, Amy will work to ensure that her students understand what she understands about the math by the end of the summary. Amy's understanding of the math may cause her to accept partially proficient explanations when she hears what students seem to mean rather than what they actually say (Van de Walle, 2007). This is where asking the conferring questions found in Figure 3 can draw out concepts and misconceptions that the original explanation did not reveal. The goal of facilitation as students are exploring and summarizing with the math is to create independent student mathematicians and this cannot happen if the teacher is talking about the math instead of the students (Reinhart, 2000). Students need opportunities to be independent of the teacher but dependent on each other, they need opportunities to be independent of each other and the teacher but dependent on technology, and they need opportunities to be independent of teacher, peers, and technology. Choosing which problems best avail themselves to these different opportunities for independence will be carefully considered as the lesson is being planned (Van de Walle, 2007). I will be looking for how Amy will be noticing and taking advantage of these different opportunities. Observations from stage two will be collected based on the components found in Figure 7 and will include how Amy's instruction provides students with opportunities to make sense of the math, justify why the math works, and generalize the math of the lesson to other contexts (Foreman, 2012).

Figure 7 **Student Discourse Analysis Tool**

Discourse Types	**Procedures and Facts** 1. Short answer to a direct question 2. Restating facts/statements/rules 3. Showing or asking for procedures	**Justification** 1. Confirm the validity of an idea or solution 2. Refute the validity of an idea or solution 3. Create a mathematical argument and use it when challenged or to challenge another	**Generalizing** 1. Make and confirm conjectures 2. Extend an understanding from a specific case to a general case
	Observations		
	Student thinking observed through the discourse	Teacher thinking observed through the discourse	

Taken from:
Foreman, L.C. (2012). *How math teaching matters*. West Linn, OR: Teachers Development Group.

Each lesson will be audio recorded with a wireless microphone designed to pick up Amy’s questions and the student’s responses in a noisy active classroom. The wireless microphone will also be used to record student-to-student discourse. The recordings will be transcribed, coded, and used along with the transcripts and codes from Stage One to look for themes in the study as they emerge. More on coding will be presented later in the chapter. I will also be keeping a research journal with ongoing data analysis and memoing throughout stage two of the study.

Stage three. On the third day Amy and I will meet to debrief the lesson. I will first have Amy share her perceptions of the lesson. If necessary, I will prompt her to review what happened in the lesson from her perspective by asking her to describe what worked and what didn’t from the lesson plan that we created (Knight, 2007). Depending on what she says, I will consider these questions concerning the effectiveness of the lesson.

- How did the lesson provide for the productive struggle necessary in advancing mathematical understanding (Foreman, 2012)?
- What mathematical understandings were students able to generalize because of the lesson (Foreman, 2012)?
- To what extent were students able to describe the math they were using and why the math worked (Foreman, 2012)?
- How were the use of conjectures able to assist students in seeing how their math understandings improved (Foreman, 2012)?

I will be listening for what she had hoped would happen, compared to what did happen, in the lesson (Stigler & Hiebert, 1999).

Amy and I will plan one or two 30 minutes reteach lesson based on the observation data and written student responses to the assessment problem gathered in the 70-minute lesson. We will be using the rubric found in Figure 8 to evaluate the student work for proficiency. This six-point rubric is designed for problems with a high level of complexity in a familiar context. It is designed to score for unsatisfactory, partially proficient, and proficient understandings on problems that are rigorous enough to provide students opportunity to demonstrate proficient ability (Anderson, 2003).

Figure 8 **Six-Point Rubric for Complex Problems in Familiar Context**

Unsatisfactory 0	**Unsatisfactory 1-2**	**Partially Proficient 3-4**	**Proficient 5-6**
Student does not access the necessary mathematics to solve the problem	The response demonstrates some evidence of mathematical knowledge that is appropriate to the intent of the prompted purpose. An effort was made to accomplish the task, but with little success. Evidence in the response demonstrates that with instruction the student can revise the work to accomplish the task.	The response demonstrates adequate evidence of the learning and strategic tools necessary to complete the prompted purpose. It may contain overlooked issues, misleading assumptions, and/or errors in execution. Evidence in the response demonstrates that the student can revise the work to accomplish the task with the help of written feedback or dialogue.	The response accomplishes the prompted purpose and effectively communicates the student's mathematical understanding. The student's strategy and execution meet the content (including concepts, technique, representations, and connections), thinking processes and qualitative demands of the task. Minor omissions may exist, but do not detract from the correctness of the response.

Anderson, L. W. (2003). *Classroom assessment: Enhancing the quality of teacher decision making*. Lawrence Erlbayum Associates Inc. Mahwah, NJ.

Amy and I will be using this rubric to score each piece of student work from the class I observed. If the student demonstrates some understanding of the math necessary to solve the problem, but their effort demonstrates very little understanding of how to use the math to solve the problem, he/she will receive an unsatisfactory score of a 1 or 2 depending on how much math was displayed and how it was used (Anderson, 2003). If the student demonstrates adequate evidence of the necessary math, and how to use it to solve the problem, but has errors in execution such that the strategies or results do not make sense, then he/she will receive a partially proficient score of 3 or 4 depending on how the math was displayed and the errors which were made (Anderson, 2003). If the student's response accurately solves the problem and effectively communicates the necessary understandings associated with the problem then the student will receive a proficient score of 5 or 6 depending on the organization and communication associated with the problem. A student may also receive a proficient score with minor errors if those errors do not detract from the demonstration of understanding necessary to accomplish the prompt (Anderson, 2003). Examples of student work and how it was scored by Amy and I will be included in the study as artifacts.

The purpose of using a rubric is to score the thinking a student is using to engage in the problem as well as the answer he/she found (Andrade, 2000). Through this information, we can determine which students have taken on the conceptual understandings required in the standard and which students have not. This will then be used in planning the follow-up lesson, and will be very beneficial in answering both research questions in this study.

Using student thinking as displayed in the observation notes, as well as the student work evaluated through the rubric, Amy and I will plan the follow-up 30 minutes reteach lesson. We will use the Launch, Explore, Summary model to plan for inquiry, but each part of the lesson will need to be reduced in time compared to the 70-minute lesson. Therefore, we will need to plan the lesson with this constraint in mind and implement the lesson with a higher level of urgency.

As in Stage One, the debrief discussion will be audio recording the decisions we make and the reasons why we made them. These recordings will then be transcribed and coded to look for insights into the problem being researched as described in the research questions. More on coding will be presented later in the chapter. I will also be keeping a research journal with ongoing data analysis and memoing throughout stage three of the study.

Stage four. On the fourth day, I will return to Amy's room to observe the reteach lesson. I will be using the same observation tool found in Figure 7 and will be looking for student and teacher understanding in the same way as I did in Stage Two. I will be focused more on the urgency in the lesson than I was in Stage Two because the amount of time devoted to the reteach lesson is significantly less. I will also be looking for how student understanding improved based on the reteach lesson that Amy and I created. Depending on what the student data tells us in the debrief we may design two or three follow-up lessons which I will also attend. These lessons will be audio recorded, the recording will be transcribed, and the transcriptions coded as described later in the chapter. I will also be keeping a research journal with ongoing data analysis and memoing throughout stage four of the study.

Figure 9 below is the document I will be using as I plan for and schedule each of the three cycles for this study. The dates for each stage in each cycle will be determined as I get closer to the time to collect data.

Figure 9 **Schedule for the Study**

Cycle One	**Cycle Two**	**Cycle Three**
Stage One- Planning- 8/14 _____	Stage One- Planning- 9/5___	Stage One- Planning- 9/25
Stage Two- Observation- 8/15	Stage Two- Observation- 9/6	Stage Two- Observation- 9/26
Stage Three- Debrief- 8/16	Stage Three- Debrief- 9/7	Stage Three- Debrief- 9/27
Stage Four- Observation- 8/17	Stage Four- Observation- 9/8	Stage Four- Observation- 9/28

Planning for the Coaching

As mentioned in the previous chapter, professional development of teachers requires those facilitating the learning as well as those engaged in the ideas being presented to be professionals. I will use the characteristics of a professional (Wiggins & McTighe, 2006) as I interact with Amy in both the role of the researcher as well as her instructional coach. I will be accessing the most current research on teaching and learning as described in chapter two to facilitate our planning and debrief sessions to focus on the results of our work, and whether our efforts are making a difference in student learning. The most important characteristic of a professional is how I adapt to meet the individual needs of Amy as my participant. This section is about how I will gather information on Amy's thinking as she works with students and as we collectively evaluate student work for proficiency.

Because the sociomathematical norms displayed in Figure 4 are so pivotal in the creation of an inquiry-based lesson through the Launch, Explore, Summary instructional model, I will be using these as the outcomes for my work with Amy. The instructional strategies described earlier (structured discourse, conferring, creating and using student record of support, and selecting and sequencing student responses) are all designed to create the sociomathematical norms in the mathematics classroom.

For this reason, the sociomathematical norms (Yackel & Cobb, 1996) will be a focus of this study to assess Amy's thinking as we work to create lessons that provide opportunity for students to demonstrate their thinking about the mathematics they are working on. To see growth in Amy's understanding of the Sociomathematical Norms, I have created an interview found in Figure 10 for her to respond to at the beginning and again at the end of the cycles in the study. The interview is related to the sociomathematical norms from Figure 4 but draws out the distinctions between the social norms and the sociomathematical norms. Social norms require students to explain their thinking. This is compared to the sociomathematical norms where students are expected to demonstrate understandings through explanations that inform the thinking of others by evaluating the similarities and differences in various presented explanations. Through these comparisons, students governed by sociomathematical classroom norms can then form a mathematical argument to use in classroom debate (Yackel & Cobb, 1996).

As part of each cycle, Amy and I will plan for the use of these sociomathematical norms in the planning stage and then reflect on their effectiveness in the debrief stage. The effectiveness will be evaluated based on how well they provided opportunity for Amy to gather information about what her students were thinking during the lesson. I will also be requesting that Amy journal about the use of the Sociomathematical Norms both during each of the three cycles as well as the lessons between each cycle. The purpose of the journaling is to capture her perceptions of the use and effectiveness of these norms throughout the stages of each cycle. I will then use this information along with survey data to assist in forming the theoretical codes discussed later in the data analysis section of this chapter.

Figure 10 **Participant Survey**

Each set below contains a social norm (a) and a related sociomathematical norm (b). Consider each as you answer the questio0ns below.

1.
    a. When students help each other work through the math.
    b. When students access mathematics as the authority in the classroom in order to engage in mathematical reasoning, justification, and/or understanding.
2.
    a. When students make descriptions and/or explanations about the solution process.
    b. When students go beyond making sense of the math for themselves and contribute to the understandings of others through their explanations of the mathematics.
3.
    a. When students solve problems using different representations and/or approaches.
    b. When students make the shift from just solving problems to comparing the solutions of others. By finding the similarities and differences between their approach and results to those of others students can begin to form mathematical arguments.

4.
   a. When students solve problems collaboratively.
   b. When students reason through the math, form explanations that inform the thinking of others, and evaluate the similarities and differences in other explanations they can then form a mathematical argument that can be used to engage in mathematical debate and form consensus.

Questions:

A. What do you find are the similarities and differences between the social and Sociomathematical Norms?
B. Which do you engage students in during classrooms lessons?
C. For the Sociomathematical Norms you use, how do you perceive them affecting the learning environment?
D. For the Sociomathematical Norms, what are some ideas for how you might implement them.

Yackel & Cobb, 1996

Assessing for Will and Skill. Robyn Jackson (2008) has created an assessment strategy designed to support instructional coaches and administrators in having more productive conversations with teachers. The normal feedback a teacher might get after a classroom visit is from an evaluator who responds from an observation form with statements generally tied to a formal evaluation. Feedback which is tied to individual teachers needs to professional growth and development is more useful (Jackson, 2008). Since simple fifteen minute visits twice a year is not adequate for creating this kind of feedback I will be spending hours with Amy planning lessons, observing lessons, evaluating the effectiveness of lessons, and planning for follow-up lessons.

Information necessary to understand a teacher's needs are best acquired through artifacts, informal observations, and the collaborative evaluation of student work (Jackson, 2008). The goal of these three actions is to determine where Amy is in her instructional practices and as a learner. Artifacts such as lesson plans, selection of assessments, and proficiency scores can convey how well the Amy matches the learning activities to the lesson objectives (Jackson, 2008). Informal observations can show me how Amy uses instructional practices designed to elicit student thinking. Looking together at students work can show me how Amy is making sense of the rubric and using it to score assessment problems for proficiency. These measures will be used during each of the three cycles and Amy's growth as shown through these components will be noted.

As I work to understand where Amy is as a teacher and a learner, I will be looking for the skills she has already developed as a teacher, and her will to improve her instructional practices. Because I have been working with Amy as her instructional coach for the last three semesters I am aware of her high level of willingness to improve as an educator. Through my previous observations of her teaching I have found Amy to be willing to listen and try on suggestions concerning her instruction. I have modeled lessons we coplanned and then observed her practice instructional moves for the same lesson in a different class period. As a member of Amy's grade level planning team I have had numerous conversations with her and the rest of the 8th grade teachers on using the rubric selected for this study to evaluate student work. It was Amy's high level of willingness to improve as a teacher, which caught my attention, and led me to requesting her as my participant in this study.

The purpose of gathering information on Amy's skill and will is to inform my coaching. This can tell me where to press Amy on taking on new planning strategies, which instructional practices designed to elicit student thinking I might model for Amy in her class, and how Amy is making sense of the rubric to evaluate student work for proficiency.

I will be using the observation tool displayed in Figure 7 to collect data on Amy's skill as an instructor and I will be using the observation tool displayed in Figure 11 to collect data on her willingness to improve her instruction. The ideas presented in this observation tool have been pulled from numerous documents I have been using in my work as an instructional coach over the years. This observation tool will also be included as an artifact in the study.

Figure 11 **Coaching Observation Tool**
• The teacher engages in coaching feedback on instructional practices. • The teacher uses the rubric to determine proficiency of student work. • The teacher uses the information from student work to make instructional decisions based on what students are thinking.

I will collect data on this observation tool based on how Amy engages in my observational statements and questions in our debrief of the lessons. I will be collecting data on how Amy uses the rubric to analyze student work for proficiency and then uses the information gleaned from the student work to make instructional decisions. I will also collect data on how Amy's makes instructional decisions based on how her students are thinking about the math. The information gathered through the prompts designed in this observational tool will then be used to support the abstracting of the codes into theoretical understandings.

The next section describes how I will analyze the data collected in this study.

Data Analysis

Data analysis in a qualitative study occurs through the transcriptions of recorded discourse between the research and participant(s), the coding of the transcripted information, and organizing of the codes into understandings useful in answering the questions posed by the study (Creswell, 2007; Maxwell, 2013; Saldaña, 2016). In this section, I will describe how I will be analyzing the data gleaned from this study to answer my two research questions.

Data in this study will be analyzed through three steps. Step one, will be to organize the data from each stage in each cycle (Creswell, 2007). Since my study will have three cycles with four stages in each cycle I will need to be very deliberate about how I organize the transcribed data, survey data, and observational data. Step two is to read through the data as a whole and attach memos in the margins as ideas and key concepts from the data as it occurs to me (Creswell, 2007). A purpose of this step is to search for major organizing topics that can be useful in coding the data. The third step is to organize codes so they can be used to describe, classify, and interpret the data (Creswell, 2007). Coding represents the heart of data analysis and the organization of the codes will be the bulk of this section.

As mentioned earlier, this study will have four stages: planning the initial lesson, observing the initial lesson, debriefing the initial lesson and planning the follow-up lesson, and observing the follow-up lesson. There will be three cycles with each of the four stages in each cycle. Data gathered and analyzed from these stages will then be used to answer the research questions. The first research question regarding a teacher's use of student thinking to improve the teaching and learning in a classroom will be answered through the analysis of data gathered in stages two, three, and four. The second question regarding an instructional coach's use of teacher thinking to support the teacher in improve the teaching and learning in a classroom will be answered through the analysis of data in all four stages.

Coding the Data. A code is a word or sentence that describes some portion of a qualitative study (Saldaña, 2016). Every sentence in the transcribed notes from an interview is a potential code. The criteria for coding are open to include anything the researcher finds interesting or surprising during an interview or while observing in the field. Generally, the researcher should code as much as it takes to understand the problem being researched while staying close to the research question driving the inquiry. The coding represents the primary essence of the study (Saldaña, 2016).

Lichtman (2005) writes about the organization of codes into categories and concepts. She suggests a six step process for working with the data generated by a qualitative inquiry. These categories provide a strong supportive structure for organizing the mass of information generated in a qualitative study.

Following Lichtman's (2005) approach, I first plan to use data provided by my participant or others in the field to create initial codes based on words or phrases that describe the events. The second step will be to revisit the initial codes in all the transcripts and field notes. I will look for redundancy in the codes and collapse them into a larger chunk that might be given a different name (Lichtman, 2005). Third, I will begin to organize the chunks into categories based on major topics and subsets of those topics. Fourth, I will want to go back to the initial codes and decide which categories are most important while possibly combining categories into larger chunks (Lichtman, 2005). The fifth step is to then revisit the categories, removing redundancies, and identifying critical elements which might form into concepts. The sixth stage is then to identify the key concepts which reflect the meaning I am making from the data. Generally, a few well developed concepts provide a richer analysis than many loosely framed and scattered ideas (Lichtman, 2005).

It is my task as the researcher to decide on the most logical manner of sorting the codes that arise from the data. By reorganizing, rewriting, and rethinking through the data I will find more powerful ideas to use for the conclusions (Lichtman, 2005).

As an organizational tool to assist in Lichtman's (2005) stages of coding and analyzing the codes, I will use Maxwell's (2013) categorical coding matrix displayed in Figure 12. The purpose of this matrix is to provide an organizational tool for coding and analyzing the qualitative data gleaned from the study (Maxwell, 2013). As a data analysis tool the categorical coding matrix allows the researcher to organize the different components of the study so that each can be analyzed based on both substantive and theoretical information.

This study, as I have addressed in detail earlier in the chapter, is designed around four stages. The four stages are planning lessons, observing lessons, debriefing and planning for the follow-up lesson, and observing the follow-up lesson. All four stages along with a short description of each make up the first row of the matrix presented in Figure 12 and are used to organize the data into these four categories.

The second row in the matrix of Figure 12 is the substantive information gleaned from the transcripts. Maxwell (2013) defines the substantive codes as descriptions of the participant's concepts and beliefs taken directly from the transcribed notes. In this study the substantive information is coded from data gleaned from both the first research question on using information on student thinking to improve classroom teaching and learning and the second research question on using information on teacher thinking to improve instructional coaching. These are labeled in the substantive row of the matrix as student thinking and teacher thinking and will be useful in organizing the codes into larger chunks as suggested by Lichtman (2005) in stages three and four above.

Figure 12 **Categorical Coding Matrix**

	Stage One **Planning the initial lesson**	**Stage Two** **Observing the initial lesson**	**Stage Three** **Debriefing the initial lesson and planning the follow-up lesson**	**Stage Four** **Observing the follow-up lesson**
Organizational	Using the Launch-Explore-Summary instructional model Amy and I will create lesson plans designed to elicit student thinking.	I will observe each lesson for how Amy provides opportunities to generate, gather, and use student thinking to make planning decisions.	We will discuss the effects of the lesson on student learning, and what we learned about student understanding, through the lesson. We will then plan a reteach lesson to target the student needs as determined in the data.	I will observe each reteach lesson for how well our targeted instruction met the needs in student understanding.

Substantive	**Student Thinking**				
	Teacher Thinking				
Theoretical					

The third row in the matrix is the theoretical understandings formed from the data. Maxwell (2013) defines the theoretical codes as themes and generalizations in the data useful for forming understandings around the questions being researched. This is where the substantive codes are abstracted into the researcher's understandings of what is going on in the study (Maxwell, 2013). This is labeled in the matrix as theoretical and will be useful for addressing the fifth and sixth stage of coding as described by Litchman (2005) above. I will also be using the journal reflections written by both myself, and my participant, to support the abstracting of the codes into theoretical understandings.

As each of the four stages in the study are described throughout this chapter I will be referring back to this matrix as the data analysis tool used to organize the transcribed information collected.

Quality in a Qualitative Study.

Tracy (2010) has developed criteria for quality in a qualitative study. They include such components as a worthy topic, valid findings, and the effects of the researcher on the field being studied. I have found a topic worth being studied because it is relevant, timely, significant, and interesting. I will need to ensure that thick descriptions with in depth illustrations demonstrate the validity of my findings. The conclusions I make will then be reviewed by my colleagues to ensure they are comprehensible and useful by audiences with no direct experiences on the topic of the study. By continually evaluating the results and how they extend to the current level of understanding in the field this study will make a significant contribution to the field. Significance in the findings will also be obtained based on how they are viewed both theoretically as well as practically (Tracy, 2010).

Finally, with ethics as an end goal of the project, I will consider the effects on the field of the research study. I will begin by using an Institutional Review Board to review the procedural components of the project. However, situational ethics which occur in the field will be addressed based on doing to others as I would want done to me (Tracy, 2010).

Rigor in qualitative study. Rigor, another hallmark of a quality qualitative study can be defined by the authenticity of the researcher to be transparent regarding the purpose of the study throughout the course of the project (Davies & Dodd, 2002; Tracy, 2010). Seeing as how a qualitative study involves people, the rigorous researcher must consider how the study approaches the participant(s) with attentiveness, empathy, sensitivity, respect, and openness. This list is different than what one would find for defining a rigorous quantitative study where objectivity, neutrality, and replication are valued. By allowing for flexibility, qualitative research defines rigor based on ethics so that its methods are not seen as sloppy and therefor lacking in credibility (Davies & Dodd, 2002).

In this study, I have discussed the purpose of this study with the participant and the administrators running the building. As I progress through the inquiry, I will be attentive to the needs of my participant and the administrators as they might be affected by conducting this research.

Subjectivity in a qualitative study. Whereas some researchers may assert objectivity as the ideal in a study, subjectivity is an inevitable component of any research project (Peshkin, 1988). For this reason subjectivity needs to be a transparent part of the study because when it remains unconscious in the mind of the researcher it cannot be attended to in a meaningful way.

Subjectivity can be a powerful part of a study because it allows for perception as a tool of observation. Any study that involves humans, as researcher or participant, will include subjectivity. Therefor all research studies, quantitative and qualitative, have components of subjectivity. Subjectivity allows for opinion that can lead to ethical considerations in the development and implementation of the inquiry. Rossman and Rallis (2010) conclude that ethics need to have stronger considerations in research that validates subjectivity as a necessary component of research.

Summary

This chapter has described a qualitative research study using a case study methodology. The study will take place in a middle school and will explore the work of a teacher on using data on student thinking to improve the teaching and learning in the classroom. This study also looks at how an instructional coach uses data on teacher thinking to improve his coaching of instructional strategies. The instruments used in each stage of a cycle include the three-part lesson planning framework, the selecting and sequencing planning tool, the student discourse analysis tool, the sociomathematical norms questionnaire, and the instructional coaching observation tool. These tools will be used to facilitate planning and debriefing conversations with the participant as well as for data collection during the study. The research procedures include; (a) coplanning lessons with the participant, (b) observing the coplanned lessons, (c) debriefing the lessons based on students demonstrated understandings and coplanning the reteach lessons based on the assessed needs; (d) observing the reteach coplanned lesson; (f) keeping a research journal with ongoing data analysis and memoing. Data will be analyzed in a categorical matrix organized based on the stages of the study as well as the reflections of the participant. A theory may emerge through generalizations as the data is analyzed throughput the three cycles.

The next chapter will focus on the results of the study. Data will be analyzed through the recordings and coding to form generalizations directed towards answering both of the questions driving this study.

Chapter 4

Research Findings

Research Questions

The design and intent of the research study was to answer these two research questions:

- How does a teacher improve the teaching and learning in the classroom by using formative assessment data to make adjustments in a current lesson as well as plan future lessons?
- How does an instructional coach use information gathered from classroom observations and student responses to assessment problems to improve the coaching of teachers?

As mentioned in the last chapter, the purpose of this study is to determine how information on teacher thinking gathered by an instructional coach through planning meetings, classroom observations, debrief meetings, and reteaching observations can support a teacher in gathering and using information on student thinking to improve his or her teaching. Data for this study was collected in collaboration with one 8th grade math teacher while planning lessons, observing instruction, collecting data on student and teacher thinking, using that data to plan the next teaching move or the next lesson, and reflecting on what was learned by both the students and the teacher. This study took place in the first nine-week period of the school year and focused on two outcomes. The first outcome of this study was to look at how a teacher uses student thinking from formative assessment data to improve his or her planning and teaching. The second outcome was to look at how an instructional coach also uses student thinking as well as teacher thinking to improve the support of a teacher through his or her coaching.

Amy, not her real name, agreed to be my participant for this study. She is a fourth year middle school math teacher and this is her third year at the school where the study was conducted. I have worked with her for the last two year as her instructional coach supporting her in improving the teaching and learning that occurs in her classroom. She is also a part of a four person Professional Learning Community composed of 8th grade math teachers who support each other in improving themselves as teachers.

The Classroom Lessons for This Study

In this section, I will give a quick overview of the three main lessons Amy and I planned for over the course of the study in order to give some background on the classroom activities used in the lesson of each cycle. These became the activities for the study because they were what Amy was planning to use on each of the days scheduled for our work. The activities in each lesson will be referred to throughout the study as the "Gateman" problem used in the first cycle, the "Boat Rental" problem used in the second cycle, and the "Temperature/Visitor/Profit" problem used in the third cycle. All three of these problems are aligned with the 8th grade Common Core State Standard for Mathematics 8.F.B.4 as presented in Figure 13.

The Gateman problem was taken from the You Tube site https://www.youtube.com/watch?v=8eXb-6wQUks&t=272s and was about a pool that needed to be drained by 8:00 in the evening. The time and the depth were recorded as the pool was draining, and the students were asked to predict, based on the time of day and the rate of draining, whether the pool would be drained by 8:00 pm. Students constructed a table and a graph to determine when the pool was drained.

Figure 13 **Standard CCSS 8.F.B.4**

Construct a function to model a linear relationship between two quantities. Determine the rate of change and initial value of the function from a description of a relationship or from two (x, y) values, including reading these from a table or from a graph. Interpret the rate of change and initial value of a linear function in terms of the situation it models, and in terms of its graph or a table of values.

The Boat Rental problem was taken from Thinking with Mathematical Models, an 8th grade book in the Connect Mathematics 2 program (Lappan, Fey, Fitzgerald, Friel., Phillips, 2009). The problem gave students a graph from which they needed to create a table and an equation. Students then needed to use the graph, table, and equation to answer questions regarding the time a boat is out based on the cost of the rental as well as the cost based on how long the boat is out.

The Temperature/Visitor/Profit lesson was taken from Say It With Symbols, a different 8th grade book in the Connected Mathematics 2 program (Lappan et al., 2009). This problem had two parts where the first was to predict the number of visitors who would come to a park based on the temperature using the equation $V = 50(T - 45)$. The second part was to predict the profit at the park's concession stand based on the visitors attending the park using the equation $P = 4.25V - 300$. There were two challenges in this problem that students needed to address. One was substituting the $50(T - 45)$ expression into the $4.25V - 300$ expression for V. The other challenge was to determine what each part of the resulting equation represented in terms of the context of the problem.

Throughout this chapte,r the term "context" will be used to refer to the circumstances that form the setting for the problem, or what is sometimes called the story of the problem.

Using Formative Assessment Data From Student Thinking to Improve Classroom Instruction

The first research question in this study is how does a teacher improve the teaching and learning in the classroom by using formative assessment data to make adjustments in a current lesson as well as plan future lessons? In the course of answering this question, three instructional strategies emerged related to how Amy used student thinking to improve her teaching. The first strategy was planning lessons based on the previous understandings her students brought to the lesson. This strategy was enacted as we planned the exploration of the lesson based on the misconceptions as well as the extensions to meet the different needs of her students. The second instructional strategy was using student thinking observed during the lesson to improve the lesson. This strategy emerged as students engaged with each other while doing the math by making their thinking visible to each other and to the teacher. The third strategy was conceptual and involved the development of a mathematical community based on the Sociomathematical Norms. Through these norms, students go beyond just sharing ideas to ensuring that all students in the room improve in their mathematical understandings through their shared experiences.

Creating lessons based on student thinking. The first instructional strategy for this study was using information on student thinking to make planning decisions. As mentioned in Chapters 1 and 2 of this study, formative assessment data can be gathered through assessment problems given during the lesson and then used to form an awareness of student thinking. By planning from the understandings and the misunderstandings students have demonstrated in past lessons, Amy was able to plan for what she needed to do during the lesson to draw out new understandings. This section has two parts. The first part is planning from understandings students bring to the lesson and the second part is planning for the instructional strategies that elicit student thinking during the lesson.

Planning from the understandings students bring to the lesson. The launch of each lesson was developed based on the conversations Amy and I had regarding what understandings her students were likely and unlikely to bring to the lesson. Many times these were characterized as the misunderstandings students brought to the lesson that we needed to be watchful of as we planned.

During all discussions between Amy as the participant and me as the researcher, I will refer to myself as “Coach”. Amy and I began the planning session for the first cycle by discussing the learning outcome for the day.

Coach: *What will the lesson topic be for tomorrow?*

Amy: *We are describing events outside the classroom using graphs and determining if there is a linear relationship.*

Coach: *So like describing real-life events using graphs*

Amy: *Yes. And tables*

This led to a discussion regarding a lesson Amy ran a few days before.

Coach: *What do you think the kids should be able to do and understand using real-life linear events with tables and graphs?*

Amy: *…[earlier this week] they have been looking at a graph of prices of peaches and then they [came] up with a table for that.*

The Peaches lesson was based on a proportionality activity where the price of peaches increases as the pounds of peaches increases. The students used a graph of the relationship between price and pounds, and they made a table from the graph and context, and answered a few questions using either the table or the graph. From this lesson Amy was able to determine that most students were able to make a table from the graph and context of a problem and use that table to answer a few questions.

However, the activity we were planning required students to graph data from a table, and whereas students had demonstrated ability to plot points, Amy was not sure if they could scale their axis.

Amy: *Today we worked on just using a table to create a graph, so I know they've had a day of work on that so just even reference what we have done.*

Coach: *Did they scale their axis today?*

Amy: *Not really, each line represents 1, so they did not need to scale their axis. Because of the 1/2 in the table [for the activity we are planning], I might give them axis that are scaled.*

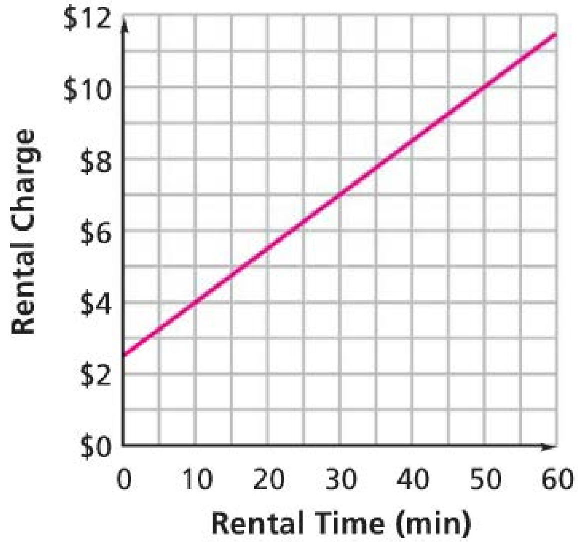
Through this discourse Amy described what her students had done with linear problems recently. She also demonstrated the value of representing linear situations in both tables and graphs as a way for students to show understanding of linear patterns. Amy and I used her understanding of her students' thinking from these first weeks of the school year to determine that her students would be able to plot points from a table. She was not sure if they would be able to scale the axis on the grid and decided to give them a grid that was already scaled to graph on.

By noticing what students are doing and thinking through previous lessons, and then bringing that understanding of student needs to the planning session, Amy was able to create better lesson plans to meet the needs of her students. From this example, her decision to have students create their own table, as well as her decision to scale the axis for her students, allowed her to plan a lesson based on her students' needs resulting in a better lesson. In this way, Amy and I used what she had observed previously about her student's thinking to answer the first question of this study by showing that the use of student thinking in the planning of lessons can improve the lesson plan. Another example of using student thinking to plan lessons was in the planning of the Canoe Rental problem for the second cycle. This problem included the graph shown in Figure 14 which was used to answer three questions on how much was charged as a function of time and how much time the boat was out based on the charge. The three questions were:

1. What is the charge for renting the canoe for 30 minutes?
2. A customer was charged $8.50. How long did he use the canoe?
3. A customer has $10 to spend. How long can she use the canoe?

Amy was concerned, due to what the students had recently done with a similar problem, that they would have difficulty determining the start value and what it meant in the context. She was also not sure how well they would work with the independent and dependent variables without

Figure 14 **Time vs. Charge Graph**



getting them confused.

Coach: *What might be some misconceptions?*

Amy: *They are going to call one of these C and the other one t. Or the other way around.*

Coach: *What might we do about that?*

Amy: *…If we were to refer back to either the car washing [problem] and they have starting co st when you show up to the car wash what would be the initial fee and then what would be cost/min. That sort of thing. So relating it back to the car wash.*

Coach: Other misconceptions?

Amy: Mixing up the time and charge. I don't think… like for the first one for the 30 minutes I think most people will get that right away. But when it gets to the $8.50 we look for 30 on the x-axis first they are going to look for $8.50 on the x-axis.

In the Car Wash problem, students were given the starting cost and the rate of change in terms of cost per minute to compare the pricing of three different cash wash companies. Students used graphs, tables, and equation to make comparisons between the three different companies but demonstrated confusion in how to identify the independent and dependent variables. For this reason, Amy was concerned while planning the Boat Rental lesson that her students would look for $8.50 rental cost on the x-axis, which represents the rental time instead of on the y-axis, which represents rental cost. To mitigate this issues Amy planned to refer back to the successes and struggles in Car Wash problem because the experiences her students brought from this lesson were important to move forward in the next day's lesson. This is another way that Amy used her understanding of student thinking to improve a lesson by intentionally meeting the needs of her students.

In the planning of the Canoe Rental lesson, Amy also engaged in an approach to understanding equations that became a central component of the lesson in the third cycle. Here she planned to have students define each variable in the equation in terms of the context of the problem. The equation for the problem was $C = 0.15t + 250$.

Coach: *What is the first thing they are going to do with the equation here?*

Amy: *… they need to understand what each part means in the equation… Two people get a job at a Canoe Rental place and there is an equation so people who come to them have to pay a $2.50 for a user fee and then $0.15 per minutes. The students have to explain in the situation what does it mean. For instance, what does the $2.50 mean and what does the $0.15 for each minute?*

Finding and using context problems where students can identify what each component of the equation means in terms of the context has been ongoing work for Amy and I over the last two years. I was encouraged that Amy intentionally planned for this in the Boat Rental problem. Whereas the book introduced the table and graph at the beginning of the lesson and the equation towards the end, Amy choose to have her students work at identifying each part of the equation in terms of the context at the beginning of the lesson. This was designed to provide opportunities for her to refer back to the context as students were working on the tables and graphs.

In the third cycle, Amy and I began planning the Temperature/Visitor/Profit lesson by discussing the students' previous experiences with solving problems where an expression from one equation is substituted into another equation. As mentioned earlier in this chapter, the two equations were P = 4.25V – 300 to find profit in terms of people visiting the park and V = 50(T –

45) to find visitors in terms of temperature. Figure 15 has the context, equations, and the questions Amy and I use for planning.

Amy: *[This] is going to be the struggle; looking at how are we going to solve this because you have a messy equation to begin with, with decimals and…*

Coach: *Yea and the fact that you've got to put visitors into the profit equation is a big substitution piece. That will be tough.*

Amy: *We've gone through a substitution piece before and it was about 50/50 with the class. Some people understood that they take this one and substitute it into that one and it took a while to get to that point.*

Figure 15 **Temperature/Visitor/Profit Questions**

A manager of a park claims that the profit P for a concession stand depends on the number of visitors V, and that the number of visitors depends on the day's high temperature T (in Fahrenheit). The following equations represent the manager's claims:

$$P = 4.25V - 300 \qquad V = 50(T - 45)$$

a. Suppose 1,000 people visit the park one day. Predict that day's high temperature.

b. Write an equation for profit based on temperature.

c. Write an equation for profit that is equivalent to the equation in part (b). Explain what information the numbers and variables represent.

d. Find the profit if the temperature is 70°F.

Amy was not sure she had enough capacity in the class to take on this complex substitution problem. Students did come into the lesson with some experiences in substituting expressions and her students had also been given opportunities in the Canoe Rental problem to describe what components of an equation represented in terms of the context of the problem. However, as Amy mentioned, these were messier equations in that they were not slope intercept equations given in the form $y = mx + b$.

Coach: *This is the part that got my attention as I was working the problem. "Explain what the information the numbers and variables represent." … This is going to be the tough part.*

Amy: *I think it would be very difficult for them to explain in the context. I think they are* *starting to do that with the [slope/intercept] equation. Most of the students are starting to understand what each part of the equation means.*

Whereas Amy’s students have been taking single equations based on a real-life context and describing what each part of the equation represents in terms of the context, this problem required them to substitute an expression into another expression, come up with an equivalent expression, then describe what each component of each expression represented in terms of the context. Her students came with some of these skills, but integrating those skills into this problem was going to be a challenge. Planning from what her students had demonstrated in previous lessons helped Amy form a better lesson where the challenge was accessible.

Planning for the instructional strategies that elicit student thinking during the lesson. Once Amy and I had established the understandings and misunderstandings students were likely to bring to a lesson, we switched to discussing what she can do through her instruction to elicit student thinking during the lesson. By planning for the instructional strategies that elicit student thinking during the lesson, I worked to answer the other part of the first research question regarding using student thinking to make adjustments during the lesson.

It is in this phase of the planning session that I began to probe Amy for her understandings about the instructional practices, which can cause students to demonstrate their thinking and how to implement them. Amy confided in me that her students many times have difficulties getting started on the problems she poses in class. Therefore, I asked her what kind of questions she could use to generate ideas about the problem.

Amy: *… if I notice that one person in the group is starting something and I have another person who is still confused with the question, I can ask that facilitator in the group to bring them together and facilitate a discussion.*

Coach: *What questions do you use? What is your role in making that happen?*

Amy: *Asking the person who has the question, "Have you asked your team the question?" "Have they attempted to help you figure it out?" "What are the questions you have for me?".*

I then asked Amy about the set of discourse strategies she had brought back from a recent training, and she was interested in trying a few of them on. Over the course of this study, Amy and I selected from this set of strategies by planning for the use of Proximity Partners in the Canoe Rental lesson, and both Ambassadors and Huddle in the Temperature/Visitor/Profit Lesson. These three strategies all came from the Core Connections mathematics course (Dietiker, Kysh, Salee, & Hoey, 2014). A short description of each follows.

The Proximity Partner strategy is used once students have generated some ideas about the problem. In this activity, all students stand up and move around the room by touching different objects such as two walls and a chair. Once they have touched each item the student they are standing closest to is the partner with whom they will be sharing their ideas. Each partner is then given time to describe the math they have been working on while the other person listens. The students are then directed to either find other objects to touch repeating the activity with a different partner, or they are told to return to their original seat and share in their groups what they learned from their discussions.

The Ambassador strategy is used when the teacher notices that a team has an idea about the mathematics that needs to be shared around the classroom. The teacher then directs members of that team to split up individually or in teams of two to bring their idea to the other groups in the room. The purpose of this strategy was to build the capacity of the students to form mathematical arguments and use them to share their understandings across the classrooms.

The Huddle strategy is used when the class is needing more direction and support, but the teacher wants to provide it through student representatives rather than to the whole class. One student from each team is called to gather in a place in the classroom where the teacher gives them a piece of information, checks that the group understands the information, and sends them back to their group to share what they now know. The teacher then checks in on each group to ensure that the correct information is being shared.

The purpose of each strategy is to use the students to promote mathematical thinking across the classroom. By making student thinking visible through the use of instructional strategies such as these, the teacher can make adjustments to his or her lesson to meet the needs of the students demonstrated during the lesson. These instructional strategies were intentionally chosen because they can assist in collecting data to answer the first research question in this study. The next section describes the use of each strategy as they play out through the lessons.

Important learnings. The first research question in the study is how does a teacher improve the teaching and learning in the classroom by using formative assessment data to make adjustments in a current lesson as well as plan future lessons? Using what the students understood related to the lesson being planned can improve future lessons by giving them better direction and focus. This can ensure that the lesson is meeting the mathematical needs of the students.

Amy entered into this research study familiar with the lesson planning strategy of working from students' previous understandings to plan future lessons (Tomlinson, 2014). She was able to look through the collected work from previous lessons to make informed decisions about how to scaffold for potential difficulties without removing the productive struggle from the lesson.

Amy's most significant learning seemed to be the intentional planning for the discourse strategy used in the lesson. Whereas I had coached Amy in using an ambassador strategy the previous year, we did not accessed the array of discourse strategies available to us during this study. Deciding which strategy to use, and what information it would give us about her student's thinking, was new learning from this study. As we will see in the next section, the intentional planning of how to get the student thinking out and in the classroom is important to using that thinking to create an effective summary to the lesson (Van de Walle, 2007).

Using student thinking observed during the lesson to improve the lesson. The second instructional strategy in this study was using student thinking during the lesson to improve the lesson. As mentioned previously, Amy is learning to implement instructional strategies that cause students to make their thinking visible across the classroom during the lesson. The strategies planned for were Proximity Partners, Ambassadors, and Huddle. However, another instructional strategy mentioned in chapter 3, Select and Sequence, was integrated into the three strategies that were intentionally planned for. In this section, I will describe how Amy implemented these strategies and what she did with the information from her students' thinking during the lesson to improve the lesson. Through the data collected as Amy worked to implement these strategies, I will continue to answer the first question of this study regarding how teachers can improve their teaching through the use of formative assessment.

Accessing the discourse strategies described in the last section occured both in the planning as well as in teaching the lesson. For instance, in the Canoe Rental problem, Amy and I had planned for the Proximity Partner strategy, but before we got to that point in the lesson, the Ambassador strategy became useful because of what the students were telling Amy about their thinking.

Recall that the Canoe Rental problem used a graph from which the students created a table, and both were used to answer a few questions. After the questions were answered, students were given the expression $0.15t + 2.50$ for the table and graph. As mentioned in the planning section, Amy chose to start the lesson by giving the expression to the class and directed them to determining what the 0.15 and the 2.50 meant in terms of the context of the problem.

Courtney: *I think the 0.15 is the starting cost. So like before you purchase anything you have to pay this.*

Amy: *OK, so just write down starting cost. What does everyone else think?*

Jonathan: *I agree. The 0.15 is the starting cost and the 2.50 is what you already have to pay.*

Miyah: *The 0.15 is the change; the rate of change; and the 2.50 is the start.*

Amy: *So Courtney do you agree with Miyah?*

Courtney: *We said the opposite. Because I think the 0.15 is the …*

Jonathan: *but the t is right there so that means…*

Shortly after this conversation regarding the values 0.15 and 2.50, and what they might mean in the context of the problem, Amy found me to ask:

Amy: *Should we do Ambassadors?*

Coach: *Do we know enough about what these people are thinking to know who to send and why?*

Amy shrugs to say she is not sure and then goes over to another group

Amy: *Hi people! What do you guys think over here?*

Amy listens to what the group has decided about what the values 0.15 and 2.50 mean in terms of the content and she revoices what she heard this group say.

Amy: *OK. So to rent is 2.50 and the 0.15 is to use the canoe.*

Amy then began to implement the ambassador strategy by calling for Courtney and Miyah to come over to the group she was currently working with.

Amy: *(To the group she has been conferring with) I am sending two people over here to share their thinking.*

Amy: *(To Courtney and Miyah) What do you think?*

Courtney: *I think the independent variable is the cost… We don't know the amount of time but we do …*

Miyah: *I think that the 0.15 the rate of change and the 2.50 is the start*

Amy: *Do you guys agree with what they are saying?*

After the members of this group had heard from Courtney and Miyah, Amy had representatives from the group go over and share their new ideas with a third group while Courtney and Miyah returned to their group. This use of classroom Ambassadors can do more than provide students a platform to describe the math and explain how they are making sense of it. Setting classroom norms where students see the value in making sure others understand the math the way they do allows the transition from the social norms of a mathematics class to the Sociomathematical Norms where students actively form arguments in order to inform others of ways to think about the math. By having students bring ideas to their peers, under the watchful eyes of a knowledgeable facilitator, the math becomes the authority in the room. By making the mathematics the authority students begin to look towards the math and how it makes sense with the problem rather than the teacher to make sense of the problem. This will be discussed more in the next section on how Amy made sense of the Sociomathematical Norms.

Later in this lesson, Amy introduces the Proximity Partner protocol when she wants the class to share ideas outside their group.

Amy: *I have not done this in class before. So, bear with me you are going to find a proximity partner, and proximity means that it is nearby. So it is in your proximity. Before you find your partner, what you are going to talk to your partner is about what you got and how you found it. So if you do not know why you found it, if you don't know how you found it or why it works that way, then I want you to listen to that other person. You are going to find somebody* *by- now listen carefully- by touching two tables and a wall. As soon as you touch two tables and a wall, then you are going to find the person that is nearest to you and you are going to talk to that person about how you solved that problem.*

Once students began to share their thinking, Amy found that she could use that information to select and sequence the students' ideas for the summary of the lesson. Recall from Chapter 2 that in the Select and Sequence strategy the teacher monitors for student ideas, both correct and incorrect, to then presents both before the class. The task then given to the class is to evaluate the responses for correctness. In this way, the Select and Sequence strategy can allow Amy to create opportunities for students to engage in higher level thinking, which in turn would improve the quality of the lesson. The following interaction between Amy and her students demonstrates her efforts to gather and use student thinking for the Select and Sequence protocol.

Amy: *5, 4, 3, 2, eyes and ears 1. Ok, so there were a lot of different strategies that I saw out there, and I want to bring up three different ways*. (Amy places a graph a student used to answer the question on the visualizer for the class to consider.) *Not many of you used the graph which surprised me a little bit because on 30 it crosses the line in a perfect spot. Perfectly the graph crosses the 7 right at the line so you can use a graph that way.*

I want to bring up a couple more. Someone who made a table; did we ever finish that table. You erased it? Oh no. I might write on yours a bit. They had (0,2.50,) then they had 10, 20, 30, 40. Table 7 why did you decide to erase what you had? What was the problem you had with this? Anyone making a table. We had others with tables.

Amy was disappointed that the group had erased the table she wanted to post for the class to see. She began to look for another group who had a similar table but was not able to find one. So, Amy transitioned to the use of the equation to find the answers to the questions.

Amy: *So what is another way?*

Neveah: *You could multiply.*

Amy: *You could multiply. So I want to bring this up. Do we all see this up at the top? What did she do? We had to multiply, but then what did we do?*

Neveah: *Add*

Amy: *Add which part?*

Jenelle: *$2.50*

Amy: *$2.50*

Amy returns the paper to the student and address the class.

Amy: *How many different ways are there to solve?*

Courtney: *Three.*

Amy: *What is one way?*

Neveah: *A table.*

Amy: *What is another way?*

Neveah: *Graph*

Amy: *and… Yes.*

Jimena: *Multiplication and addition*

Amy: *Using any of those [two] ways, now I want you to try #2, if you have not already. Try your strategy first… then do a new way.*

Whereas Amy did get two of the three representations up for students to consider, she had experienced difficulties in creating a summary where students evaluated the difference between solution methods.

In the third cycle, Amy and I planned for the use of the Huddle strategy in the Profit/Visitor/Temperature problem. We chose this because we were concerned that students would have difficulty making sense of the problem and what to do with it. As mentioned earlier, the Huddle strategy is useful when the students need direct support from the teacher, but the teacher still wants students to share the ideas they have been given in their groups.

Working from the visitor equation *V= 50(T – 45)* the class established that if the 50 is distributed into the expression then it will be in mx + b form as *V = 50T - 2250*. They also established that the 50 represents the increase in the number of visitors for an increase of every one degree in temperature. The -2250 value was not related back to the context, but Amy decided that this was not necessary to move on to part *a* of the problem. How students arrived at this will be discussed later in the chapter.

Part *a* asked the students to predict the temperature if the visitor count is 1000 people.

Amy: So we know that we are changing by 50. Now we are going to focus on question a… Suppose 1000 people visit the park one day. Predict that day's high temperature. What does the 1000 represent?

Neveah: people, visitors.

Amy: [Because] you know the number of visitors… do it in your groups. You guys have 2 minutes.

Amy then set the class to work in their groups on predicting the Temperature if the number of visitors is 1000. She moved among the groups to observe her students' thinking on problem.

Courtney: Where do I put the 1000 into the equation?

Amy: what do you know for "V"?

Jonathon: "V" is the visitors. So that means its 1000.

Amy: Share with your group.

Amy moves to a different group.

Amy: … Do you have something that tells you about visitors? So. What does this mean in *the problem? Ok, we know that 1000 people are what?*

Christian: Visiting

Amy: Yep, and if we read the actual question, "Predict that day's high temperature?" What are you trying to solve for?

Jazmin: How high the temperature is

Amy: Do you have an equation which deals with visitors and temperature? Do you think you can see what happens with that? Where would you put 1000?

Amy visited with three additional groups and determined that some students had values of 57, 67, and 65 for the temperature if the number of visitors is 1000 people, while other students had not been able to start the problem. At this point Amy appeared to have found enough students with ideas about the problem to start sending them out to other groups who were not generating ideas. This ambassador strategy was not planned for, but since Amy found enough students with ideas about how to approach the problem, she chose not to use the Huddle strategy.

Amy: …I am going to have Neveah … go to table 6 and share with them what you have. Maxwell, I want you to go to table 7. We are going to try and join forces here. Courtney, come over here and you three come over here; come over to table 2. Yes all of you. You are going to each need a chair.

Amy gives the students about 30 seconds to move to table 2

Amy: *Roselyn I like your equation. Maxwell can you explain your work to this group?*

Amy left this group to discuss their thinking.

Amy: *Christian, what did you guys talk about? What do we think? Do we like it? Did we check it? How could you check it? Aiden come back to this group and work with them.*

Christian: *I think it might be 65.*

Amy: *Why*

Christian: *Because it gives you 22 when you subtract 67 from 45 and that would give you way more than 1000. So it would be 65. 65-45 would be 20.*

Amy: *Ok. Is there a way that you could prove that? That you could test it.*

Christian: *50 times 20 would give you 1000. Which is what we are looking for. So 50 times 22 gives you 1,100. So it would have to be 65 degrees.*

Amy: *So we were putting more than two minds together to eventually get it right.*

Amy: *Jonathan, I want you to go talk to Christian over here. Christian, I am sending Jonathan to get some ideas from you. Courtney, will you go talk to one of these ladies over here? Because this table [they are] working on it different than yours.*

Courtney: *But I don't understand, and if they tell me when I don't understand…she told me 67 and I don't even know how you guys got 67? Because if it's 67 then you get 1100 visitors.*

Amy: *This group is going to share why they think its 67 and you can share why you think it is not.*

Amy allowed this discourse across the classroom to continue for about four more minutes and then she pulled the class back together. She decided to not select and sequence the responses she had received because most groups had found the temperature to be 65 degrees through the Ambassador strategy and because she was running behind schedule in the class period. Instead, she moved to part b of the problem. As discussed in the planning, we expected the substitution of the Visitor expression into the Profit equation to give students significant difficulties. After giving her students about 6-7 minutes to struggle with the problem, Amy told me she wanted now to use the Huddle strategy. When I asked her why, she responded that no one was coming up with an idea to share and that time was beginning to run out on the period. Amy got the class's attention and introduced the Huddle instructional strategy.

Amy: *I am going to ask one person from a table [and] teach them what to do and then I am going to send them back to your groups. If you are one of the people who are not coming up, I don't want you to just hang out for three minutes while I am teaching. I want you to see if you can't figure it out before they come back.*

Amy calls for one student from each group and directs them to huddle around her Promethean Board.

Amy: *This is just part B. We are just writing the equation. We need to write an equation for profit… based on the temperature. What is it saying in both of these equations?*

Amy goes on to describe how to substitute the expression for the visitors into the Profit equation. She checks for understanding along the way and then checks to ensure that students know what to say when they get back to their groups. After a 3 to 4 minute huddle, Amy sent these student representatives back to their group to share how to make the substitution for part b.

Amy then checked in with each group. She observed that most were showing the correct substitution, and so she focused on the one group that was not making sense of what their huddle representative had brought back. The class finished part b with some students moving around the room to support other students in making sense of the substitution and why it worked.

In this lesson, Amy saw that students improved in their ability to both relate the component of an equation back the context of the problem as well as to substitute one expression in for another. Later in this chapter, I will discuss what Amy decided to do with this information and what she learned about the instructional strategies she used to gather it.

Important learnings. Again, the first question in this study is how does a teacher improve the teaching and learning in the classroom by using formative assessment data to make adjustments in a current lesson as well as plan future lessons? Amy's ability to create group discourse where students shared their thinking and then use what students were sharing to adjust her instructional support allowed us to collect data to answer this research question for this study (Duckor, 2014). By having students share with other groups through the Ambassador, Proximity Partner, Huddle, and Select and Sequence protocols, Amy was able to both generate and use student thinking. Then acting on this information, Amy was then able to make improvements in the lesson while teaching.

A significant discovery was that successfully selecting and sequencing student responses in the summary of the lesson requires discourse strategies during the exploration of the lesson. The purpose of discourse strategies are to draw out the student thinking so the teacher can select and sequence with that student thinking to create an effective summary (Smith et al, 2009). In the Gateman lesson Amy struggled to get an effective summary into the lesson, but in the Boat Rental and Temperature/Visitor/Profit lessons the select and sequencing were much more effective because we had planned for and used discourse strategies during the explore section of the lesson.

In this section, I have demonstrated how Amy uses student thinking to plan lessons. I have also given examples of how the instructional strategies we planned for worked during the lesson to help Amy make instructional decisions in the moment. Through the planning and teaching phases of this research study, I have shown that when a teacher uses student thinking to plan a lesson, as well as make adjustments in the lesson, their teaching improves.

In the next section, I will discuss Amy's initial understandings of the Sociomathematical Norms and how these became an indication of what she learned about creating a classroom culture, where student thinking was made visible.

Building the social and Sociomathematical Norms in Amy's classroom. The third instructional strategy in this study was to build the Sociomathematical Norms in Amy's classroom to supports the teacher and instructional coach in making student thinking visible.

The questions for this research project are how a teacher and instructional coach can use student thinking to improve teaching and coaching. The Sociomathematical Norms give a strong description of what a math classroom looks like when students are making their mathematical thinking visible. By making the Sociomathematical Norms a focus of this study, I explored the work a teacher and instructional coach need to engage in to create a learning environment where student thinking is available to them.

The norms of a group are simply the way the group normally functions to achieve a desired end. As mentioned earlier, the social norms of a mathematics classroom are designed to support students in making descriptions and explanations about the math to help others work through problems and get correct answers. The Sociomathematical Norms, on the other hand, are designed to go beyond descriptions and explanations where each student works to contribute to the understandings of everyone else in the class. Norming a classroom with the Sociomathematical Norms allows both the teacher and instructional coach to observe student thinking making it useful for improving both teaching and coaching.

Students who make their thinking visible to their peers are also making their thinking visible to the teacher. The teacher can then, through his or her facilitation, support the students in synthesizing these ideas into their own thinking, making their mathematical arguments more powerful. The instructional strategies that create the Sociomathematical Norms in a classroom make student thinking explicit so the teacher can then use that thinking to make instructional moves during the current lesson as well as in future lessons.

Amy is practicing with instructional strategies that promote the formation of mathematical arguments in order to promote a variety of ways for students to think about the math. The practice of having students take the ideas they have been forming in their groups through the social norms and then bringing those ideas to other groups to assist the class in improving the mathematical understandings of all members, creates the shift from the social norms of a mathematics classroom to the Sociomathematical Norms of a learning environment. This section is about the work Amy and I engaged in to build the Sociomathematical Norms in her classroom.

Amy has been working over the last year at generating better student-student discourse in her classroom. She values the practices that allow students to explore the math by sharing ideas as they are formed. The discourse created through Amy's facilitation prior to this study can best be described as supporting the social norms in a mathematics classroom. Through group activities, students help each other with the math problems by sharing descriptions or explanations about the solution process.

To demonstrate growth in her awareness and use of the Sociomathematical Norms, I created a set of interview questions, found in Figure 10 of Chapter 3. These were designed to elicit Amy's understandings of the Sociomathematical Norms and how they differ from the social norms in a math classroom. The interview questions were given to Amy before the study began and then again after the study was over. Her initial responses to the interview questions indicated that she understood the need for students to explain their thinking beyond just getting a numeric answer. In her summaries, Amy selects problems which cause students to describe how they used the math to find the answer and to explain why the math works. She also has classroom discourse structures in place that are designed to give students opportunities to share their ideas in their groups as those ideas are forming.

However, Amy's initial responses to the interview questions also indicated that she did not understand the difference between students who work together to solve math problems and students who contribute to the understandings of others through mathematical reasoning. As Amy's coach, I worked to meet her instructional needs as demonstrated in the baseline data from the interview as well as from past experiences I have from working with her as her instructional coach.

I also collected baseline data on Amy's understanding of the Sociomathematical Norms through classroom observations. An example of Amy promoting a social norm in her classroom occurred about halfway into the Canoe Rental problem in the second cycle. The students had been working on using their graph to answer questions, and they were beginning to make a table from the graph or equation to answer other questions. Amy directed them to work quietly on their own for a few minutes.

Amy: *What I would like you to do right now is to answer question 1. What is the charge for renting the canoe for 30 minutes and I am going to let you guys decide; do you want to use the graph, do you want to make the table, is there another way you want to answer this question? So I am going to give you a minute or so to answer just the first question however you like; graph, table, or another way possibly*.

After the students had time to complete their table, Amy introduced the Proximity Partner instructional strategy as described in a previous section. In this instructional strategy, students were directed to share with each other how they did the math and solve a problem collaboratively. Generating opportunities for student to talk to each other about the math in an active learning environment can bring ideas into the classroom for the students to consider.

Through the Proximity Partner protocol, I observed two students who both used the equation to find the answer to the problem. They both had worked the equation correctly and they both had the same answer of $7.00. As result, there was not much for this pair of students to discuss.

Seeing how another student solved the problem can result in students writing down the answers from other students to simply get the assignment finished. For example, with one pair, a student showed how she found $7.00 using the graph while her partner had not yet found an answer through her table. Using the table, the student chose to increment time by one minute and did not have the time to reach the cost at 30 minutes. The result of the conversation was for the student who worked the table to take the answer from her partner. I also observed another pair of students where one found the answer using the equation, and the other used a table where the time was set in 10-minute increments. Each student had a different answer and the student who used the table erased her work and took the answer of the student who used the equation.

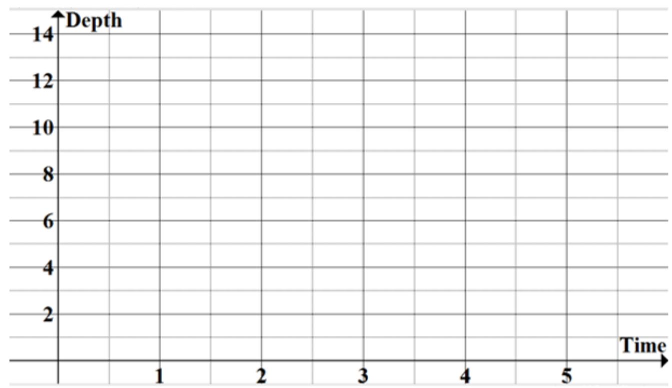
Whereas social norms can promote simply finding answers to problems, the goal of the Sociomathematical Norms are to promote understanding. However, the use of the Sociomathematical Norms should in no way diminish the importance of finding correct answers. Instead they should be used to emphasize that while answers are important, math is more than simply getting answers.

An example of Amy pressing into the development of the Sociomathematical Norms was in the Gateman problem from the first cycle. In this case, Amy facilitated a conversation that went beyond the sharing of descriptions and explanations to get answers. The discussion began when a student did not like the way Amy and I had scaled the axis on the grid for the graph. The information the student had placed in her chart from the problem was based on the time of day and the scale at the bottom of the graph was based on the number of hours spent draining the pool. Figure 16 shows a rendition of the table the student had created and the grid with the scaled axis that she had been given.

The difference in units, one being time spent draining the pool and the other the time of day, caused a significant amount of confusion on the part of some students. The following dialogue describes what Amy did with the disequilibrium to create productive struggle in the lesson.

Figure 16 **Table and Graph for the Gateman Lesson**

Time	Depth
12:00	12’
1:30	10’
3:00	8’
4:30	6’
6:00	4’
7:30	2’
9:00	0’



Courtney: *Can I rewrite the graph so that it works with my table?*

Amy: *What do you mean?*

Courtney: *So it’s 12 00 here… but why wouldn’t it be 1:00, 1:30 (along the x-axis) to be like time?*

Amy: *So you want to change the numbers (on the x-axis)?*

Courtney: *Yes*

Amy: *So like you would start…*

Courtney: *at 12:00 and then 1:30…*

Amy pulls the class together to discuss Courtney’s idea.

Amy: *(to the class) Courtney has a great idea. She wants to change the graph… she wants to change the numbers on the bottom.*

Hiyaw: *I disagree*

Amy: *Why. Do you like this one better?*

Hiyaw: *Yes. Because going in the order of like; just the starting point… there is no reason for that… and I don’t feel that the graph has to be like that*

Courtney: *It does*

Hiyaw: *It does not matter… it's still a constant rate.*

Amy: *So. We are having a math battle. It's ok. But I do want to validate both of your arguments. Courtney you are saying you have to start at 12, right? Hiyaw you're saying that it has to be a constant rate; so it has to be a line, right?*

This debate, which Amy calls a math battle, goes beyond the act of sharing descriptions or explanations about the math. Here Amy validated Courtney's concern with the structure of the given graph and gave her the opportunity to share that concern with the class. This allowed Hiyaw to take issue with the proposed changes and resulted in the two students looking for similarities and differences in in each other's thinking to use in forming their own mathematical argument. This debate was created when Amy revoiced each students' position and asked Hiyaw why he preferred the scale that was given to the one the Courtney had proposed. The students had formed mathematical arguments aligned with the Sociomathematical Norms, but the goal was to battle with each another rather than to inform the class on how each was thinking about the problem.

Important learnings. Responding to both questions guiding this research study requires student thinking to be made visible to the teacher and instructional coach. Creating a learning culture where students engage with ideas beyond simply sharing answers, or procedures to get answers, is important for determining what students are thinking about as they work on the mathematics. It is for this reason I made the Sociomathematical Norms a focus of the research project.

Forming arguments to do battle with other students is an extension of a social norm and can increase the engagement in the lesson, especially those using their arguments to outsmart their opponent. However, if winning the debate is more important than sharing ideas, the socialization of the class may promote getting correct answers at the expense of promoting understanding (Guven &Dede, 2015; Yackel & Cobb, 1996). For Amy's classroom to transition into an environment governed by Sociomathematical Norms, the students will need to use their arguments to inform and support each other's mathematical understandings rather than to convince the other student that he or she is wrong (Kezemi, 1998, Yackel & Cobb n1996).

In this section, I provided some base line data on Amy's understanding of the Sociomathematical Norms and how they differ from the social norms of a mathematics classroom. This data was collected both through her responses to the interview questions, as well as through classroom observations. I worked to determine and develop Amy's understandings of the Sociomathematical Norms so I could decide how they might play a role in answering both questions of this research project.

The most significant finding from this part of the study is the difficulty Amy had with making sense of the Sociomathematical Norms and what they look like in a math classroom. This is not surprising since classrooms where students engage with each other through these norms are difficult to find. Without concrete examples of what a classroom looks like which is governed by the Sociomathematical Norms, Amy was many times at a loss for what to expect of both her students and herself in bringing them into her classroom culture. My efforts as her instructional coach to draw out the distinctions between the social norms of a mathematics classroom as compared to the Sociomathematical Norms of a learning environment seemed to confuse rather than inform her. Later in this chapter, I will discuss what Amy learned about the Sociomathematical Norms and again in Chapter 5 I will propose future research on coaching practices that can support a teacher in creating the sociomathematical norms in a math classroom.

New Understandings Acquired by the Teacher

Coming into the study, I knew that Amy valued group discourse. As her instructional coach over the last year we had been working on posing questions, giving the class opportunity to quietly work towards a solution, and then creating structures for sharing the emerging ideas in their groups. During the course of the study, I found Amy to be a risk taker, demonstrating a willingness to try on instructional strategies she had never used before.

I also knew that Amy struggled with knowing what to do with the information students gave her during lessons to make adjustments during the lesson. Over the course of the study this was reinforced as Amy grappled with how to proceed in a lesson when the ideas she had anticipated during planning did not surface during the lesson.

In this section I will present what Amy learned about using data to improve her instruction. I will discuss both her new understandings about planning lessons using data from previous lessons as well as what she learned about using data to make in the moment adjustments to a lesson as it unfolds.

What Amy learned about using data to improve teaching and learning. Throughout the three cycles of this study, Amy was able to both improve her use of the instructional practices she had already learned in her career as well as try on new instructional practices. These classroom teaching strategies allowed her to gather information on student thinking and use that information to improve the teaching and learning in her classroom. In this section, I will give an analysis of how Amy improved in the use of instructional practices that can assist in making student thinking visible.

From the Gateman lesson in the first cycle Amy was reminded that there needs to be a written reflection that students turn in to truly assess each individual student's thinking. The difficulties described in the previous section with the table students created not matching the given scale on the axis for the graph threw the lesson off, which kept Amy from asking the reflection question we had created in the planning of the lesson.

As a result, Amy and I used the dialogue between Courtney and Hiyaw, presented in the previous section, in our debrief of the Gateman problem. We discussed how this dialogue affected the rest of her students and then used this data to plan the follow up lesson. As discussed earlier in the planning of this lesson, Amy and I decided to scale the axis to make the graph more accessible to her students. Upon reflecting on the difficulty Courtney experienced during the lesson, Amy decided that in this situation giving students axis that were already scaled created more difficulties than it solved since many students were not able to use their table to graph the data in the problem.

Coach: *What did we notice about student thinking from the lesson?*

Amy: *They brought up a lot of stuff that we did not expect like the 12:00 start time instead of zero hours start. There were some students who were talking about if it is 12:00 and we are putting on the graph as 12:00 then we need to know whether it is 12:00 am or pm. So they brought up the issue that the 12:00 am showing [on the right] is the wrong and 12:00 pm showing [on the y-axis] is right. But I think the point that was made was we are doing it for the reason to make the graph linear. I think that this was the main idea which was retained.*

A lot of them just started with the noon or 12:00 time, but even after we had addressed that they switched the start time from 12 to zero [but] kept the 1:30 and 3:00. They did not switch it to 1.5 and 3.0 and 4.5.

Coach: *What does this tell you about their thinking?*

Amy: *I think that it kind of messed them up because…its one and a half hours and they are thinking of it as [1:30 in the afternoon]. So they kept it as one hour and thirty minutes and not 1.5 hours.*

Coach: *Who do you think is still confused about this?*

Amy: *I think after the discussion we had most everybody was thinking about it in terms of* *hours, but they were writing it as 1:30. But it just so happened that [it started at] noon so 1.5 hours after that was 1:30. If he had started at 1:00, then it would have been at 2:30 for 1.5 hours.*

Coach: *When we look across the students' work on the assignment most kids changed the 12:00 to a zero.*

Amy: *I think [most students] wrote down what I said, that it is linear because we had to change the time to hours. So I think in the future, if we give a similar problem, and they had to switch time to hours or minutes or seconds or whatever it is and we ask them to explain their thinking there.*

Coach: *So is that maybe a problem we could design for numeracy tomorrow? Something similar… without as much scaffolding from you and see what they can say about starting from 12:00 or from zero?*

Amy: *Yea*

Even though Amy was able to generate good arguments and debate between Courtney and Hiyaw, she still believed that the results in the student work may be because of what they saw her do in the summary rather than what they understood on their own. Amy and I have talked about the need to create independent student mathematicians as students who can solve problems with their group independent of the teacher, as well as solve problems independent of each other. This experience became another step in Amy's ongoing work to create a student-centered classroom.

From this conversation, Amy decided to create the reteach lesson for the next day by modeling how to write a description of the steps taken to create a proficient graph. Because of the difficulties in getting the graph together, she chose this direct approach so that her students would have an example of the different steps to creating a proficient graph.

The debrief for the Canoe Rental lesson in Cycle Two provided Amy with three ideas to consider for improving her teaching. First, Amy reflected on some advantages and disadvantages of allowing students freedom to explore. Next, her surprise at how students choose graphs and tables over equations opened up some conversation on multiple solution strategies. She also continued in her understanding of when and why to use ambassadors to promote a student-centered classroom.

Recall in the Canoe Rental problem that students were given a graph to use to create a table. Students were also given an equation for the cost to rent the canoe based on the amount of time it was used. All three representations, graph, table, and equation, were then used to answer the questions in the activity.

By drawing a comparison between the problems experienced in the Gateman problem from the first cycle, Amy reflected on how her instruction in Canoe Rental activity tightened up the lesson by providing students with less freedom to explore.

Coach: *What did you think about the lesson? How did it go?*

Amy: *I think there were less surprises than the first lesson. Which helped. Teach the lesson more as planned instead of changing things in the moment.*

Coach: *What are some reasons why you think that happened?*

Amy: *I think in the first lesson some of the things came in the moment because we weren't expecting students to think of one of the variables as time instead as hours. That was something that threw us off, but [in this lesson] there was less chance for that to happen because they gave the variables specifically. I think [in the first lesson students] were given too much freedom to decide… they were confused on what to do.*

So today we looked at different problem and we made a table and then a graph, and we did it all at the same time; everybody made their table at the same time and everybody made *their graph at the same time… looking at the similarities between those two.*

Coach: *Let's say a kid says, "I choose the graph", What would be the proficient response and a good explanation about why [they] would choose the graph?*

Amy: *If the graph was given it is a tool that already has the information on the graph so it is an easy way to look for information that is already there especially if they are looking for answers which are exact on the line.*

Amy was happier with this lesson than the first because it was more focused, and there were less places for the students to get confused. She found that giving the students less freedom to explore allowed the lesson to remain more tightly focused on the learning outcome. In the Gateman lesson Amy was uncomfortable with how we used the information students were giving us to adjust the lesson. She felt much better about the Canoe Rental lesson because we ran the lesson as we had planned it.

Amy's response to my question concerning a proficient explanation for why the graph would be chosen was simply that it is a tool where information is easy to find. The vagueness of this response may play a role in some of her difficulties with bringing focus to her lessons. Planning for how you want students to respond by considering what a proficient response to the prompt might be, can give the lesson more focus while still allowing the freedom to explore with the idea. If a teacher is going to give students freedom to explore with ideas, then he or she needs to be aware of the different places they will go with the ideas associated with the lesson. I will address this further in the next chapter.

Amy taught a lesson between the Canoe Rental lesson and our debrief. As a result, she had an opportunity to do more with graphs and tables in her class before our debrief discussion. In this lesson, Amy was surprised at her student's decisions to solve with tables and graphs rather than with the equation. I continued the discussion on solution strategies students chose in the Canoe Rental problem by mentioning that most students did not use the table or graph to answer the questions in the activity.

Coach: *We did not have many students using graphs and tables. Any thoughts about why that is?*

Amy: *That is actually interesting because today's warm up was using the same problem. I gave them different numbers to solve with; instead of 30 minutes I said 20 minutes and instead of $8.50, I said $9.50, and what happened was I had a few students ask for their paper back [from the day before] so they could look at the graph and that is why I ended up passing it back out.*

And I said sure and then I said does anybody else want their graph and then everybody's hand shot up. I think as soon as they did it yesterday and realized how easy it was they wanted the graph again. The problem was for #3, because I did almost the same types of questions I gave them, "A customer has 17.50 to spend" and that is not on the graph… [so] most people ended up making a table. Initially they all wanted the graph because they saw it yesterday at the end and then I through them a curve ball, what happens if it is not on the graph. A few kids said, "Well we could make the graph bigger" but most chose to use a table.

You may recall that Amy launched the Canoe Rental lesson by having students find what each part of the equation meant in terms of the context so that students would then be drawn to the use of the equation for the problem. However, to Amy's surprise, she discovered that once the students had a graph to use, this was the representation most chose for solving the problem. She was also surprised that they chose to make a table to find an answer when the graph was difficult to use.

It is very typical for teachers to push the solution strategy they were taught as students and assume that their students will want to use the same strategy. By promoting different representation to solve problems, Amy's students were able to demonstrate a variety of desired solution methods, and by observing her student's thinking Amy was able to adjust the lesson.

Amy's reflection on her students' affinity to graphs and tables can help her make different planning and teaching decision in the future. Opening the class to different ways to solve the problem provides more freedom on the part of the student, and expecting some students to choose these representations can help Amy maintain the focus on the lesson as she opens it up to these different ways to solve problems.

In the last part of the debrief Amy and I discussed her on going understandings about how to implement the Ambassador protocol in her classroom.

Coach: *What is your thought about the use of ambassadors yesterday?*

Amy: *I liked it because I did not have to spend time with that student one-on-one. I could send them over and they could explain their thinking. Except [one group] I said go talk to that table and they just went and said hey…*

Coach*: Yea. You need to be more explicit.*

Amy: *Yea. So, we need to do more work on what to do when you are sent. How do you explain your thinking to somebody else without giving them the answer? Helping them come to a conclusion without, "here is [the answer]".*

Coach: *What is your thought about how do you decide when to send somebody and who to send?*

Amy: *When they are completely confused and they need a quick help or reminder. But you could ask someone at their table to help them. But if [the whole group is] lost, and you know that somebody [in another group] has got it down, sending them.*

As mentioned earlier, Amy and I have been working over the last year to notice when some groups are taking on understandings from the lesson and how to then use that student understanding to promote student-to-student discourse. In this debrief Amy reflected on her need to be more explicit with students about what they need to share when they go to another group.

A next step in Amy's understanding about the use of ambassadors might be to make sure she returns to the group where the information was shared and make sure the students now have a better understanding. I will address more about my next steps with Amy as her instructional coach in the next chapter.

What Amy learned about the Sociomathematical Norms through the study. Earlier in this chapter I wrote about Amy's initial understanding of the differences between the social norms and the Sociomathematical Norms before the study. Data on these original ideas were collected both through a written reflection to a set of interview questions as well as through classroom observations.

In this section, Amy and I will reflect on what new ideas she has taken on about the use of the Sociomathematical Norms to make student thinking visible in her lessons. Rather than a written response, I chose to have a conversation with Amy about how she sees the differences between the social norms and the Sociomathematical Norms. We accessed the video recording and transcripts from the Temperature/Visitor/Profit activity used in the third cycle, as well as referencing Figure 10 from Chapter 3 that draws the distinctions between the social norms and the Sociomathematical Norms, in this discussion

Coach: *What are the differences that you see in the types of norms? For instance, in the first one: Describe what you see and hear as students question each other's thinking as opposed to describe what you see and hear as students press each other for mathematical reasoning; such as justification [and] looking for understanding.*

Amy: *In, "Describe what you see and hear as students question each other's thinking." Students are asking about how they themselves have an unsure answer on where to go. So, they* *are asking about how do you go about getting this problem done. What did you do to finish the problem? The mathematical reasoning is almost like arguing; prove it. You have done this but I need you to prove it to me. Why did it work the way that you did it instead of, "Help me, I am confused?"*

Coach: *What is something you could do as a teacher to teach your students how to ask questions where they are required to ask each other to prove why they believe what they believe?*

Amy: *Maybe using the table tents with sentence starters and questions. Instead of… I guess continuation questions like if your table group gets your problem finished you are not done yet. What kinds of conversation can you have as students to get the final answer? So students don't raise their hand when they are done instead now question each other's thinking.*

Coach: *Have you tried some of that? Have you tried putting questions at the table and having them use those to ask each other questions?*

Amy: *No*

Amy has had difficulty with instructional practices designed to structure the discourse in her lessons. I will refer to this in the next chapter regarding next steps I will take in supporting Amy as her instructional coach.

Coach: *Based on what you saw in the video, describing the question vs. pressing for mathematical reasoning, what did you see and what did it tell you about what your students are thinking?*

Amy: *I remember Neveah at the beginning [of the Temperature/Visitor/Profit lesson] was pressing Edelawit for her reasons. Neveah said, "My way works because of this" and Edelawit said, "My way works because of this" and Neveah was pressing by, "Well why does yours work?*

Amy went on to contrast this interaction with Neveah and Edelawit to a conversation at a different group.

Amy: *Jesse may have gotten it wrong, [his group] told him he got it wrong.*

Coach*: Did his group mates ask him to demonstrate how he got his answer or did they just say that he got it wrong?*

Amy: *There was a number that he heard from a different group and they were saying not to trust that because it might be wrong. The rest of the group was trying to prove to Jesse that their answer was correct.*

Coach: *Were you able to get as much understanding about student thinking from Jesse's group as you were from Neveah's?*

Amy: *In Jesse's group it was just a statement and they did not follow up on it. Neveah's group pressed each other more for reasons.*

Through this dialogue Amy showed an understanding of the difference between students helping each other with the math to get correct answers and students forming arguments to justify why the math works to the answer being proposed. She was also able to express that when students are just sharing answers she does not get as much information as when they are pressing each other for mathematical reasons.

Coach: *Let's go to the next one, "Describe when you see/hear students explain their thinking" as opposed to "Describe when you see/hear students explain their solutions using mathematical arguments" what do you think is the difference between explaining your thinking and explaining your solution using mathematical arguments?*

Amy: *You can explain what you did to some body but that might not prove anything. I still agree that Neveah and Delawit, when [they] were arguing about why they were doing what they were doing, but they never came to a clear solution… At one point I was having them use their numbers to prove why they thought 65 was right. I had moved [them] to this group and* *they were all working on the white board saying that it was 65 because of this and it's not 67 because you get the wrong answer. They were proving why 65 degrees works.*

Coach*: How does thinking about discourse this way change the way you observe your students or create opportunities for discourse?*

Amy: *I think there are times… like if you have a student who doesn't understand why they got what they got, then having them start to explain their thinking and then press them for mathematical arguments. Sometimes they get an answer and they have no idea. So, I ask, "How did you get there?" or "Now prove it"*

Coach*: By getting a chance to dig into this one section of the video, the questions, and the conversation about the Sociomathematical Norms? How has this effected your thinking about yourself as a teacher. Was this helpful?*

Amy: *When I try to remember a lesson I don't always remember what the kids say. At least for myself I ask questions based on what is happening in the lesson. Figuring out the questions that pull these types of things out of the students; asking them to prove their answers. Like in #4, explain their solution using mathematical arguments. I did not necessarily plan that but it happened and I got some explanations when I had students answering how they got what they got. I think that in the future I'll be more aware of this if I am asking those types of questions, or when I need to ask those types of questions, and if they are even ready for those types of questions.*

For a teacher determine how to use student thinking to improve the teaching and learning in mathematics classroom, the students must make their thinking visible to the teacher. A purpose of the Sociomathematical Norms is to make student thinking available to the teacher so he or she can use it to improve their instruction. For this reason, I have made the development of the Sociomathematical Norms in Amy's instructional practices a focus of this study.

As her instructional coach, I used Amy's thinking to meet her instructional needs as demonstrated by her responses to the interview questions as well as our previous collaborations in planning and teaching lessons. Many times my work as her instructional coach in this study was to press her beyond the social norms of a mathematics classroom to the Sociomathematical Norms where student value the intellectual abilities of all members in the learning environment.

Using Formative Assessment Data from Student Thinking to Improve Instructional Coaching

The second research question for this study asked how an instructional coach can use information gathered from classroom observations and student responses to assessment problems to improve the coaching of teachers.

As mentioned in Chapter 1, professional development which places teachers at the center of the work, provides more consistent support for teachers as they incorporate new ideas into their teaching. Coactive, cognitive, and instructional coaching are three widely accepted forms of coaching to draw upon when establishing teacher-centered professional development. The work Amy and I engaged in was most closely aligned to instructional coaching. However, I incorporated components of coactive coaching in my efforts to build a strong working relationship based on mutual respect as well as cognitive coaching through planning from student thinking, teaching for student thinking, and reflecting on student thinking.

Just as a teacher needs to focus on student thinking gathered through formative assessments, an instructional coach needs to focus on teacher thinking through planning, teaching, and reflecting on lessons. In this study I assisted Amy in planning and implementing lessons which incorporated the instructional practices shown to create a student-centered classroom where the interactions of the students are governed by the Sociomathematical Norms. Amy's growth in supporting students to make sense of the math by justifying why the math works, generalizing it beyond the problems presented that day, and forming mathematical arguments that inform the thinking of others was the focus of my work as her instructional coach. In the next two sections, I will discuss the work I engaged in to support Amy in using data to improve planning and teaching as well as how this work supported Amy in developing the Sociomathematical Norms in her classroom.

Through the questions I posed during the planning and teaching of lessons, I will address in the next section how I used assessment data from student thinking to improve my coaching. I will also address how instructional coaching supported Amy in the continuing work of establishing the sociomathematical norms in her classroom.

Supporting a teacher in using data to improve planning and teaching. Two themes emerged during the course of this study as I used student thinking to improve my instructional coaching. The first was the use of questions to prompt Amy in considering ways of using data from student thinking to create better lesson plans. The second was my support of Amy as she tried on various instructional practices designed to elicit student thinking and then challenging her to take that student thinking and use it to make adjustments in her lessons.

First, the questions I asked during the planning and debriefing sessions in each cycle were designed to stimulate Amy's thinking about the way she uses data to guide her planning and teaching. Just as Amy used questions to confer with her students for the purpose of discovering their thinking about the math, I used questions to confer with Amy to discover how she was thinking about her teaching. In both cases questions were used to elicit thinking for the purpose of determining the next teaching or coaching move. One difference is that as an instructional coach I used student thinking to uncover the teacher thinking. As a coaching practice, there is a deficit in the literature for using student thinking to reveal teacher thinking. I will address the need for further research on coaching practices that can bring out teacher thinking in Chapter 5.

The two upcoming excerpts from planning sessions demonstrate the questions I used to elicit Amy's thinking. The conversations between Amy and I have been used previously in this chapter to describe the work we did to elicit student thinking. The same dialogue will be used again, this time to show the effects of the questions I posed to Amy and how they prompted her to think differently about her teaching.

One example of using questions to elicit Amy's thinking about the use of data was planning the Gateman lesson in the first cycle. I asked her to consider what she understood about what her students knew at this early point in the school year. We had just finished a short discussion about the content in the lesson and I asked her to consider what her students already knew about the mathematics for the lesson.

Coach: *What do you think the kids should be able to do and understand using real-life linear events with tables and graphs?*

Amy: *…[earlier this week] they have been looking at a graph of prices of peaches and then they [came] up with a table for that.*

Amy's response gave me information about what her students had been doing and it also told me that she had been working with her 8th graders on an 8th grade standard. The 8th grade standards regarding proportionality are similar to the 7th grade proportionality standards and beginning the school year working on these standards can create a strong bridge between 7th and 8th grade. I was encouraged that the lesson Amy and I planned for this first cycle took the ideas from this standard and used them to press student into linear nonproportional problems.

Knowing the experiences that students have coming into a lesson and what they have been thinking about in terms of the mathematics associated with the lesson can be beneficial to an instructional coach in making decisions about how to best support a teacher. Amy's responses to my questions gave me an indication that she has been considering what base line mathematical understandings students need coming into the 8th grade. By having students make sense of proportional relationships in tables I can infer that she values algebraic representations beyond just equations.

Another example of using questions about student thinking to coach Amy occurred during the planning of the Canoe Rental lesson in the second cycle. Amy and I had been discussing the understandings students needed to bring into the lesson and what some of the deficits in that learning might be.

Coach: *What might be some misconceptions?*

Amy: *They are going to call one of these C and the other one t. Or the other way around.*

Coach: *What might we do about that?*

Amy: *…If we were to refer back to either the car washing [problem] and they have starting cost when you show up to the car wash what would be the initial fee and then what would be cost/min. That sort of thing. So relating it back to the car wash.*

Coach: Other misconceptions?

Amy: Mixing up the time and charge. I don't think… like for the first one for the 30 minutes I think most people will get that right away. But when it gets to the $8.50 we look for 30 on the x-axis first they are going to look for $8.50 on the x-axis.

As mentioned in chapter 2, students come to class with preconceptions about how math works to solve problems. This interaction with Amy was designed to determine some of the misconceptions that Amy has noticed in her students which might affect their ability to cognitively engage in the lesson. The misconceptions that Amy identified, distinguishing the independent and the dependent variables within the context of a problem, are typical struggles for 8th grade students. Amy became aware of this deficiency in her students based on their performance in the car wash problem a few days before our planning session.

Earlier in this chapter I described how this conversation lead to a focus in the Canoe Rental lesson where Amy directed students to state what each part of the equation meant in terms of the context of the problem.

Coach: *What is the first thing they are going to do with the equation here?*

Amy: *…they need to understand what each part means in the equation.*

Coach: *What each value means within the context?*

Amy: *Yea*

Coach: *So that's your first success criteria. Label the values in terms of the context. Maybe [we] give them an equation and don't say anything other than the fact that they need to write about each of the four parts of the equation in terms of context.*

Amy: *Ok*

The question I asked at this point in the planning session was designed to determine Amy's thoughts about the word "understanding" and what it meant in terms of this lesson. By planning the lesson to include an analysis of the equation in terms of the context, we gathered very useful information about student understandings of the independent and dependent variables in the equation. We also discovered how well students made sense of how the equation holds values for where the dependent variable starts and how it changes within the context of the problem. This information proved to be beneficial to planning and teaching the Temperature/Visitor/Profit lesson in the third cycle. I will speak more about the Temperature/Visitor/Profit lesson later in this chapter, specifically to what I as the instructional coach learned about coaching through this study.

Knowing the experiences students have coming into a lesson, and what they have been thinking about in terms of the mathematics associated with the lesson, can be beneficial to an instructional coach in making decisions about how to best support a teacher. Determining the understandings and misunderstanding students bring to the lesson is a critical component to knowing how the mathematical experiences students bring will affect the progress of the lesson. Planning from the place of what students know and can do, as well as the misunderstandings they bring, is a response to the second question in this study regarding how an instructional coach can use information gathered from classroom observations and student responses to assessment problems to improve the coaching of teachers.

Second, the questions I asked Amy during the teaching of the lessons were designed to encourage her to try on the instructional moves we had discussed in the planning of each lesson. These were also conferring questions used to make Amy's thinking visible as she made decisions about her next steps in the lesson.

One example of using questions to elicit Amy's thinking during a lesson occurred in the second cycle. About halfway through the Canoe Rental problem Amy was noticing that enough groups had formed responses to begin having students share their answers. She asked me if I thought it was time to begin using the Ambassador protocol.

Amy: *Should we do Ambassadors?*

Coach: *Do we know enough about what these people are thinking to know who to send and why?*

Amy went on to find a group where the students were able to describe what they thought the values in the equation meant in terms of the context. She then identified another group that did not have a clear understanding of what they were doing with the equation. So, she selected two students from the first group to share their understandings with the students in the other group. After the ideas were shared, I asked Amy why she selected those two students to share and why she selected that particular group for them to share with.

Coach: *What was the reason why you choose these two [to share]?*

Amy: *They were a little bit more vocal about their thinking.*

Coach: *Does everyone here have the same answer?*

Amy: *Yea.*

Coach: *So one thing to consider when sending ambassadors is probably bringing a difference so they have something to talk about. Sending someone over here because they have a difference creates that conversation.*

As mentioned previously in this chapter, Amy and I worked on using ambassadors to generate student-student discourse the preceding year. She practiced the logistics, but based on this interaction, may be missing some of the rationale for their use. This interaction made some of Amy's thinking visible in regards to why students are sent and why she sent them to a particular group.

My response to her was designed to provide her with an in the moment opportunity to consider why she sends students to help other students. In this response I emphasized looking for differences in student responses to promote the forming of arguments and using them to enter into debate. As mentioned in Chapter 2, this is a Standard of Mathematical Practice and can be very useful in increasing behavioral, cognitive, and affective engagement. Transitioning from debate as a means of competition to debate as a means of supporting everyone's understandings about the math is a purpose for the establishing the Sociomathematical Norms.

As mentioned at the beginning of the section, one difference between a teacher's use of questions and those used by a coach is that the teacher is asking questions about the math and the coach is asking questions about the teaching. What I learned about Amy as a developing teacher, as well as what I learned about myself in my personal development as a coach, will be discuss both in the last section of this chapter as well as in chapter five.

Supporting a teacher in developing the Sociomathematical Norms in a classroom. In a previous section of this chapter, I described what Amy learned about the Sociomathematical Norms through the course of the study. Recall that social norms of a mathematics classroom create a learning environment where students make descriptions and explanations about the math to help others work through problems and get correct answers. The Sociomathematical Norms create a learning environment where students evaluate the different approaches and results of their peers for the purpose of contributing to the understandings of each member in the class.

A purpose for developing the Sociomathematical Norms in a classroom is to make student thinking visible to the teacher so he or she can use that thinking to make instructional moves based on students' demonstrated needs. My support of Amy in creating these classroom norms was a response first research question regarding the use of student thinking to improve classroom teaching. In this section, I will discuss the coaching moves I used to support Amy in creating a learning culture in her classroom through the development of the Sociomathematical Norms, and this will be a response to the second research question regarding the use of student thinking to improve my instructional coaching. I used student discourse data to demonstrate how I provided this support in order to answer the second research question regarding the use of student thinking to improve my coaching.

An example of pressing Amy to think beyond the social norms to the Sociomathematical Norms of a classroom learning environment occurred in the planning of the Canoe Rental lesson in the second cycle. I engaged Amy in a short dialogue at the beginning as well as at the end of the planning session because I perceived that there was a need to be more explicit with what the Sociomathematical Norms are and how they can create a learning culture where students make their thinking visible to both to each other and to the teacher.

To set this discussion up, I asked Amy a few days before the planning session to reflect on a piece of student discourse from the Gateman lesson in the first cycle and select which Sociomathematical Norm(s) the discourse best represented. I selected the following piece of classroom dialogue because it demonstrated her students' willingness to disagree with each other in a full class discussion.

Recall that in the Gateman problem students were asked to analyze a pattern to determine whether the pool would be drained by 8:00 in the evening if Gateman began draining the pool at 12:00 noon. After the class had determined that the pool would not be drained until 9:00pm, Amy asked them when Gateman would have needed to start draining the pool so that it would be empty at exactly 8:00pm.

Amy: *When would Gateman have had to start the pool draining to get it finished [at 8:00pm]?*

Edelawit: *He needed to start at 10:30am*

Amy: *Why do you think that?*

Edelawit: *He checked each hour and thirty minutes so I want to subtract one hour and 30 minutes from 12:00 to get 10:30.*

Neveah: *I disagree. I think that Gateman needed to start draining the pool at 11:00 because since he started at 12:00 he would be finished draining by 9:00. That's an hour later than the time he was supposed to have it drained so to have it drained by the time he was supposed to have it drained, he would have to start an hour earlier.*

I opened the planning session by referring to this piece of student discourse.

Coach: … *towards the end [of the lesson] Neveah was talking about how she was able to figure [that] Gateman should have started an hour earlier [and] Edelawit said that he needed to start draining it at 10:30. Which of the Sociomathematical Norms do you think this scenario best* *matches?*

Amy: *Explain the solutions.*

Coach: *Could we have done more with this lesson to get at some of these Sociomathematical Norms?*

Amy: *They probably could have come up with who agrees with this person and who agrees with that person and why they agree or not.*

Coach: *What is the teaching move or strategy [that you might] have used to make that happen?*

Amy: *Who agrees with this person and who agrees with that person. Raise your hand if you agree and then have one person explain why. Have the other person explain what they think then have the other person decide what they think and then have the class decide.*

In this piece of classroom discourse, Edelawit and Neveah presented their thinking with descriptions and/or explanation about how they solved the problem without necessarily contributing to each other's understanding. Amy identified this as students explaining their solution but she did not refer to whether this was a social norm or a sociomathematical norm. When I pressed her to consider her teaching move, which might have drawn out more of the Sociomathematical Norms, she was able to describe how she could have opened up the discourse between Edelawit and Neveah to include the whole class.

Due to the limited amount of time available to plan the lesson, I did not press Amy to share more about instructional practices that could more fully develop the Sociomathematical Norms. However, at the end of the planning session I asked Amy to think back over the lesson plan we had just created and look for places where the instructional strategies we selected could help to establish the Sociomathematical Norms.

Coach: *I am wondering about those Sociomathematical Norms which create that* *students-centered classroom and how the instructional strategies in this lesson can make those happen?*

Amy*: How to make the Sociomathematical Norms happen?*

Coach: *Yes*

Amy: *Well the debate will be part of this lesson. I have never been very awesome at pointing out [instructional practice] during class, but I think they happen.*

Coach: *How could we be more concrete with the students around the purposes of [them] being the mathematicians, the way we are going to do that is to create a student-centered classroom based on you and your thinking, not me and my thinking.*

Amy: *The only thing that comes to mind… is to specifically state when they are being used.*

Amy and I planned for the use of Ambassadors and Proximity Partners for the Canoe Rental problem. As she reflected on how the instructional practices we selected could help to create the Sociomathematical Norms in her classroom, she was able to connect the idea of classroom debate as a means to produce these norms. After I suggested that she might share with the class the goal of them being the mathematicians in the classroom where their thinking is valued, Amy was only able to respond that she could state when each practice is being used. The need to share with students the purpose of instructional practices as a means to create student-centered classrooms where the students are the mathematicians will be discussed more in chapter five.

In this section, I have described how the study supported the second research question regarding how an instructional coach can use data from student thinking to improve his or her coaching. In the next section, I will share what I learned about myself as an instructional coach and how I can improve in this work.

New Understandings Acquired by the Instructional Coach

As a seasoned instructional coach, I came into the study with an array of experiences with supporting teachers in planning and teaching mathematics lessons. Over the course of this study, I discovered how analyzing the video recordings of lessons through the transcribing process improved my analysis of the lesson by causing me to focus more deliberately on student thinking. The intentionality of this coaching practice was new to me and represents a significant new learning that I took from this study.

Through the analysis of the audio and video recordings, I also discovered that I do not give teachers adequate opportunity to consider and process the questions I pose to them. My reflections of these discoveries will be addressed later in this chapter as well as in Chapter 5.

Recall that the second question in the research project is, how can an instructional coach use information gathered from classroom observations and student responses to assessment problems to improve the coaching of teachers? In the first chapter, I listed out a set of beliefs which undergird this study. One of them was that effective coaching requires the ability to gather and use information on teachers' instructional practices using student thinking to target the instructional needs of a teacher. In this section, I will discuss what I learned about the effectiveness of my coaching by how well I was able to make Amy's thinking visible as she planned for and implemented instructional practices designed to make student thinking visible.

A point of frustration for me as the researcher and instructional coach in this study was the tight time frame which kept me from analyzing the video recording of the planning and teaching in each cycle. I was not able to finish transcribing the video from each lesson until after we had debriefed the lesson. There were significant coaching events in the video that I was not bringing into the debrief because I had not analyzed the video at a level where I could discover the significance of these events.

Fortunately, Amy and I adjusted our schedule in the third cycle because the lesson Amy was going to run was not going to be a very good lesson for the study. As a result, we pushed the lesson to Thursday. Since I was going to be out of the building on Friday we pushed the debrief to the Monday of the next week and scheduled the reteach for Tuesday. This had a positive influence on the debrief. In this revised schedule I had the weekend to get into my transcribing and was able to analyze this data in enough detail to get a video observation set into the debrief discussion. As a result, I was able to run a more effective debrief based on what I had discovered from transcribing the recordings.

In the debrief of the lesson in the third cycle, Amy and I watched two shorts sections of the video from the lesson and discussed what she saw in her students' thinking. The clips had been selected as I analyzed the video recordings, and they were coupled with a set of questions designed to elicit what Amy thought about her students thinking. The dialogue in the following sections describes the discussion Amy and I had while watching the video of her lesson.

First video clip. As mentioned earlier, in this lesson Amy gave the class the task of determining what each component of the Visitor equation, $V = 50(T\text{-}45)$, meant in terms of the context of the problem. As the students were working on the task, Amy walked over to a group and noticed that the students had written that 50 was the slope and -45 was the starting point or y-intercept in the problem.

The first section of video Amy and I observed led to a discussion about what her conferring with the students told her about what the students were thinking about. The following dialogue is taken from the video recording of the lesson. Amy and I both watched it together during the debrief of the lesson.

Amy: … *Ok, this is a great idea. Because you saw that this number is right next to this T, next to the variable.*

Amy turns to Jenelle and asked,

Amy: *Ok, why would she [Neveah] say that 50 is the slope and -45 is the starting point?*

Jenelle: *Because the equation y = mx + b …*

Amy points to the parenthesis in the problem and Neveah begins to distribute the 50 into the terms inside the parenthesis.

Amy: Ok. *That was a great idea actually; to distribute it out. Now we have a new equation 50T- 2250, so let's ask this question again. What is 50 and -2250 in the context of the problem?*

Neveah and Jenelle do not respond.

Amy: *We are talking about visitors, right? What is "T" again? So based on the temperature what does 50 mean? OK. Talk in your group now that we have a new equation. What does 50 mean in the context of the problem, what does -2250 mean? What are we trying to get?*

After watching this video clip, I turned to Amy and began the following discussion about what we saw.

Coach: *So what are you thinking about at this point the kids making sense of the 50 and the -2250?*

Amy: *I think they know that 50 is the slope and -2250 is the start. But in the context we ended up talking about 50, but we really did not talk about the -2250 number*

Coach: *Right… We just went with the 50 and tried to deal with that first.*

Amy: *We spent a long time on the first one; the first equation. I think a few of them knew why we did distributive property. I think they just ended up seeing the first number and the second number; they just saw the 50 and the -45. [With] the 50 they immediately jumped to the slope and the -45 was the starting point. But then we had to distribute it out. I don't think all of* *them understood that we had to do the distributive property to get that.*

Coach: *… trying to find that form within a factored equation is going to lead to some misunderstanding. This seemed to be where some kids were going. So what does this mean in terms of what we might do [in tomorrow's reteach lesson]?*

A: *We could give them equations that aren't in form y=mx+b and they'll have to solve for, or find, slope and intercept from that type of equation.*

Amy has done a good job of identifying a critical misconception students have when looking at a linear equation. If students assume the first number in the equation is the slope and the second number is the start, then they will routinely make the mistake Amy is describing here. Whereas Amy states that she believes her students understand what both the 50 and the -2250 mean in terms of the context, she then backed away from this and was not sure they really understood what the -2250 meant.

Conferring was not one of the instructional strategies mentioned in the previous section because it is something Amy has been working on over the last year. However, I did not want to minimize the importance of conferring with students to gather the initial information on student thinking so that she could then make a decision about which additional strategy, Ambassadors, Huddle, Proximity Partners, or Select and Sequence, she would choose.

This clip and our discussion shows that Amy is improving in her ability to ask focusing questions, which lead to responses from students that revealed their understanding. When Amy asked Jenelle why Neveah wrote that 50 was the slope and -45 was the starting point, she was able to determine that Jenelle saw the need to use the y=mx+b form. Then when Amy pressed them for what the 50 and the -2250 meant in terms of the context, and they were not able to respond, she left them to consider this as she went to confer with other groups.

Through our dialogue, I was able to reflect on what Amy did with these two students to determine their understandings of using the distributive property to find the slope and y-intercept of a linear equation. Whereas Amy might have developed a reteach lesson for the next day based on the distributive property her ability to target that lesson based on the determine needs of her students likely improved due to this dialogue.

The analysis of the conversation between Amy and I validated how my use of conferring questions caused her to draw out understandings of student thinking. By selecting this particular piece of student-teacher discourse, we were able to discuss what her students did and did not understand about linear equations. We were also able to begin the process of generating the next experience students would have with these ideas in the reteach lesson.

Through the analysis of this dialogue, I discovered that I could improve the focusing questions I use to draw out teacher thinking. For example, when Amy admitted that most of the time spent on this equation was determining the rate of change I could have followed up with a question about why the starting value of -2250 was not developed in this conversation with her students. I could also have bought in a question about how to make students understand what it means for the visitors to be -2250 if the temperature is 0° Fahrenheit. Second, I could have taken Amy's comment that a few of her students knew to use distributive property and asked her which students she found did and which students did not know that using distributive property needs to be used to find the starting amount and the rate of change in this equation. This question would have been helpful for differentiation in the reteach lesson.

Second Video Clip. In the second section of video, Amy and I observed students making sense of the rate of change, and what it meant in terms of the temperature and number of visitors.

Amy: *50 is…? 50 is not the temperature. "T" is the temperature. If the temperature was like one, how many people would come? 0ne times 50, so every time the temperature goes up by* *one how many more people come? 50 more, ok?*

A: *If I said the temperature was 47 degrees today instead of 48 degrees, how many more people would show up?*

Neveah: *One more person.*

Amy: *Just one more person?*

Neveah: *A lot more. It would be like 50 more. Yea because it is not the same.*

Amy: *If this is one degree how many people?*

Neveah: *50*

Amy: *If this was 2 degrees how many people?*

Neveah: *100*

Amy: *So what is our increment? What are we changing by?*

Neveah: *50*

Amy and I then began to discuss what we had seen in this section of video.

Coach: *Your thoughts about how that went?*

Amy*: Initially we've got a change of one degree and everyone was saying one person.*

Coach: *So what does that tell you about what they are thinking?*

Amy: *If you change one by one then you need to change the other by one. They are not seeing the change in y and the change in x as being separate. The temperature goes up by one so the visitors go up by 1. I think they are thinking of slope as being a single number instead of a change in y over a change in x. Even though in the equation it is either a fraction or a whole number, they are not thinking of it as this goes up this goes up or down.*

Coach: *What might have a been a different way to build from that misconception?*

Amy: *I think using fractions possibly… because I could have shown them that 50 is a fraction of 50 over one. So, 50 is the change of visitors and one is the change in degrees. Our* *slope is not just 50 it is 50 over one. I think that gets lost; the fraction gets lost. It is the slope and the slope is a whole number then students don't necessarily think of the change in x being one. They just think of the change in y.*

Amy did a good job of diagnosing a typical misconception students bring to linear situations. Neveah's initial one-to-one response about the rate of change often is due to a misunderstanding of what the numerator and the denominator in the slope represent in terms of the context. When I asked her which might have been a different way to build understanding from this misconception Amy was able to respond by providing a more concrete approach through the use of ratios.

Whereas the questions I asked were able to draw out these ideas in Amy's response, a better approach would have been to be more concrete in how I framed the question. For example, if I had referred back to the question set she used and then asked her to consider a different way to approach Neveah's misunderstanding, this would have given us a better opportunity to compare the two approaches and discuss which was better and why.

Drawing out comparisons like the one just mentioned can increase the level of thinking on the part of the teacher just like it does on the part of the student. A discussion regarding the comparison between the two approaches could have then been followed up with a connection between the independent and dependent variable class work from previous weeks where students made sense of the numerator and denominator in the slope. My coaching in this debrief would have been better if I had prompted Amy to consider the questions she could ask her students which would allow them to make the connections between rate of change, independent and dependent variables, and the numerator and denominator in the slope of the equation.

Amy and I begin to look through the student work to locate examples of proficient work. Once we had identified six students who were able to proficiently label each part of the equation in terms of the context, we began to plan the next day's reteach activity.

Coach: *Based on what happened in the lesson on Thursday and Friday what do you think we should plan for in the reteach?*

Amy: *I am almost thinking could we start writing stories?*

Coach: *How might we differentiate the lesson?*

Amy: *Well. We could have a similar but not as complicated equations. Give them a simple equation; write your own story. Based on what you know about linear equations are you able to… label each part based on this story [you created]?*

Coach: *Do we want to have a starting value other than zero?*

Amy: *Maybe we have one without to start with.*

Coach: *Do you want to model how to write a story from an equation?*

Amy: *Yea.*

Coach: *So what context might you choose?*

Amy: *Chores. Somebody's allowance. With a proportional starting at zero you just say somebody earns $10 in allowance each week. So your allowance equals 10 times the number of weeks.*

Coach: *Do you want to ask the question, "How much do you have in so many weeks?"*

Amy: *Yea.*

Coach: *So, given an equation, create context and create a question. Do you want them to answer the question?*

Amy: *Yea*

Coach: *And you are going to give them a proportional equation?*

Amy: *Yea.*

Coach: *So y=10x might be good. I like your chore context. Most kids will know what* *you're talking about, probably.*

Amy and I worked the previous year with giving students equations to create context from, and we found moderate success in using this approach to helping students make sense of the context in other problems. Amy's decision to create a reteach lesson based on this activity was well aligned with what she had been doing in the Canoe Rental, as well as the Temperature/Visitor/Profit, problems. Her students were given numerous opportunities to write equations from stories and now they were assigned the task of creating a story from an equation.

The questions I asked in this dialogue were very leading. If I am going to ask Amy, "Do we want to have a starting value other than zero?" I might as well simply make the suggestion that we could or should have some equations where the staring value is zero and others where it is not. Better, more focused questions, might have been, "How do you want to differentiate the lesson?", "What would be good equations to give students to write stories from?" and/or, "How do you want to launch the lesson?

This planning session with Amy led to the most effective reteach lesson in the study. Amy created four different equations for her students to write stories from. Two were proportional and two were not, two had a slope where the denominator changed by one and the other two did not, and the equations were selected and given to groups of students based on what we determined their next steps to be based on the student's work turned in at the end of the Temperature/Visitor/Profit lesson. Amy demonstrated how to write a story from an equation using the y=10x equation we had discussed, and the students created a wide variety of stories based on the equations they were given. After the lesson, Amy and I reflected on how much better her students performed in this writing activity than what we had seen the year before.

In this chapter, I have demonstrated how a teacher can improve the teaching and learning in his or her classroom by using data collected on student thinking. I also showed how an instructional coach could use information on student thinking to improve the coaching of teachers. By creating lessons based on the mathematical understandings that students bring to the lesson, as well as modifying the lesson in the moment based on student thinking during the lesson, the teacher can improve the teaching and learning occurring in the classroom. I have also demonstrated that while student thinking can become more visible when a classroom is governed by the Sociomathematical Norms, teachers can have significant difficulties in putting these norms in place. Finally, I revealed how coaching through the use of student thinking can be used to make teacher thinking visible which in turn can assist an instructional coach in making decisions about how to best support the teacher in improving classroom instruction.

In the next chapter, I will make some concluding statements, reflect more on what I learned about effective instructional coaching, and make suggestions for future research in how to improve the effectiveness of instructional coaching.

Chapter 5

Research Implications

Research Questions

- How does a teacher improve the teaching and learning in the classroom by using formative assessment data to make adjustments in a current lesson as well as plan future lessons?
- How does an instructional coach use information gathered from classroom observations and student responses to assessment problems to improve the coaching of teachers?

Overview of the Study

From this study, I determined that using data on student thinking to plan future lessons, as well as making in the moment adjustments to a current lesson, could improve teaching and learning (Duckor, 2014, Guskey, 2003; Herbal-Eisenmann & Breyfogel, 2005; Kazemi, 1998; Tomlinson, 2014). I also determined that an instructional coach who uses data from student thinking in his or her coaching could improve their coaching of teachers (Aguilar 2013, Knight, 2007). In this chapter, I will return to the beliefs which undergird this study as shared in chapter one. I will share what I discovered about using student thinking to improve teaching and coaching, and I will present some generalities from this analysis as well as make suggestions for future research related to this study.

The research questions I chose for the study are based on the difficulties teachers and instructional coaches have with using data gleaned from formative assessment to improve the learning environment in the classroom. There are two guiding beliefs that undergird this study. First, effective teaching requires the use of formative assessment data to target the educational needs of students (Bambrick-Santoyo & Peiser, 2012; Dufour, 1998). A student-centered learning environment, based on instructional strategies that draw out student thinking, makes that thinking visible to both the teacher and students. By making that data visible, the teacher can then use it to guide the class in drawing conclusions by justifying and generalizing with the mathematics (Dukor, 2014; Tomlinson, 2014). Second, effective coaching requires the ability to gather and use information on teachers' instructional practices as well as evaluation of student work to target the instructional needs of a teacher (Carpenter et al., 2000; Knight, 2007). This will improve the effectiveness of the coaching, which in turn will improve the instructional practices of the teacher being coached.

These conjectures, made before the study began, are a response to the two research questions guiding the study. They were designed to direct the methodological approach I took for the study and therefore played a role in the conclusions I have drawn from the data collected. This chapter will present the results of this study based on the analysis of the data collected during the study.

I used the case study methodology for this research project because it provided an opportunity to engage in action research by describing a phenomenon in the context of a classroom (Flyvbjerg, 2006). I engaged in this case study through a constructivist paradigm allowing for the creation of meaning on both the part of the researcher as well as the participant (Baxter & Jack, 2008). Data from the study was collected through a four part planning and teaching cycle. I audio recorded the planning sessions before the lesson as well as the debrief after each lesson and I videotaped the main lesson as well as the follow up lesson. The study was comprised of three cycles where cycle one was focused on the Gatemen problem, cycle two was focus on the Canoe Rental problem, and cycle three was focused on the Temperature/Visitor/Profit problem. There were four parts, planning, teaching, debriefing, and reteaching, to each of the three cycles. I transcribed the data and coded it in a matrix that separated the information based on what the teacher was learning about her students and their learning compared to what I was learning about Amy and her learning. The data was then analyzed to answer the research questions regarding the use of student thinking to improve classroom teaching and instructional coaching.

Results

This research study allowed me to collect data on student thinking, the teacher's thinking, and the coach's thinking in regards to improving the teaching and learning in a math classroom. Throughout the nine weeks of this project, I was able to observe Amy as she developed as a teacher. I was then able to reflect on Amy's thinking about how her decisions, while planning and teaching the lessons and how the affected the learning occurring in her classroom. During the time of the study, I was also able to consider how I developed as an instructional coach and reflect on my thinking about coaching. In this section, I will consider what I learned about Amy as a developing teacher and what I learned about myself as a developing coach through this research project.

How Amy improved as a teacher through the use of formative assessment data. The first research question asked how the use of formative assessment data can improve the teaching and learning in a mathematics classroom. Amy's ongoing work to create a student-centered classroom, and how she made sense of the coaching she received during the study, is at the heart of how I observed Amy developing as a mathematics instructor. During the study, Amy was able to demonstrate the use of discourse strategies, as well as responses to assessment problems, for collecting data on student thinking. Amy improved in her ability to use the data to both plan better lessons as well as use data to make instructional decisions during the lesson. In this section, I will discuss how collecting and using data on student thinking improved the teaching and learning in Amy's classroom.

Becoming comfortable with the discourse strategies Amy practiced in the lessons we planned is a strong indication that Amy saw both the need and the means to make her classroom more student-centered. Whereas Amy implemented the Select and Sequence strategy in the Gateman lesson, she was not happy with the student's responses during whole group sharing. Planning for and implementing the Proximity Partner discourse strategy in the Canoe Rental lesson provided better opportunities for Amy to listen to student conversations, determine their thinking about the mathematics, and plan a more targeted select and sequence than in the Gateman lesson.

Amy also used ambassadors, another discourse strategy, to improve the pacing of the Temperature/Visitor/Profit lesson. She used the information students were sharing through the ambassadors to make the decision quickly to move from the first part to the second part of the lesson. This was beneficial because, as we had anticipated in planning the lesson, students had a more difficult time with the ideas in the second part of the lesson. Since she had more time, Amy was able to implement the huddle discourse strategy, which provided students with the additional ideas necessary to make sense of the second part of the lesson.

Along with developing the strategies for collecting data on student thinking, Amy demonstrated progress with using that data to improve her teaching. She came in with some understandings on how to use student's previous experiences to plan lessons. In the Gateman lesson from the first cycle, she was able to use what students had been doing with tables and graphs from the peaches lesson the previous week to make planning decisions. Because of the thinking students demonstrated in the Peaches lesson, Amy felt confident in opening up the Gateman lesson for students to explore with less direction from her. This decision created productive struggle, as students were able to access experiences from the previous lesson to create tables and graphs in the Gateman lesson. However, because we did not implement specific discourse strategies to gather additional information on student thinking during the lesson her efforts to select and sequence with student responses in the summary of the lesson was not effective.

Over the nine weeks of the study, Amy improved in her ability to both collect data on student thinking and then use that data to plan lessons that targeted the needs displayed in the student work. From the Gateman lesson in the first cycle to the Temperature/Visitor/Profit lesson in the third cycle, Amy planned better lessons, which resulted in higher levels of student thinking. By the third cycle, Amy was gathering information on student thinking and turning it into lessons that were more effective.

The successful reteach lesson in the third cycle was a demonstration of Amy's increased effectiveness in using data to plan better lessons. Based on the data gathered in the Temperature/Visitor/Profit lesson we were able to create a targeted reteach lesson where students were working to create stories from one of five different equations. The equations were designed based on a varying level of complexity and each student group was assigned an equation based on the understandings they had demonstrated in the main lesson the day before.

Another component that also played a role in Amy's ability to target her instruction was that she was getting to know her students better over the nine weeks of the study. Amy ran the Gateman lesson in the second week and she ran the Temperature/Visitor/Profit lesson in the eighth week of the school year. Since she met with her students daily, Amy was learning about them as mathematicians apart from the lessons we ran together for the study. As a result, both the lessons designed for the study, as well as the lessons Amy created on her own, played a role in Amy knowing more about her students as mathematicians, and how they thought about the mathematics, over the course of this nine-week research project.

One difficulty associated with the study was Amy's struggle to make sense of the Sociomathematical Norms. Whereas the learning environment established by the third cycle allowed Amy to make better decisions, both during the Temperature/Visitor/Profit lesson and the reteach lesson, Amy was not able to identify how the Sociomathematical Norms played a role in this.

As discussed in Chapter 4, Amy used discourse strategies to create social norms in her math class where students shared answers with each other. When Amy pressed them, they were also able to share some math ideas associated with the answers. Whereas these social norms did provide us with the necessary information to create an effective follow up lesson the next day, they did not give students opportunities to challenge each other's thinking in order to form consensus across the classroom regarding the mathematics.

How I improved as an instructional coach through the use of formative assessment data. The second research question asked how the use of formative assessment data could improve the coaching of a mathematics teacher. In this section, I will discuss how the analysis of the discourse data between Amy and me as we planned and debriefed lessons, as well as the data collected during lessons, allowed me to see where I am in need of improvement as an instructional math coach.

In chapter four, I wrote how about new understandings I took on as an instructional coach as I analyzed the dialogue between Amy and myself from two video clips. One observation regarding my coaching was that I could improve my use of focusing questions as I conferred with Amy during the debrief of the lesson in the third cycle. By analyzing classroom discourse from the second video, I was also able to discover the need to improve in how I pressed teachers to compare different instructional approaches. I concluded that by drawing out the comparisons I would raise the level thinking on the part of the teacher as well as model the use of connecting ideas to create understanding. In this section, I will continue with more of what I learned about myself as a developing instructional coach by writing about how asking strong focusing questions that elicit thinking on the part of the teacher, and then waiting for the teacher to respond, is necessary for a coach to plan his or her next coaching move.

Instructional coaching which elicits teacher thinking. Discovering what students are thinking requires the teacher to ask questions and wait for students to respond. If the teacher is too quick to move onto the next question or proceeds to answer his or her own questions regarding the math, he or she will remove opportunities to discern what the students are thinking. The same is true for an instructional coach who wants to determine a teacher's thinking regarding his or her instructional practices. The coach needs to ask questions about instruction and then wait for the teacher to respond with his or her ideas and understandings.

An unexpected discovery I made in the analysis of the recordings from the planning session in cycle one is that I answered many of the questions posed to Amy. Without her responses to my questions, I was not able to determine what Amy was thinking about as we planned this lesson.

For example, early on in the planning session, I made a suggestion about asking the class to form a conjecture and then I explained what a conjecture was before I gave Amy the opportunity to share what she already knew about this. This was a lost opportunity to determine Amy's baseline understanding of what a conjecture is and how it might be developed in a lesson. Through this analysis, I realized that if I want to effectively research teacher thinking I am going to need to ask questions, wait for Amy's response, and then listen carefully to what she says. Additionally, in order to support Amy in building her capacity as a teacher, I needed to work with the understandings she brought to planning and teaching effective lessons so I could target my coaching from her strengths. Just as Amy's questions to her students are designed to work from the mathematical ideas they bring to the lesson, my questions to Amy need to work from the instructional ideas she brings to the planning sessions.

There were also times I interrupted Amy as she was responding to my questions. Here I realized that I needed to minimize my ideas so she can develop and make sense of her own ideas. Just like a teacher is not going to know what students are thinking if the teacher is doing most of the talking, an instructional coach in not going to learn about what a teacher is thinking if the coach is doing most of the talking. Discovering this issue early on in this study gave me the opportunity to be aware of a deficiency in my coaching which I could then address through the rest of the cycles. As I analyzed the recordings throughout the study, I became aware of these coaching deficiencies and this motivated me to improve my questions as well as how I waited for Amy to respond with what she knows.

I identified improvements in my coaching during the Temperature/Visitor/Profit lesson when Amy wanted to use the Huddle strategy and I asked her why she wanted to use it at that point in the lesson. She responded by explaining that the mathematical ideas needed to get out and into the classroom soon because we were nearing the end of the period. Upon reflection of this exchange, it appears that Amy was not asking for my opinion but rather was processing with me the effectiveness of implementing the Huddle strategy at that time. This was encouraging to me as it indicated a level of independence on Amy's part to make decisions about what discourse strategy to use. It also demonstrated that I was doing a better job of asking questions and listening to responses.

An instructional coach needs to listen carefully to the teacher's thinking and not project his or her own opinions into what the teacher says as they are saying it (Aguilar, 2013; Knight, 2007). Just as a teacher needs to be a leaner of kids, an instructional coach need to be a learner of teachers. Effective listening, which leads to an understanding of thinking, comes from being attentive to the verbal and nonverbal messages. Pressing a teacher into considering and then taking on new ideas in the classroom must first come from honestly wanting to know what experiences the teacher brings and what new understanding the teacher wants to develop (Knight, 2007).

Beyond this project, I plan to continue to improve my coaching through the experiences gained from this study. I found the analysis of audio and video recordings through the transcribing process to be beneficial in evaluating my coaching moves and improving them. Since the time I have finished collecting data for this study, I have continued recording planning sessions and math lessons with other teachers as well as professional development meetings I have facilitated. Whereas I have not have the opportunity to transcribe the recordings, my plan is to dig into them in the near future.

Discussion

Limitations. A limitation in using the case study approach to research is generalizing the results to other contexts. Questions remain as to whether a different teacher would take on the discourse strategies as well as Amy did and whether another teacher would be able to use the data to create a reteach lesson as strong as what was observed in the third cycle.

As expected, I found Amy to be a good candidate for this case study inquiry. She was willing to take on risks by trying new instructional strategies possibly because we had formed a strong professional relationship over the past 18 months and we trusted each other. As a result, I was able to observe her efforts to incorporate discourse strategies and evaluate their effectiveness in making student thinking visible. However, Amy displayed difficulties in making sense of the Sociomathematical Norms. This might be due to her still novice experiences as a classroom teacher as well as my lack of experience in coaching teachers in how to incorporate them into the learning culture of the classroom. As described in Chapter 3, a critical component in a successful case study is a deep understanding on the part of the researcher as to the issues involved in the study. In this way, limited experiences on the part of both the participant and researcher regarding the Sociomathematical Norms created limitations within the study and therefore possible errors in the conclusions.

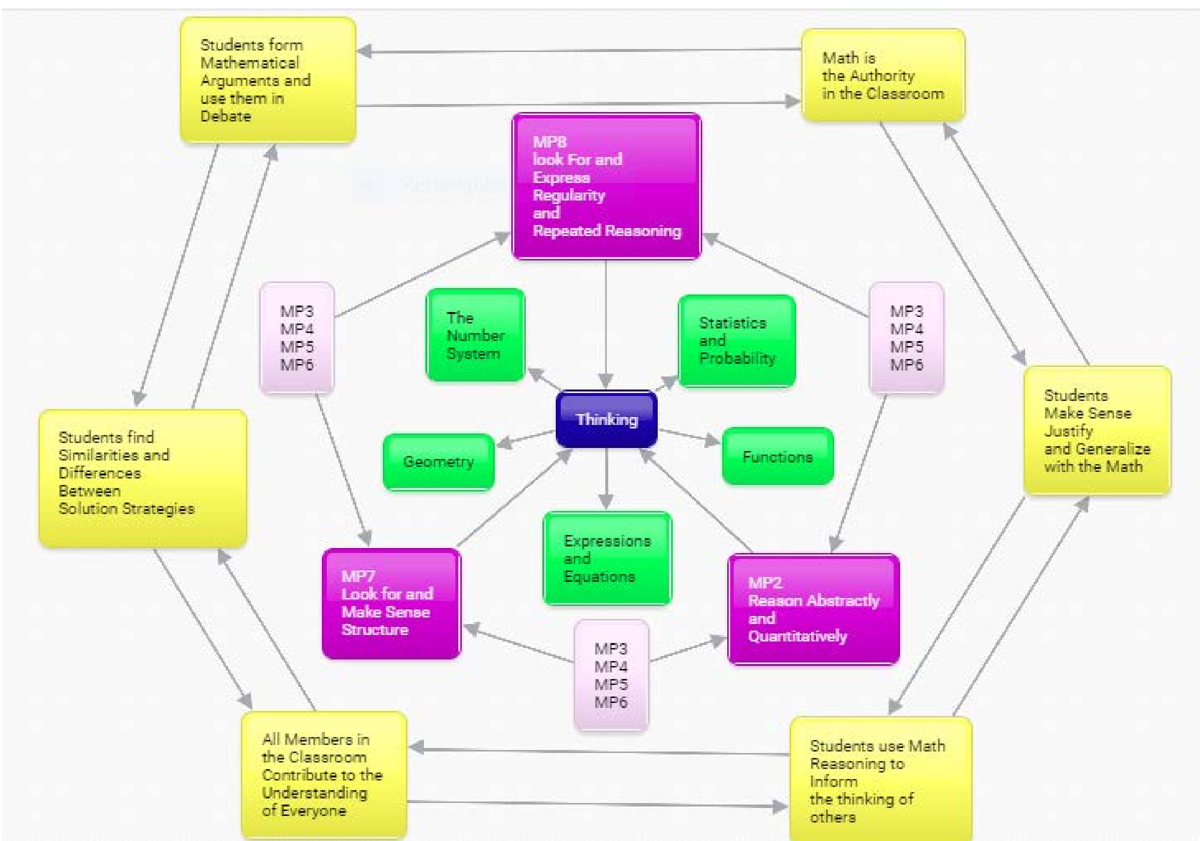
Generalizations. While the case study approach to qualitative inquiry is useful for generalizing a hypothesis regarding a phenomenon, the goal of this action research project was not necessarily to generalize the findings to other schools or subjects. However, generalizations regarding connections between the Common Core Math Content Standards and the Common Core Math Practice Standards, as well as the difficulties of creating a classroom based on the Sociomathematical Norms, can be beneficial to the reader (CCSSI, 2010a; CCSSI 2010b). In this section, I will present a conceptual framework that demonstrates the connections between the Common Core Math Content Standards, the Common Core Math Practice Standards, and the Sociomathematical Norms. I will also share some of my experiences with difficulties in supporting my participant with implementing the Sociomathematical Norms into her classroom learning environment.

Conceptual Framework. The conceptual framework for this study, shown in Figure 17, has three components that support thinking. The inner section in green shows the five main categories of the 8th grade Common Core Math Content Standards. The middle section in purple displays the Common Core Math Practice Standards and the outer section in yellow exhibits the Sociomathematical Norms. This framework developed over the course of the study as an illustration of how assessment data supports thinking.

The word *Thinking* sits in the middle of the framework as the central purpose for engaging in math. The goal of a student-centered math class is to create challenges where the students engage with the mathematics collaboratively and independently so that the student thinking is made visible to the teacher and to each other.

The Math Practice Standards, shown in purple, define the behaviors a mathematician engages in when he or she is working on mathematics. Teacher facilitation of the Math Practice Standards supports how a student can think about mathematics as they are engaged in solving math problems. Kelemanik, Lucenta, and Creighton (2016) have identified the three Math Practice Standards in dark purple as the main avenues students use to think about mathematics.

Figure 17 **Conceptual Framework**



The four in light purple, construct and critique arguments (MP3), model with mathematics (MP4), use tools strategically (MP5), and attend to precision (MP6), are supports to the three main practice standards. Each Math Practice Standard collectively point towards the center because they support the thinking a student engages in as a student mathematician.

The Math Practice Standards point in to support *Thinking*, and *Thinking* points back out to support the Math Content Standards. The purpose of the Math Practice Standards is to develop the thinking processes necessary to being a proficient mathematician. In this way, the content is more central than the processes while the processes are necessary for students to make sense of the content. This is why, as I have stated previously in this study, finding correct answers in math is important, but math is more than just answers.

Surrounding the Math Practice and Math Content Standards in yellow are the descriptions of the Sociomathematical Norms. These define the learning culture of a strong mathematical classroom environment. While I believe they are an outgrowth of the intentional use of the Math Practice Standards to support the Math Content Standards, I have also discovered through this study the need to deliberately address and monitor for them in both the planning and the teaching of the lesson.

Through the creation of this conceptual framework, I have formed a theory regarding how to make student thinking available to the teacher for the use of improving the teaching and learning in a mathematics classroom. The incorporation of social norms into a mathematics classroom where students help each other work through the math by providing descriptions and explanations about the solution process creates better opportunities for students to make their thinking visible to the teacher than a direct instruction model. In the same way, the incorporation of the Sociomathematical Norms where students see the mathematics as the authority in the classrooms and use it to ensure that each students understands the math at a proficient level creates even more opportunities for students to show their understandings to the teacher and to each other. Through this study, I am proposing that as teachers move along the continuum from a direct instructional approach to a collaborative instructional approach governed by the Sociomathematical Norms they will find that student thinking becomes more visible and will therefore be more useful for improving the teaching and learning in their classroom.

In the next sections, I will discuss the difficulties in creating a classroom based on the Sociomathematical Norms, describe the ideas this study brings to the fields of teaching and instructional coaching, and make some recommendations for further research into instructional coaching which could support math teachers in developing the Sociomathematical Norms in their classrooms.

Difficulties with implementing the Sociomathematical Norms in a mathematics classroom. Described in this research project are three different levels of instructional practices ranging from those that create a traditional teacher-centered classroom to those that create a progressive student-centered classroom. A direct instruction model where the teacher shares what he or she knows and the students practice what the teacher shared would be on the traditional end of the continuum. The collaborative instructional model based on the Sociomathematical Norms where students form mathematical arguments and use them in debate with their classmates would be on the progressive end of the continuum. A collaborative classroom structure based on social norms where students share descriptions of procedures and answers to problems would be between these two ends.

This study has argued that classrooms based on a collaborative instructional model provides teachers with better understanding of student thinking than a direct instructional model. I have then taken the collaborative instructional model and proposed that creating a learning environment based on the Sociomathematical Norms gives more information on student thinking than the social norms of a collaborative mathematics classroom. In this section, I will discuss the difficulties an instructional coach has in pressing teachers from a direct instructional model to a collaborative instructional model, based on the social norms of a math classroom, and from a collaborative instructional model based on the social norms to one based on the Sociomathematical Norms (Kazemi, 1998, Yackel & Cobb, 1996).

Guven and Dede (2015) write that the norms of a group are the manners and expectations that govern the behaviors of each member in the group. It is the role of the teacher to create the learning environment in the classroom and is therefore the teacher's task to create the norms that govern student behavior. A teacher's experiences as a student in math classrooms from a young age as well as his or her experiences as teachers of mathematics in their career together influence how they create the learning environment in their classroom (Donovan et al., 1999). Since these experiences are usually teacher centered, overcoming them to create a learning culture founded on the social norms of a mathematics classroom is a difficult task. However, there is a similar level of difficulty for teachers who have found success in creating social norms in their mathematics classroom to transition towards constructing a classroom learning culture based on the Sociomathematical Norms.

Whether the coach is working with a teacher who brings a teacher-centered direct instructional approach or a teacher who brings a student-centered collaborative approach the first step is to convince the teacher that a classroom governed by the Sociomathematical Norms will result in deeper learning on the part of the student. Taking on a belief in students as mathematicians who can make sense of mathematics by finding the similarities and differences between approaches to solving problems and then use their understanding to ensure that all students contribute to the learning of each student is a daunting task. Complicating this endeavor is the need to release control of the learning environment in order to develop autonomous student mathematicians who are free to support each other with the mathematics (Yackel & Cobb, 1996). The complexity occurs on two levels. One level is the teacher's beliefs in their students' ability to engage with the math and with each other based on these norms, and the other level is the students' belief in themselves as capable of thinking about math and working collaboratively in this way (Dweck, 2006).

One reason I chose Amy as my participant is that she had demonstrated some success in creating a collaborative classroom based on the social norms of a mathematics classroom and had shown willingness to press on to the next step. As her instructional coach, I worked from these collaborative practices to press her into understanding and implementing instructional practices that create the Sociomathematical Norms. This was the first time I had intentionally worked to support a teacher in making this transition and I found it much more difficult than I had expected.

Weaving the Sociomathematical Norms into the existing social norms of a mathematics classroom is an artistic endeavor based on what the coach knows about the norms as well as what he or she knows about the teacher's beliefs concerning how to run an effective mathematics classroom (Guven &Dede, 2015; Yackel & Cobb, 1996). As with any artistic endeavor, time and efforts are necessary to perfect the results making it difficult to observe Amy's progress in the short time frame of this study. However, having this as a goal for my work with her as well as the other teachers I coach in my school can help me to form a long-range plan for my work by defining what success would look like.

Possibly the most difficult part of the successful implementation of the Sociomathematical Norms is forming a belief in the benefits of students working as autonomous members of a learning community (Guven & Dede, 2015). The fear that chaos, and with it a lack of learning, will result by giving control to students is deep seated and difficult to overcome.

One of the first and most challenging lessons a teacher learns in his or her rookie year is the difficulty of bringing control back to a classroom once it has been lost. This leads teachers to adopt a more teacher-centered approach to managing a classroom, even if they believe in the benefits of student-centered collaborative learning.

A second difficulty is creating a mental model of what a classroom governed by the Sociomathematical Norms looks like. It is easy for an instructional coach to say that each student should work to ensure that all student understands the math, but it is difficult to envision what this might look like in practice.

Amy’s confusion regarding the Sociomathematical Norms, and my difficulty in clarifying this, kept us from successfully incorporating them into her classroom learning culture. For a teacher to take on a conceptual understanding of the sociomathematical norms when he or she did not experience them as a math student is a challenging task. I have found that teachers can only take on instructional practices that they can map on to their previous experiences. I believe this to be true for other classroom norms such as white privilege, power, and related social justice issues.

Understanding what a teacher is thinking about as he or she is working to integrate the Sociomathematical Norms into their learning culture is important to the instructional coach who is supporting him or her. The next section speaks to the need for further research on coaching practices that make teacher thinking visible so that an instructional coach can use that thinking to improve the professional development of teachers.

Advancing teaching and instructional coaching. I have found two developments over the course of this study to be beneficial to the field of math teaching and instructional math coaching. First, as mentioned earlier in this chapter, I was surprised at how the analysis of the audio and video recordings through the transcribing process drew out deficiencies in my coaching. By transcribing the recordings, I was able to consider deeply the quality of the questions I asked as well as how I used them to draw out Amy's thinking regarding her instructional practices.

I would recommend this as an approach to the professional development of instructional coaches. The typical work of a supervisor sitting in on a coaching session to give the instructional coach feedback can be helpful but is generally ineffective at helping a coach analyze what did and did not go well. For the coach to transcribe a section of a coaching session, consider the quality of the questions being asked based on how well they stimulated teacher thinking, observe their interactions with the teacher through their questions, and take those reflections to the supervisor would be transformative to how an instructional coach approaches his or her work with teachers.

Second, this study cause me to face the difficulties a classroom teacher has with understanding the Sociomathematical Norms and how to create them in the learning environment of math classroom. I also became aware of the difficulties an instructional coach can have in supporting a teacher in this endeavor. I was able to make sense of the complexity involved in understanding how the sociomathematical norms work by connecting them to the content and practice standards developed by the Common Core (CCSSI, 2010a; CCSSI 2010b). Bringing this framework into the conversation can be useful for supporting both the classroom teacher and the instructional coach in making sense of the Sociomathematical Norms, and how to create a learning environment based on them.

Recommendations for further research. We have seen that a teacher's use of data on student thinking can improve the teaching and learning in their classroom. We have also looked at various assessment strategies that a teacher can use to make student thinking visible so that it is available to the teacher for planning future lessons as well as making in the moment decisions during the lesson. Whereas we have an abundance of research on instructional strategies for teachers to use in making student thinking visible, there is a deficit of research on coaching strategies for making teacher thinking visible.

Understanding what the Sociomathematical Norms are, and then implementing instructional strategies designed to create them, is a difficult undertaking. Assessing a teacher's thinking as he or she struggles with this can give the instructional coach vital information necessary to support the teacher in this endeavor. However, assessment plans a coach can use to make the teacher's thinking visible are limited to the questioning strategies described in chapter four. Whereas the questions a coach asks, and how the teacher responds are important, I have found that they may not be sufficient to engaging a mathematics teacher in the difficulties of making student thinking visible and then assessing that thinking.

In the previous section, I suggested the use of the conceptual framework developed through this study, as a structure to help teachers makes sense of the Sociomathematical Norms. This, along with other structures, could be beneficial in drawing out the teacher's thinking for the coach to use in making coaching decisions.

I also suggest the use of transcribed notes in coaching trainings, as described in the previous section, as useful in both drawing out how to make teacher thinking visible. A facilitated discussion among coaches who have brought transcribed notes could lead to discoveries about strategies to draw out teacher thinking.

As we have seen, setting up an learning culture where student thinking is made visible and then using that thinking to make planning and teaching decisions is complex. Knowing how the teacher is thinking about this as they are thinking about this would be beneficial to the instructional coach wishing to press the teacher to improve their instructional practices.

Conclusions

This study researched how a teacher and an instructional coach can use student thinking generated by formative assessment to improve the teaching and learning in a mathematics classroom. The study included three instructional strategies to investigate the two research questions that guided the project. The first strategy was the use of student thinking from a previous lesson to plan for the learning in future lessons. The second strategy was the use of student thinking during a lesson to make in the moment decisions about how to proceed with the lesson. The third strategy was creating a learning culture based on the Sociomathematical Norms to make student thinking visible so it can be used to plan and implement better mathematics lessons.

Through the course of the study, the teacher improved in her use of discourse strategies, which in turn made student thinking more available to both herself and the instructional coach. The learning that occurred over the course of the study also improved due to the increased availability of student thinking to plan and teach lessons. However, the participant's ability to generate a classroom culture based on the Sociomathematical Norms was limited.

A theory was proposed for the use of the Sociomathematical Norms as an avenue for creating better opportunities for students to make their thinking known to the teacher. It is founded on the proposal that classrooms based on collaborative structure provide better information on student thinking than classrooms based on direct instruction, and that collaborative classrooms based on the Sociomathematical Norms provides more information on student thinking than collaborative classrooms based on social norms.

Finally, I have made an appeal to the research community for further study into assessment practices that make teacher thinking visible to the instructional coach. The use of the conceptual framework developed in this study that shows the connections between the Common

Core Content Standards, the Common Core Practice Standards, and the Sociomathematical Norms was given as a structure for making teacher thinking visible. Just as a mathematics teacher can use student thinking to improve the teaching and learning in her classroom, I believe an instructional coach could use teacher thinking to improve the coaching of math teachers.

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