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Why do I teach math this way: A qualitative examination of how teacher experiences impact the implementation of instructional practices

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Why Do I Teach Math This Way: A Qualitative Examination of How Teacher Experiences Impact the Implementation of Instructional Practices

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Abstract

Since the 1960s, there has been an effort among the mathematical education community to shift instructional practices from a focus on arithmetic, memorizing rules, and completing practice worksheets to instructional practices that allow students to see mathematics as content that requires thinking and pattern explorations. Many mathematics teachers have not fully embraced these shifts in instructional practice. This study aimed to examine secondary mathematics teachers' experiences and how those experiences connect to teachers' implementation of student-centered instructional practices in the lessons they design. This qualitative study utilized a grounded theory approach to examine how a teacher's experiences as a student of mathematics and instruction impact the instructional practices considered for use in their classroom. Two research questions guided this study: (a) How do teachers understand the student-centered instructional practices they implement in their classrooms? and (b) How do teachers experience the implementation of student-centered instructional practices? The study used two interviews and classroom observation to collect data from the 12 secondary mathematics teachers who were participants in this study. This study was conducted during the 2020-2021 and 2021-2022 school years. Student-centered instructional practices are significant ways to support students in developing their mathematical knowledge. For many teachers, these practices were not a part of the secondary mathematics instruction they experienced. Student-centered instructional practices can be challenging to incorporate into a teacher's instructional repertoire due to the misalignment with an educator's own student experience. This study has identified two key experiences that support teachers in considering student-centered instructional practices as a part of their instruction. These experiences are the failure of an individual's mathematical knowledge in a way that causes identity reconstruction and the belief that learning mathematics

is a pursuit meant to increase mathematical knowledge and develop critical habits of mind. In addition, this study identified three key supports for helping teachers build their knowledge and skill in utilizing student-centered instructional practices. These supports for assisting teachers in incorporating these practices into their repertoire are (a) collaborating with others, (b) engaging in long-term learning opportunities around student-centered instructional practices, and (c) having student-centered instructional practices modeled through mathematical content.

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Chapter One: Introduction

As a math educator, there is no greater reward than when a student tells you, “I finally get math” or “I used to think math was hard, but after this class, I realize I can do it.” Unfortunately, as a middle school math educator, I often hear these comments. The idea that students went 6 to 8 years of their educational experience until they felt they could say those things is heartbreaking. When I was a student, math class was not always a place where I felt comfortable, yet I was a competent mathematics student. I remember being chastised by my third-grade teacher for not memorizing my math facts. My teacher identified me to the whole class as somebody who had not done what she needed to be “smart.” In reality, I had used the time she gave us to memorize our facts to identify patterns in the numbers, realizing that I could determine any product on the multiplication chart with these patterns. My focus on understanding the multiplication chart did not align with how she measured my mathematics learning. In hindsight, I was engaging in sense-making, a practice currently identified as a key instructional practice in developing student understandings (National Council of Teachers of Mathematics [NCTM], 2014; Schoenfeld, 2016), but that was not my teacher’s instructional goal; her focus was on procedures and memorization.

Classes like these were an instructional mismatch for my needs as a learner. As a k-12 mathematics student, I experienced them repeatedly, creating dissonance for myself and my mathematical identity. I completed the work assigned and got the correct answer but often received feedback that I had done the work incorrectly. The disconnect between my learning style and the instruction in my math class left me to question whether I was a capable math student. To my benefit, I encountered some high school and college teachers who focused on more than developing my procedural knowledge of mathematics. In those classrooms, I was able to build my identity as a mathematical thinker, maintaining access to the benefits and opportunities that come from being able to make sense of mathematics. I identify as a mathematical thinker; I interpret the world through a mathematical lens. Yet this identity could have easily been taken from me had I not benefited from educators working to develop their instructional practices to put sense-making, discourse, and reasoning at the forefront of how they asked students to engage with mathematics (NCTM, 2014). The classrooms I thrived in were influenced by educators developing their understanding of instructional strategies categorized as student-centered instructional practices (SCIP). Thirty-plus years later, too many students are still experiencing mathematics instruction that does not allow them to engage with learning in a way that connects their understandings to the content they are working to make sense of (NCTM, 2014).

Mathematics is a subject that many students quickly feel alienated from (Attard, 2013). While many reasons impact students' beliefs about their mathematical abilities, classroom experiences and interactions with content significantly impact how students develop mathematical understandings and engage in learning (Attard, 2013). Students have very little control over the instruction they encounter in the classroom; the teacher designs the experiences that students engage with during a mathematics lesson, which puts educators in control of meeting the needs of students in their classroom (Kriegbaum et al.,2015). Since the 1960s, there has been an effort among the mathematical education community to shift instructional practices from a focus on arithmetic, memorizing rules, and completing practice worksheets to instructional practices that focus on allowing students to see mathematics as content that requires thinking and pattern explorations. This focus looks not at the application of procedures but on engaging students in analysis and sense-making, allowing students to access and apply mathematics in meaningful ways (Schoenfeld, 2016). As collected and reported by the National Council for Teachers of Mathematics (NCTM) and the National Council for the Supervisors of Mathematics (NCSM), much work has been done to identify instructional practices that support the development of students as mathematical thinkers and problem solvers. Unfortunately, there has been a significant lag between identifying and implementing these practices in classrooms (Battista, 1999). Much of the research about the resistance to implementing student-centered instructional practices (SCIP) has focused on the impact of teachers' beliefs or a lack of teacher knowledge (Battista, 1999). Organizations such as NCTM and NCSM have utilized this research to make recommendations addressing teacher beliefs and knowledge in changing instructional practices. Teacher beliefs and knowledge are considered a key contributing factor to the implementation of these recommended practices (Attard, 2010; Ball & Forzani, 2009), and this begs the question, how does a teacher's perception of the study of mathematics and themselves as a mathematician impact their instructional beliefs? Does a teacher's propensity to rely on procedural understandings of mathematics support a procedural understanding of classroom instructional practices?

Instead of viewing the content taught in mathematics courses via conceptual knowledge and understanding, many teachers see the mathematics content they teach as a set of rules and procedures (Stipek et al., 2001). A foundational idea about learning is that prior knowledge and preconceptions should be accessed to allow new information to be fully comprehended (Bransford et al., 2000). As teachers make sense of and attempt to implement SCIP, they often experience initial failures. In response to this failure, it is not uncommon for teachers to access their prior procedural understandings to support their implementation.

Thinking through a conceptual practice procedurally, can negatively impact the efficacy of the methods they are utilizing (Anderson et al., 2018; Oleson & Hora, 2013).

Problem Statement

NCTM (2014) has reviewed the current mathematics instruction research. They state that the use of the following eight teaching practices will improve students' mathematical understandings.

- Establish mathematical goals to focus learning,
- implement tasks that promote reasoning and problem solving,
- use and connect mathematical representations,
- facilitate meaningful mathematical discourse,
- pose purposeful questions,
- build procedural fluency from conceptual understanding,
- support productive struggle in learning mathematics, and
- elicit and use evidence of student thinking.

The use and implementation of these practices have been met with resistance by families and classroom teachers despite significant research supporting them (Battista 1999; Sam & Ernest 2000). When students do not have access to mathematics instruction that allows them to see themselves as mathematical thinkers, they miss the opportunity to develop their mathematical understandings; these understandings are needed to interact in a society where mathematical reasoning and algebraic thinking are becoming increasingly necessary for success (NCTM, 2014; Schoenfeld, 2016).

Purpose Statement

Student-centered instructional practices have been slow to weave themselves into mathematics teachers' everyday practice (NCTM, 2014, 2020). This study aims to look at how a teachers' experiences as a student of mathematics and as a student of instructional practice impact the ways teachers make sense of and implement instructional practices that support student learning. Identification of potential connections between mathematical understandings and the interpretation of instructional methods could inform ways to improve teacher utilization of SCIP with their students.

Theoretical Frameworks

Sense-making theory explains how individuals look at the underlying phenomenon in a situation to resolve a gap or inconsistency in their understanding (Dervin,1983; Dervin, 1998; Odden & Russ, 2018). As teachers work to understand and implement SCIP into their daily lessons, they continually engage in sense-making to align their experiences as students and mathematics teachers. A focal point of the data analysis in this study will be understanding how a teacher makes sense of instructional practices for teaching mathematics. The application of sense-making theory as a framework for the study will support this data analysis.

Mathematical knowledge for teaching (MKT) is the result of the work done by Ball et al. (2008) regarding Shulman's seminal work on the subject of pedagogical content knowledge. MKT is the mathematics knowledge essential in supporting the teaching of mathematics; it is specialized and detailed in ways that are not utilized by mathematicians or for the completion of everyday tasks (Ball et al., 2008; Hill & Ball, 2009). MKT consists of four domains that describe the knowledge necessary to teach mathematics effectively (Hill & Ball, 2009). The four domains that make up MKT are the knowledge of the mathematics taught, known as common content knowledge; the subject matter knowledge that supports the act of teaching, known as specialized content knowledge; the knowledge of how students interact with the mathematics, known as knowledge of content and students; and the knowledge needed to tie the content to the teaching practices for designing instruction, known as knowledge of content and teaching. MKT will be utilized as a framework to inform this study.

Research Questions

Many researchers have turned their attention to the question, what is it that allows an individual to develop as an effective mathematics teacher? This exposure has provided many perspectives and studies identifying key ideas and understandings about how teachers develop their teaching knowledge. Shulman (1986, 1987, 2009) and Ball (2008, 2009) have identified key types of knowledge that comprise the knowledge and skills needed by teachers to teach mathematics effectively. Many researchers have identified instructional practices that significantly impact student understanding (Boaler, 2016; Fosnot et al., 2008; NCTM, 2014; Schoenfeld, 2016; Smith & Stein, 2018; Van de Walle et., al, 2018). Other researchers have identified the role of teacher identity, beliefs, and values on the impact and absorption of instructional practices into their teaching repertoire (Stipek et al., 2001). This study seeks to continue developing the understanding of how teachers make sense of effective instruction by investigating potential connections between how a teacher's learning experiences impact how they make sense of what they do as a teacher. The research questions addressed in this study are (a) How do teachers understand the student-centered instructional practices they implement in their classrooms? and (b) How do teachers experience the implementation of student-centered instructional practices?

Significance

The work of teachers changed dramatically during the 20th century, yet it is sometimes hard for individuals to see or communicate these changes (Ball & Forzani, 2009; Darling-Hammond, 2006). For many adults, the physical structures of schools look similar to when they attended as a student. Despite our current existence in a new age of technology, on the exterior schools doesn’t appear to have changed significantly from what most adults experienced during their schooling (Darling-Hammond, 2006). Even teachers struggle to communicate the shifts in education they have seen during their tenure (Shulman, 1987). When teachers struggle with these shifts, they often rely on their experiences as a student to inform their decisions (Elliot et al., 2013). As adults, it is easy to rely on our experiences as the foundation for our decisions about schools. However, when looking at changes in education, we must look at the students in our schools to see the difference. Darling-Hammond (2006) states:

> In previous decades, teachers were expected to prepare only a small minority for ambitious intellectual work, whereas they are now expected to prepare virtually all students for high order thinking and performance skills once reserved to only a few. (p. 300)

This shift is significant. When adults reminisce about what was educationally good for them, it does not align with students’ current realities. The mathematical knowledge taught in schools is often broken into two categories arithmetic and conceptual understanding. In 1977, the National Council for Supervisors of Mathematics (NCSM) issued a position statement to address the “back to basics movement” gaining attention. This movement looked to shift mathematics education back to basic skills like arithmetic, removing the development of conceptual understandings as an instructional focus. This NCSM position paper identified the need for students to demonstrate proficiency with calculations; however, it also highlighted other "basics," like problem-solving skills, identification of reasonable solutions, estimation, geometric understandings, and more. These additional basic skills get ignored when we reduce the scope of mathematics into two categories. The standards for mathematical practice and the mathematics standards defined in the Common Core State Standards highlight mathematics as a robust content area to be explored and understood (National Governors Association Center for Best Practices & Council of Chief State School Officers, 2010; NCTM, 2014). In the past, a person only needed an understanding of arithmetic to be successful in the many low-skill jobs available or complete a household's managerial responsibilities. With the increase in the use of technology, the skills employers need from their workforce are changing. Currently, there is a demand for a workforce that requires a mathematical understanding that moves beyond arithmetic into areas of data analysis and algebraic reasoning. The content, once reserved for the "ambitious intellectuals" has become necessary for all students (Darling-Hammond, 2006). Currently, many teachers still utilize instructional practices that emphasize procedural methods (Russell, 2012). Without a shift in instructional practices, the understanding that students develop will not involve the depth necessary to move beyond arithmetic into conceptual understandings, positioning students to enter the workforce unprepared for the mathematical demands they will experience.

Success in mathematics affords students significant advantages throughout their lives. Data indicate that the more math courses you complete, the increased likelihood of high school graduation. Students who do not fail a math course in high school are 82% more likely to graduate (Levin & Belfield, 2009). Students who graduate from high school have a median weekly income of $749 compared to $606 for those without a high school diploma (*U.S. Bureau* *of Labor Statistics*, 2019). Studies indicate that completing calculus increases earnings by 9% (Levin & Belfield, 2009). At the same time, mastery of high school mathematics courses impacts the post-secondary options for students. Cohen and Kelly (2019) studied the impact of math and science classes on course completion at community colleges and found that; 61% of students who enroll in community college place into a remedial math course, and 53% of students who did not complete their degree had requirements to complete remedial math course(s).

The postsecondary world that students enter into has changed significantly as well. Understanding mathematics is growing in its importance as an essential skill to interact with the world around us. Employment in STEM (science, technology, engineering, and math) fields are growing and predicted to continue growing faster than non-STEM fields. According to the U.S. Bureau of Labor and Statistics, from 2019 to 2028, STEM fields are projected to grow 8.8%, compared to 5.0% for non-STEM fields, and have a median annual wage of approximately $48,000 higher (2020). Yet only 33% of undergraduate degrees are in a STEM field (Kennedy et al., 2018).

Summary

We are all capable of learning mathematics; there is no such thing as "a math person" (Boaler, 2016). Unfortunately, this belief in mathematical abilities extends beyond students and impacts how teachers design instruction (Boaler, 2016; Craig, 2006; Geijsel & Meijers, 2005; Schoenfeld, 2016). When students leave school feeling that they are not "mathematically minded," we have done them a disservice. Traditionally underrepresented student groups continue to be disproportionately represented in honors mathematics and math intervention courses. Too often, in schools, mathematics is used as a tool to create inequities; instead of removing them. The Trends in International Mathematics and Science Study (TIMSS) results were initially released in 1995. Several times since then, these results have provided evidence that current instructional practices in mathematics are impeding our student's ability to compete as mathematical thinkers on the world stage (Phillips, 2007). Classrooms that support students in developing their abilities as mathematical thinkers and problem solvers are essential to creating schools that prepare students with the academic tools necessary to interact with society. Too many teachers are trying, unsuccessfully, to create these classrooms. Many teachers struggle to implement rich mathematical tasks in their classrooms. Even when U.S. teachers use rich tasks, their instruction often reduces the work to one requiring little thinking on the students' part (National Research Council, 1999).

By identifying connections across the way teachers process mathematical ideas and make sense of the instructional approaches they are implementing, we can improve students' mathematical learning experiences. These ideas can inform those responsible for supporting teachers as they implement instructional practices and engage students with mathematics. Supporting teachers to design effective mathematics instruction impacts the students' mathematical experiences in our classrooms, creating a learning environment where students develop their mathematical knowledge and use those understandings to interpret and improve the world, we live in.

Chapter Two: Literature Review

Mathematics education has been in flux for 60 years. In 1957, the launch of the Russian satellite Sputnik put a spotlight on public education in the United States. This spotlight shone brightly on student achievement in math and science studies. These events fueled an in-depth analysis of the components deemed necessary to increase student achievement in the science, technology, engineering, and math (STEM) fields. One of the many complexities that impact students and their ability to achieve are the teachers and teacher-designed classroom instruction that they experience (Boaler, 2002). This literature review identifies what research defines as essential teacher knowledge to support students in developing in-depth content knowledge. After identifying the essential knowledge for teaching, we look to the literature to identify current understandings regarding what prevents teachers from utilizing that knowledge to design classroom instruction. Finally, we look at the theoretical frameworks identified for use in this study, using the literature to support how their use can guide the research methods and interpretation of the collected data.

Teaching Knowledge: What is It?

Throughout history, the views of what a teacher needs to know to teach effectively have varied. Shulman (1986) described the history of what constituted essential understandings for teachers and how that knowledge has transformed over time. Shulman (1986) states that at the end of the 19th century, a teacher was deemed to have significant expertise if they understood the math they were planning on teaching. In the middle of the 20th century, the knowledge identified to teach effectively had less to do with the subject matter and was impacted more by general pedagogical knowledge (Shulman, 1986). At this time, it was believed that if you understood effective teaching methods, you did not need to fully grasp the subject matter to be an effective teacher. In the 21st century, the knowledge necessary to teach effectively shifted to involve subject matter knowledge, pedagogy, and more (Shulman, 1986). Research has identified additional layers and subtleties to subject matter and pedagogical expertise that make up the critical understandings held by effective teachers (Ball & Forzani, 2009; Ball, et al., 2008; Darling-Hammond, 2006; Shulman, 1986). Identification of effective teachers' requisite knowledge is the first step in supporting the creation of opportunities for growth and development in these areas (Shulman, 1986).

Due to the subtle nature of the skills that make up a teacher's knowledge base, teachers can struggle to articulate all of the knowledge and skills they utilize in their daily instruction (Shulman, 1987). When teachers are unable to communicate the knowledge and skills that impact their instructional decisions, a teacher's ability to reflect upon and refine their practice is impacted (Dervin, 1987). Effective teachers are reflective. It is this reflection that allows teachers to identify and replicate strong instructional practices (Danielson, 2008).

Shulman (1986) believed that teaching a subject effectively required a depth of knowledge beyond knowing its facts and concepts and a pedagogical understanding that went deeper than utilizing wait-time. Shulman looked to explain what was necessary to prepare a teacher to implement effective instruction. In his research, Shulman asked the question: What were the types of knowledge that a teacher needed to deliver instruction that moved beyond memorization to conceptual understandings effectively? Shulman's seminal work regarding pedagogical knowledge resulted in the identification of seven major categories of teacher knowledge that were necessary to address the complex interactions that occur when engaged in the acts of teaching and learning (Shulman, 1987). These categories are as follows:

- general pedagogical knowledge, with special reference to those broad principles and strategies of classroom management and organizations that appear to transcend subject matter;
- knowledge of learner and their characteristics;
- knowledge of educational contexts, ranging from workings of the group or classroom, the governance and financing of school districts, to the characters of communities and cultures;
- knowledge of educational ends, purposes, and values, and their philosophical and historical grounds;
- content knowledge;
- curriculum knowledge, with particular grasp of the materials and programs that serve as "tools of the trade" for teachers; and
- pedagogical content knowledge, that special amalgam of content and pedagogy that is uniquely the province of teachers, their own special form of professional understanding.

While many of these categories fall under subject matter or pedagogical knowledge, the details are flushed out, allowing for a more thorough discussion regarding what teachers must know and be able to do to teach effectively. These seven categories describe a special set of skills and understandings that a teacher needs to develop as a part of their professional practice. While the ideas of general pedagogical knowledge and content knowledge were considered a part of recognized skill sets (Shulman, 1986), other categories had not been considered a part of a teachers' professional practice. Of the seven categories that Shulman identified, pedagogical content knowledge (PCK) was a new idea to those studying teachers' instructional knowledge. PCK described the blending of content knowledge and pedagogy to address the ways teachers organized and adapted their instructional content to meet the needs of the diverse learners in the classroom (Shulman, 1987). PCK is what differentiates an expert teacher from a subject matter expert (Cochran et al., 1993). While it includes the most commonly taught topics in a subject area, PCK also consists of recognizing the most effective ways that teachers can represent that content to students and the alternatives that would allow teachers to address misconceptions and alternative learning approaches (Shulman, 1986). PCK emphasized the intellectual rather than behavioral aspects of teaching (Shulman, 1986), and this focus allowed for continued research that refined the understandings of PCK.

Many scholars have worked to improve Shulman's theory; particular emphasis was placed on the impact of PCK in the development of teaching supports (Depaepe et al., 2013). Grossman (1989), one of Shulman's colleagues at Stanford University, identified PCK as being defined by four key central components: knowledge of student's understanding and potential misunderstandings, knowledge of curriculum, knowledge of instructional strategies, and knowledge of the purpose for teaching. To align PCK with the constructivist perspective, Cochran et al. (1993) redefined the concept as pedagogical content knowing's, shifting thinking from the conceptual understanding to identifying the skills teachers need to support students in constructing their knowledge. PCK is an essential skill for all teachers, regardless of the subject they teach. Still, PCK is nuanced within different subjects, and this has led to much research identifying how PCK would present in various content areas (Depaepe et al., 2013).

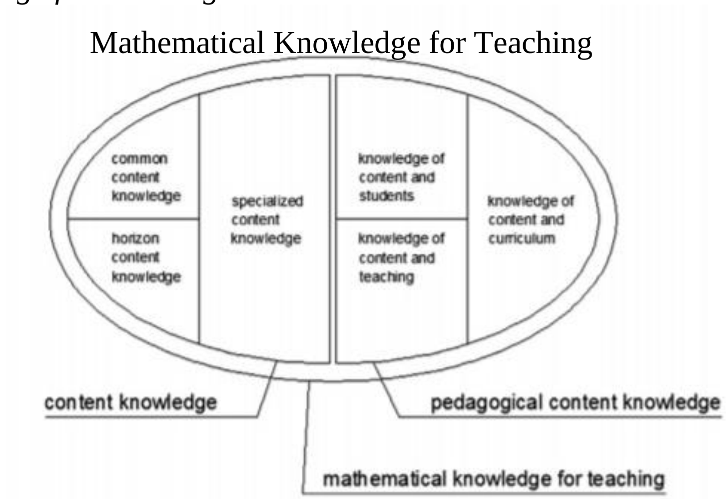
Mathematical knowledge for teaching (MKT) results from the work done by Ball et al. (2008) to apply the theoretical framework of PCK to mathematics teaching. The mathematics knowledge essential in supporting the teaching of mathematics is specialized and detailed in ways that are unnecessary for mathematicians or everyday tasks (Ball et al., 2008; Hill & Ball, 2009). MKT consists of four domains that address how "good teachers know both content and how to 'get it across' to their students" (Hill & Ball, 2009, p. 68). Identified below are the four domains that make up MKT:

- common content knowledge, the knowledge of math needed for outside of teaching;
- specialized content knowledge, the subject matter knowledge used in the acts of teaching;
- knowledge of content and students, the knowledge of how students will interact with the mathematics they are learning; and
- knowledge of content and teaching, the knowledge regarding how to tie the content to teaching practices to design the instruction they are providing students;

These four domains represent the combination of the differing types of knowledge to portray the understandings necessary to teach mathematics effectively. In addition to the descriptions of the four domains of MKT, Figure 1 provides a visual representation of how the four domains work together to represent MKT.

Figure 1

Mathematical Knowledge for Teaching



Note. From "Pedagogical content knowledge: A systematic review of the way in which the concept has pervaded mathematics educational research." by F. Depaepe, L. Verschaffel, , & G. Kelchtermans. (2013). *Teaching and Teacher Education*, *34*, p.14. (https://doi.org/10.1016/j.tate.2013.03.001)

MKT offers a way to make sense of the many layers of knowledge available for a teacher to teach mathematics effectively. Understanding a teacher's path as they develop this knowledge and utilizing it in their lesson design is a key component of what this study looks to investigate. MKT will serve as a theoretical framework used to situate this study.

We Know What It Is. What's Stopping Us From Utilizing It?

While there is consensus in the literature about what effective mathematics instruction looks like, there continues to be a misalignment between the knowledge of effective practices and their implementation in mathematics classrooms across the United States (Anderson et al., 2018; Darling-Hammond, 2006; Shulman & Shulman, 2009). A review of international data shows that students in the United States do not demonstrate levels of understanding that match their international peers. Students in mathematics classes across the United States experience mathematics as a series of exercises completed by following a set of steps or procedures

(National Research Council, 1999), with little attention to understanding the concepts that these procedures are built upon. This instructional approach is problematic since engaging with mathematics in this manner prevents learning mathematics in a way that develops a student's ability as a mathematical thinker (Schoenfeld, 2016). A closer look at the day-to-day actions of mathematics teachers indicates that, despite being provided opportunities to learn MKT, there is a disconnect in the implementation of MKT practices. A shift in instructional practices requires more than just exchanging old knowledge with new understandings; it requires analysis and reflection on the disconnect between the practices (Anderson et al., 2018). Ball and Forzani (2009) state that teaching is unnatural and intricate, reinforcing teachers' need to develop their teaching practices. How do teachers make sense of the MKT and the PCK they must develop to be an effective mathematics teacher?

Resistance to Implementation

Picture a mathematics teacher clinging to traditional instruction methods, ignoring SCIP for the comfort and assumed reliability of the techniques they experienced as a student and have replicated as a teacher. When discussing the failure to implement SCIP, the image previously described is what most people conjure. The "resistant" teacher often shoulders the blame for the inability to shift mathematics instruction in a manner that creates math classrooms that address the inequitable and inconsistent student experiences with math instruction. This placement of blame has allowed education systems to stall discussions regarding institutional disparities in mathematics education by shifting the focus on classroom teachers (Valoyes-Chávez, 2018; NCTM, 2020). Research has indicated many reasons that teachers are resistant to implementing SCIP. Often, a resistant teacher is viewed negatively and as incapable of learning a new instructional practice due to a lack of skill or ability. While lack of knowledge and skill impact implementing SCIP (Battista, 1999; Geijsel & Meijers, 2005; Rickard, 2005; Valoyes-Chávez, 2018), it is not the only factor impacting the implementation of SCIP.

Reasons Other Than Lack of Skill and Knowledge

The way that a teacher views the discipline of mathematics can impede their ability to make sense of and implement SCIP. Teachers who view mathematics as sequential or fact-based can find the implementation of SCIP to create cognitive dissonance with how they understand and use mathematics as an individual (Horn, 2007; Rickard, 2005; Weldeana & Abraham, 2013). Another factor that impacts implementation is how a teacher views the abilities of those who are learning the mathematics taught. Anderson et al. (2018) state that a teacher who believes in a “math gene” or “math people” can struggle to implement SCIP with the diverse learners in their classrooms. While opportunities to develop knowledge can address some of these issues, merely providing knowledge development opportunities is not enough to handle the entirety of barriers that exist when implementing these reform-based practices (Geijsel & Meijers, 2005).

Learning is one way we form our identities; what we know becomes a way to understand who we are (Geijsel & Meijers, 2005). Langer-Osuna (2017) identifies that SCIP force a shift in the traditional authority roles in a classroom, requiring a change in beliefs about the role of a teacher to implement SCIP. SCIP position the study of mathematics as something different than the rules, procedures, and structured tasks that many math teachers experienced success with as they developed their mathematical understandings. This shift in the definition of what it means to understand mathematics can cause many teachers to question their abilities as mathematicians, at times challenging their identity as an individual, teacher, and mathematician (Langer-Osuna, 2017). In addition to how teachers view themselves as individuals, how a teacher sees themself belonging to the larger organizational structures of a department, grade level or school can play a role in how a teacher takes on the implementation of SCIP (Craig, 2006; Horn, 2007; Rickard, 2005; Spillane et al., 2017). Conflicts with aspects of an individual's identity are reasons for teacher resistance to implementing SCIP. To understand an individual's resistance to the implementation of SCIP requires a more detailed understanding of an individual's personal experiences and understandings.

Making Sense of Instructional Practices

Another theoretical framework utilized in this study is sense-making. Sense-making ascertains that humans are part of a world that they do not entirely understand. The act of sense-making is the process that individuals utilize to examine the underlying phenomenon in a situation, to resolve a gap or inconsistency in their understanding (Dervin,1983; Dervin, 1998; Odden & Russ, 2018; Ganon-Shilon & Schechter, 2016). Teachers are engaged continuously in sense-making as they design lessons and select instructional practices to utilize in their classrooms. The act of sense-making is an ingrained part of daily living that is easily taken for granted (Weick et al., 2005), warranting it as a tool for use in this study to understand teachers' use of SCIP.

Sense-making is a three-part reticular process that allows an individual to infer meaning in a situation (Ganon-Shilon & Schechter, 2016; Weick, 1995). These three processes are creation, interpretation, and enactment. Ganon-Shilon and Schechter (2016) define these three processes as follows: creation is the identification of the event that does not align with expectations in that situation; interpretation is where the individual tries to explain or interpret the event; and enactment is the use of the explanation to return to a state of alignment with an individual's understanding. Despite the brevity implied by a three-step process, many factors impact how an individual makes sense of a situation. Weick (1995) identified seven properties of sense-making:

- Sense-making is grounded in identity construction.
- Sense-making is retrospective.
- Sense-making is enactive of sensible environments.
- Sense-making is social.
- Sense-making is ongoing.
- Sense-making is based on extracted cues.
- Sense-making is driven by plausibility rather than accuracy.

While these seven properties are not linear, they can be utilized as a guideline as one looks deeper into a teacher's act of sense-making (Weick, 1995). When using sense-making as a framework for understanding how teachers develop their MKT, it is vital to keep in mind that sense-making is not about truth or accuracy but the continued redevelopment of practice until it becomes more comprehensible for the individual (Weick et al., 2005).

For humans to "fill their gaps" and make sense of new knowledge, there has to be a shift away from the traditional means of communicating knowledge as a one-way route from teacher to student (Dervin, 1983; Dow et al., 2015). When teachers develop their MKT, they are looking to fill the gaps in the knowledge needed to teach mathematics effectively. Sense-making requires building from your prior knowledge (Warren, et al., 2001). To make sense of new learning, we try to align new knowledge with something we already understand. With complex concepts or alternative understandings, we may not have the prior knowledge to build upon (Oden & Russ, 2018). Dervin (1998) states there is an "intertwined connection between how you look at a situation and what sense of it you are able to construct" (p. 39). Making sense is not just a simple act of absorbing the information transmitted, but a personal act of interpreting the situation on your terms (Dervin, 1983). When teachers try to develop their MKT, the procedural foundation they built as a student is the prior knowledge; they are using to personalize their understanding. This procedural knowledge may not provide enough of a foundation to support them in making sense of the conceptual understandings necessary to facilitate mathematics learning. Teachers have difficulty with shifting instructional practices (Cohen, 1990). What we make sense of is not likely ready for application immediately (Dervin, 1998), which reinforces the gap between a teacher's understanding and implementation of the instructional practice.

Time is of the essence when considering sense-making. Geijsel and Meijers (2005) identify that much of the professional learning needed to support teachers must be done in the classrooms. Developing an instructional practice as a part of a teacher's repertoire takes time. Also, the use of these practices requires a sense of emotional safety. Taking risks and trying new approaches create points of vulnerability for educators. These are just a few of the multiple layers that combine to make the whole picture of how a teacher develops the tools necessary to design effective instruction.

A key idea for teaching mathematics is building upon the relationship between procedural and conceptual understandings, allowing students to connect the how with the why (NCTM 2014). For a student to understand the procedure they are learning, that procedure must build from the conceptual understandings they have developed for themselves (Kajander, 2010). To support students in this type of learning, teachers must develop their conceptual understandings of the mathematics they teach and the instructional tools they utilize in that instruction. Developing the instructional practices that facilitate this learning can be difficult for teachers who have not effectively built the conceptual understanding around the mathematics content they teach. Many teachers experienced learning mathematics in a very traditional manner. As a result, the foundations upon which their mathematical knowledge is built may not be conceptual, meaning teachers' prior knowledge to make sense of conceptual understandings will likely be procedural. One has to wonder, are conceptual understandings and constructs built off of procedural understandings still procedural in nature?

Additionally, if a teacher makes sense of MKT utilizing a procedural foundation, what impact does that have on the MKT used in the classroom? Developing a classroom that supports these types of instructional exchanges requires teachers to be aware of many things outside of just the content presented that day in class (Ball & Forzani, 2009; Darling-Hammond, 2006; Hill & Ball, 2009; NCTM, 2014). With so many responsibilities, teachers can find it difficult to designate the time needed to develop these conceptual understandings independently. Instead, teachers review what they think they need to demonstrate conceptual understanding and facilitate the next steps in the lesson to advance to using the procedure. This response to a shortage of time dismantles the opportunity to build procedural fluency from conceptual understandings (NCTM, 2014), so neither the student nor the teacher makes an authentic connection between mathematical thinking and the skills utilized.

Classrooms where students share authority for learning with the teacher lead to greater conceptual understanding for students (Langer-Osuna, 2017). Shared authority comes when a teacher is comfortable with their role in the classroom. When a teacher does not feel confident in their classroom role, they can be uncomfortable sharing their authority for fear of losing control of the classroom (Jarvis, 2016). This shift in a teacher's view of their authority creates a scenario where a teacher's lack of conceptual understanding impacts their classroom management decisions, doubling the decrease in opportunities for students to develop their conceptual understandings. Learning new instructional approaches is difficult; it usually requires a shift in the individual’s identity (Anderson et al., 2018; Geijsel & Meijers, 2005; Stipek et al., 2001). When individuals are at a disequilibrium point, they tend to regress to what they are most comfortable with (Elliot et al., 2013). Teachers who are feeling disequilibrium around the conceptual understandings they are trying to develop with students may apply their prior procedural thinking processes to provide structure and balance the dissonance felt as they weave their understandings in with the new knowledge.

Definition of Terms

The desire to increase student’s achievement in mathematics has generated a substantial body of research regarding mathematics teaching and learning. This research has identified many key ideas and components of mathematics instruction. The definitions of some key practices and concepts addressed in this study are below:

- *Conceptual Understanding:* Conceptual understanding is when a student knows more than isolated facts and methods but has made sense of mathematics in a way that allows the application of that knowledge in a new situation. An understanding of and connection between concepts, operations, and relations (Findell et al., 2001).
- *Instructional Practices*: Instructional practices are the tools and methods utilized by teachers as they design lessons that engage students in understanding the presented mathematical concepts. Instructional practices are designed to uncover meaning and provide opportunities for problem-solving and sense-making as students engage in mathematics (Findell et al., 2001; Hill & Ball, 2009).
- *Mathematical Discourse:* Mathematical discourse is whole-class or small group discussions in which students talk about mathematics in such a way that they reveal their

understanding of concepts. Student thinking should drive mathematical discourse, while facilitated by teacher questioning, mathematical discourse should be student-centered (Smith & Stein, 2018).

- *Mathematical Identity:* Mathematical identities are personal narratives about mathematics learning and experiences that allow the individual to identify as a certain kind of mathematics user (Larnell, 2016).
- *Mathematical Thinking:* Mathematical thinking is the ability to make sense of a situation mathematically and apply mathematics tools to understand the structure of the problem (Schoenfeld, 2016).
- *Problem-Solving*: Problem-solving is when students are engaged in solving and discussing tasks that promote mathematical reasoning. Usually, the work of problem-solving involves tasks that allow for multiple entry points and varied solution paths (NCTM, 2014).
- *Procedural Fluency*: Procedural fluency is when a student can choose flexibly among methods and strategies to solve mathematical problems, explain their approaches, and produce accurate answers efficiently (NCTM, 2014).
- *Professional Learning Community (PLC):* A PLC is a group of people sharing and critically interrogating their practice in an ongoing, reflective, collaborative, inclusive, learning-oriented, growth-promoting way (Stoll et al., 2006).
- *Student-Centered Instructional Practices (SCIP):* SCIP are instructional practices that keep student thinking at the center of instructional decision making (Wilson et al., 2015: NCTM, 2014).

- *Teacher Centered Instructional Practices:* Teacher centered instructional pare instructional practices that involve review, demonstration, and practice. Sometimes referred to as traditional teaching (NCTM, 2014).

The regular use of the terms above can lead to varying definitions and understandings. The definitions identified here provide a calibration of meaning between the researcher and the reader.

Summary

This literature review has discussed how the concept of PCK is essential in defining what knowledge is necessary for teachers to design effective instruction. The work of Ball et al. (2008), has provided a more in-depth analysis of what PCK looks like in a mathematics classroom through the theoretical framework of MKT. Despite the knowledge of MKT, consistent evidence of instruction in mathematics classrooms that aligns with the eight instructional practices identified by NCTM is not evident. The literature supporting sense-making theory identifies areas of concern regarding how teachers make sense of their MKT and utilize it to implement the instructional practices identified by NCTM. Mathematical identity, mathematical understandings, and personal experiences all impact how an individual makes sense of a situation. This study looks to understand how these concepts might influence a teacher as they make sense of their MKT and the SCIP utilized in their classrooms.

Chapter Three: Methodology

In this study, I examined secondary mathematics teachers' experiences and the way those experiences connect to how teachers include and implement student-centered instructional practices (SCIP) in the lessons they design. Much initial research regarding teacher resistance to implementing SCIP cites a lack of teacher knowledge or skill (Battista, 1999). That research has informed a shift toward developing pre-service teachers' knowledge of SCIP as a part of the experiences provided in their university program. The identification of standards, such as those communicated by the National Council for Accreditation of Teacher Education (NCATE), has shifted teacher preparation programs' work to focus more on conceptual understandings as a part of the knowledge necessary to prepare teachers for the classroom (Diez, 1998).

For those who have already completed their teacher certification programs, professional teacher organizations have worked to design standards of practice and professional development experiences that support teachers as they continue developing their knowledge (National Board for Professional Teaching Standards [NBPTS], 2016; NCTM, 2014; NCSM, 2008). These experiences provide teachers with the knowledge and skills necessary to build their understanding and increase their use of SCIP in their classroom instruction. Despite this work, there continues to be an implementation gap, in secondary mathematics classrooms, regarding the use of these SCIP (Buchbinder et al., 2019). Hence the question, what else could be hindering the implementation of these practices? This work aims to understand the factors that impact a teacher's development of their mathematical knowledge for teaching (MKT) and the implementation of SCIP in their classrooms. MKT is the specialized mathematical knowledge that is necessary to teach mathematics. MKT is different from the mathematical knowledge that is needed by mathematicians or for an individual's completion of everyday tasks (Ball et al., 2008; Hill & Ball, 2009).

Research Questions

In this study, I address what knowledge is necessary for teachers to design and deliver effective mathematics instruction. Pedagogical content knowledge is a complex and subject-specific set of essential understandings that enable teachers to support students in making sense of the content they are learning (Ball & Phelps, 2008; Shulman, 1987). A research study's design is determined by the questions the study is trying to answer (Vollstedt & Rezat, 2019). Is there a connection between the way teachers learn the math they are teaching and how they learn the instructional practices they utilize in their classrooms? If so, does an experience learning in a procedural manner mean that a teacher is more likely to use procedures to learn about teaching mathematics? How does a teacher's mathematical identity impact their choices in designing instruction? This study aims to understand how teachers make sense of and implement SCIP. This study addresses the following research questions (a) How do teachers understand the student-centered instructional practices they implement in their classrooms? and (b) How do teachers experience the implementation of student-centered instructional practices?

Research Design

Effective qualitative research guarantees that the participant's voice remains in the data, and it is the researcher's responsibility to communicate that voice as accurately as possible (Atkins & Wallace, 2012). While quantitative research is more deductive, qualitative research is inductive, employing data to establish themes or theories (Clark et al., 2011). To understand teachers' actions, it is vital to accurately and thoroughly listen to the stories that they share.

These stories are the data necessary to illuminate recurring themes that will bear the weight considered as evidence for the study (Atkins & Wallace, 2012). Since this study involved human subjects, the researcher sought approval for the study through the human subjects review committee at Eastern Michigan University. The approval documentation for this study can be found in Appendix A.

This qualitative research study was conducted utilizing the method of grounded theory. Grounded theory is a research approach where the primary purpose is to generate theory based on the observations and data collected via traditional qualitative methods (Baker et al., 1992; Creswell, 2013; Lichtman, 2011; Marjan, 2017). Charmaz and Thornberg (2020) state that grounded theory research shows the connections between actions and their meanings to make a process explicit. This study aims to discover and analyze the elements that contribute to a teacher's implementation of SCIP. Grounded theory research focuses on the meaning made by individuals as they engage in different actions and phenomena (Flick et al., 2014). Grounded theory was developed by Barney Glaser and Anselm Strauss in the late 1960s. Since then, many approaches to grounded theory research have been developed; some are Glasserian, Straussian, constructivist, and postmodern (Charmaz, 2006; Charmaz, 2014; Charmaz & Thornberg, 2020).

This study looks at secondary mathematics teachers' experiences to determine how these experiences impact how teachers develop their instructional knowledge. Despite numerous studies regarding teachers' inability to implement SCIP effectively, there continues to be an implementation gap (NCTM, 2020). Baker et al. (1992) state that the purpose of using grounded theory as a methodology is to explain a situation by identifying the processes operating to discover "what is going on." The purpose of grounded theory research, as stated by Baker et al. (1992), aligns with this study's research goal of understanding how secondary mathematics teachers' experiences impact the implementation of SCIP in their classrooms; this reinforces the decision to utilize grounded theory in this study.

Identifying Participants

Purposeful sampling provides an opportunity to explore the iterative relationship between sampling and analysis while conducting research (Rapley, 2014). The target population of this study is secondary mathematics teachers who currently teach math in a public middle or high school in Southeast Michigan and Metro Denver, Colorado. Due to the nature of qualitative studies, the sampling plan is unlikely to be random (Clark, 2011; Rapley, 2014). Participation in this study was voluntary, with participants self-selecting to be a part of the study. Potential participants were solicited via email through building contacts, county-wide educator newsletters, and local professional teacher organizations. This study was conducted during the 2020-2021 and 2021-2022 school years. During this time, educators had to manage many health, safety, and emotional responsibilities in addition to the educational needs of students. In addition to these stressors, educators were dealing with emotional turmoil in the wake of a school shooting. The events during the two school years this study was conducted took their toll on teacher energy, taking many to a breaking point (Kiertzner, 2021). My initial plan was to include participants from Southeast Michigan; however, the current school environment impacted my ability to recruit only Michigan teachers. Due to the need to address COVID safety precautions, the interviews and classroom observations for this study were conducted virtually. The virtual nature of this design unintentionally removed the travel limitations the original focus on participants from Southeast Michigan was designed to address. This ability to meet virtually provided an opportunity to open the study beyond Southeast Michigan, increasing the number of study participants. To utilize my professional networks, the study locations were extended to include participants from Colorado, specifically the Metro Denver area. Participants were self-selected for the study based on their responses to previously mentioned solicitations. The study consent form can be found in Appendix B. I relied on my professional networks and the contacts made through participants to recruit participants who matched the study criteria. Rapley (2014) states that sampling needs to be thoughtful and rigorous to collect data that communicates the "rich perspective" that is the goal of qualitative research. The recruitment letter used for this study can be found in Appendix D. This study consisted of 12 secondary mathematics teachers. When this study was conducted, all participants taught a secondary mathematics course in a public middle, junior, or senior high school. Of the 12 participants, four taught at the middle school level, Grades 6–8; two taught at the junior high school level, Grades 8–9: and six taught at the high school level, Grades 9–12. Years of teaching experience among participants ranged from 9 to 38 years. See table 3.1 for participant information.

Table 1

Study Participant Information

Pseudonym	Gender	Race	Years Teaching	Grade Level Middle School (6- 8) High School (9-12) Junior High (8-9)	Course Observed
Angela	F	White	22	High School (9-12)	Algebra 1
Midge	F	White	38	Middle School (6-8)	Math 7
Olivia	F	White	13	High School (9-12)	Geometry
Jack	M	White	10	High School (9-12)	Summer School (Pre-Algebra)

Table 1 continued

Pseudonym	Gender	Race	Years Teaching	Grade Level Middle School (6- 8) High School (9-12) Junior High (8-9)	Course Observed
Meggin	F	White	9	High School (9-12)	Algebra 1
Alyssa	F	White	17	High School (9-12)	Geometry
Matt	M	White	25	Junior High (8-9)	Algebra 2
Sarah	F	White	27	Junior High (8-9)	Algebra 1
Neil	M	White	17	Middle School (6-8)	Math 8
Jeff	M	African American	27	High School (9-12)	Algebra 1
Andrea	F	White	28	Middle School (6-8)	Math 6
Jenny	F	White	23	Middle School (6-8)	Math 8

Note. All Participant names have been changed to preserve anonymity.

Information regarding participant school demographics and percent of students identified as economically disadvantaged can be found in Appendix D.

Interviews

The purpose of this research study is to analyze the role of a teacher's experiences and understand how those experiences play into the interpretation of SCIP. This study involved two interviews conducted before and after classroom observation. This study utilized the semi-structured interview format. A semi-structured interview does not follow a complete script, allowing for versatility and flexibility (Kallio et al., 2016; Myers & Newman, 2007). This semi-structured design guarantees uniformity of questions yet provides the ability to follow up or encourage elaboration based on a participant's response and coding. Identifying key questions for the interview allowed the researcher to provide uniformity among the data collected from all participants but also kept the focus of the interview broad enough so that the questions did not inhibit what was seen by the researcher (Anzul et al., 1991). With this study's purpose in mind, I conducted interviews with participants by posing prompts that revealed the participants' experiences as teachers. Some examples of these prompts are "How would you describe yourself as a math student?" "Tell me about a time you learned a new math concept," and "Tell me why you chose to be a math teacher." Additional questions regarding how teachers internalize their teaching practices were also a part of the interview. Some examples of those prompts are "How are the ways you teach math similar to and different from the ways you were taught math as a student?" "Tell me about a time that you learned a new instructional practice," "After reviewing the eight instructional practices, tell me about your experiences with implementing these practices in your classroom." The interview protocol can be found in Appendix E. Interviews were conducted via Zoom. Each interview lasted approximately 45 to 75 minutes.

Data analysis is iterative (Rapley, 2014), yet data collection, analysis, and theory development are not successive; these actions are intertwined and woven together (Vollstedt &

Rezat, 2019). The second interview was conducted following the classroom observation to create opportunities to gather data in this iterative and interwoven way. This second interview provided the opportunity to ask any follow-up questions identified upon the review of the first interview. The second interview also offered a chance to ask specific questions about the instructional practices utilized during the classroom observation. Examples of these prompts are "During the lesson I observed, I noticed you _____ (identify an instructional practice witnessed during the classroom observation); tell me how you developed that practice as a part of your teaching practice?" and "What makes you want to try a new instructional practice in your classroom?". These questions provided clarification and additional data to inform this study.

Classroom Observations

In addition to participant interviews, classroom observations provided additional data for this study. "The most essential means of gathering ethnographic data are looking and listening" (Anzul et al., 1991); conducting classroom observations as a part of this research study provides a means of looking and listening to the instructional practices that are occurring. Wolcott (2005) states that participant observation is a broad term that includes many qualitative data collection techniques. By observing classroom instruction provided by teachers participating in the study, data was gathered regarding the general instructional practices that were discussed during the interviews. In addition, classroom observation created an opportunity to observe the subtle details in classroom instruction, which supported the work of making the invisible visible (Marvasti, 2014). Interviews with the participants created an opportunity for the researcher to listen to the participant's experiences and see their instructional understandings through their personal lens. Still, these interviews lacked the opportunity to view these instructional practices in action (Caldwell & Atwal, 2005). To address this omission, the researcher observed a math lesson in each participant's classroom. Marvasti (2014) states that observations from the field are a tool to provide insight into the milieu that is a part of how individuals describe themselves and their actions. Guba and Lincoln (1989) state that when conducting qualitative research, one difficulty is identifying what is truly a part of what is being studied and what is presented for the observer's benefit. In this study, classroom observation will serve as an opportunity to locate some of these instances in the collected interview data. In addition, the classroom observations provide a specific example of instructional practice usage that can be explored during the second interview. This data offers material for a focused discussion regarding how participants built the practice into their instructional repertoire, targeting specific experiences to collect rich data that represents the nuanced experiences shared by participants. Classroom observations in this study provided data that informed interview questions and prompts that led participants to discuss how they arrived in their environments and identify the structures that impacted their pursuits (Fitzgerald & Mills, 2022). Each classroom observation lasted for the entire duration of the class period which was observed, approximately 55–90 minutes.

Many considerations need to be considered when utilizing participant observation in research. One of those considerations is the researcher's role as a participant observer. Participant observer roles range from a fly on the wall to being fully immersed as a participant in the phenomena that are being observed (Anzul et al., 1991). These roles range from those with little to no interaction with what is being observed to those who have some interaction with the group in terms of trust and exposure, and finally, those who are fully embraced by a group and play a part in what is being observed (Wolcott, 2005). Wolcott (2005) identifies three participant-observer styles: active participant, privileged observer, and limited observer. In this study, the researcher took on a limited observer's role; I did not engage with the participant in any other role than to observe and ask questions. As the researcher, I had no outside relationship with the participants that could impact their focus during the observations. The lesson observation took place between interviews, allowing the researcher to ask any necessary follow-up questions regarding the lesson during the second interview, allowing the researcher to guard against divorcing the interview from the rest of the data-gathering experience (Anzul, et al., 1991). Three phenomena that can impact qualitative studies of this type are the Hawthorne effect, the Heisenberg effect, and the Observer effect. Salkind (2010) identifies that the Hawthorne, Heisenberg, and Observer effects describe the ways in which the observation itself can impact observations of a phenomenon. The varied approach to gathering data utilized in this study is meant to provide the researcher with data that minimizes these effects' potential impact while providing an authentic expression of how participants make sense of instructional practices.

Analysis

To identify and delineate the complex set of skills and knowledge that will be documented during the lesson observation and discussed during the interviews, the mathematical knowledge for teaching framework will be utilized as a part of this study. The MKT framework supports the identification and categorization of teaching knowledge data collected during the study. Also, sense-making theory (SMT) frames the data regarding the development of a teacher's understanding of SCIP. MKT and SMT were used to support the analysis of the data collected regarding the research questions in this study.

Classroom Observation Framework

Utilizing an observation framework allows for identifying foundational "look-fors" (Boston et al., 2015; Praetorius & Charalambous, 2018); this practice enabled the researcher to compare observation data among multiple classrooms. The Teaching for robust understanding in Mathematics (TRU Math) framework was the observation tool used for this study. The TRU Math framework's design identifies equitable and robust teaching practices while observing a mathematics lesson (Kaiser & Presmeg, 2016; Schoenfeld et al., 2016). The Mathematics Assessment Project (MAP) uses the TRU Math framework as part of its professional development resources. The TRU Math framework provided benchmarks for identifying five domains of powerful classrooms. The five domains addressed in the TRU Math framework are (a) content, (b) cognitive demand, (c) equitable access to content, (d) agency, ownership, and identity, and (e) formative assessment (Schoenfeld et al., 2016). Inside these domains is evidence of the eight instructional practices researched and communicated by NCTM as practices that will improve student mathematical understandings. The TRU Math framework provided a 3-point rubric with descriptors of what each of those dimensions looks like in differing instructional settings (e.g., whole-class activities, small group work, student presentation), allowing the tool to align with the type of instruction that is being observed. The TRU Math framework observation rubric protocol can be found in Appendix F.

Data Analysis Procedures

Grounded theory guided the data analysis and theory identification in this study. Using grounded theory to inform data analysis is best done when the research aims to explain and predict choices and behaviors in social interaction (Volstedt & Rezat, 2019). Delve Qualitative Analysis Tool was used for coding and analysis. For each participant in this study, there were three data collection points: the initial interview, classroom observations, and the second interview. Initial coding was completed for all of a participant's data upon completion of the second interview. This engagement in initial coding allowed for a close look at the data and the opportunity to mine the data in a way that allowed for the recognition of analytic ideas that could be pursued with future participants during data collection (Charmaz, 2014). In addition to coding, I also engaged in memo writing throughout the data collection and analysis process. Completing initial coding in this manner allowed for the data analysis to align with the data analysis structure shared by Charmaz (2014) that grounded theory methods should be iterative, comparative, and interactive. Upon completion of the initial coding, focused coding was conducted utilizing the initial codes identified across interviews, identifying more conceptual codes to advance the work's theoretical direction (Charmaz, 2014). Theoretical coding was completed using the focused codes. The theoretical codes identified during this phase became more coherent and comprehensible (Charmaz, 2014). The theoretical codes and memos written during the data collection and analysis process illuminated the four themes that informed the grounded theory that resulted from this study. The coding process also allowed for the identification of saturation. Categories are saturated when they are well developed, and further data gathering or coding no longer sparks new theoretical insights (Charmaz, 2014; Corbin & Strauss, 2008). The purpose of using grounded theory research methods, as stated by Marjan (2017), is to understand the factors that account for the behaviors of the people being studied. Using grounded theory for this research study provides an approach to understanding the factors that impact teacher behaviors regarding implementing SCIP.

Assumptions and Limitations

Assumptions are a part of all research projects, and it is essential to acknowledge these assumptions to benefit the credibility of a research study (Bryant, 2004). An assumption of this study is that how a person makes sense of and learns mathematics impacts how they understand and utilize instructional strategies in the mathematics lessons they design.

There are three limitations to this study. The first limitation of this study is the researcher’s background as a secondary mathematics educator. Anzul et al. (1991) defined bracketing as the work a researcher must do to make ourselves aware of preconceptions, assumptions, and beliefs to elucidate the observation data. As an experienced secondary mathematics educator, I must keep my experiences from entering the data. The second limitation is the sample size. Identifying sample size in qualitative research focuses not on quantity but on its richness (O’Reilly & Parker, 2012). The small sample size in this study allowed for more in-depth discussions with each participant, supporting the development of the thick description necessary to address and interpret the level of detail involved with human activity (Wiebe et al., 2010). While this smaller sample size allowed for detail and depth of interaction, it also has the potential to miss essential stories. Purposeful sampling was utilized to address this limitation. Purposeful sampling allowed the researcher to choose the participants representing the population’s variation (Rapley, 2014). Adequate representation is a goal in any study; a small sample size decreases the likelihood of achieving that goal. Finally, the participant’s ability to self-select their participation, even with efforts to include a variety of secondary schools, increased the possibility that all secondary mathematics teachers’ subgroups are not represented.

Summary

Connecting a teacher’s experiences to their understanding and use of instructional practices is the focus of this study. SMT and MKT will organize and describe the data collected as a part of this work. Using a qualitative approach, specifically grounded theory, I interviewed twelve secondary mathematics teachers’ regarding their experiences as a mathematics teacher and their use of SCIP in their classrooms. In addition to interviews, I also observed a mathematics lesson taught by each participant. The results of this study identify ways to support teachers in developing their understanding and knowledge regarding SCIP and will be discussed in the following chapters. A deepened understanding of this relationship will inform ways to support teachers in adopting these instructional practices, supporting the closing of the implementation gap that exists across secondary mathematics classrooms.

Chapter Four: Research Findings

For many teachers, the way they experienced mathematics as a student did not involve a focus on student-centered instruction. As teachers look to build understanding and the ability to implement student-centered teaching practices in their classrooms, teachers with a traditional mathematics experience are unable look to their own student learning experiences as examples to build their practice from. Student-centered instructional practices (SCIP) have been slow to weave themselves into the everyday practice of mathematics teachers (NCTM, 2014).

SCIP practices keep student thinking at the center of instructional decision-making (Wilson et al., 2015: NCTM, 2014). These practices focus instruction on how students think about and solve problems. Instruction designed in a student-centered manner focuses on building mathematics knowledge through active engagement with content. This engagement builds student understanding through personal experiences and feedback from peers, self-reflection, and adults (NCTM, 2014). This focus puts the teacher in the role of a facilitator supporting students in building their mathematical understandings. When viewed as the holders of mathematical knowledge, students are provided the opportunity to engage in mathematics learning that builds their mathematical identity and agency. A focus on student-centered instructional practices is a significant shift from the teacher-centered methods utilized in what is often referred to as traditional mathematics. These teacher-centered practices put the teacher's thinking at the center of instruction, making the teacher the keeper of the classroom's mathematical knowledge. Teacher-centered instructional practices often emphasize memorizing facts and formulas, applying procedures, and practice (NCTM, 2014). One example of teacher-centered practice is gradual release, commonly referred to as I do, we do, you do. In this model, teachers tell students the math knowledge they need master through lecture or note taking. Students then practice a few similar problems as a whole class, followed by practice problems students work independently. To meet the needs of the varied learners in any classroom, mathematics teachers need a diverse and plentiful repertoire of instructional practices. The types of instructional practices that teachers choose to develop as a part of their repertoire varies from teacher to teacher.

This study aims to look at the connection between a teacher's learning experiences as a K-12 mathematics student and their implementation of student-centered teaching practices. In order to determine what impacts these experiences have on the ways teachers make sense of and implement instructional practices that support student learning, I conducted a qualitative study of twelve secondary mathematics teachers over the 2020-2021 and 2021-2022 school years. The research questions that guided this study were as follows:

1. How do teachers understand the student-centered instructional practices they implement in their classrooms?

2. How do teachers experience the implementation of student-centered instructional practices?

Data gathered from teacher interviews and classroom observations informed the discussions in Chapters Four and Five.

Chapter Outline

In this chapter, I outline the four themes that resulted from analysis of the data in this study. These themes are as follows:

- Shifts in instructional practices are prompted by disequilibrium between procedural mathematical knowledge and an individual's identity.

- Instructional practices are driven by an individual’s belief in the purpose for learning mathematics.
- Shifts in instructional practices are not done in isolation.
- Modeling, student-centered instructional practices allow teachers with procedural backgrounds to connect the practices to their learning experiences.

The findings shared in this section are based on coding and analysis of the interview sessions and classroom observations for all the study participants. The excerpts shared in this section are used to elucidate the themes that emerged as a result of data analysis. Participant names and other identifying information have been changed to preserve anonymity.

Math Let Me Down

The first theme for discussion is the following: Shifts in instructional practices are prompted by disequilibrium between procedural mathematics knowledge and an individual’s mathematical identity. Larnell (2016) identifies mathematical identity to be a personal narrative about mathematics learning and experiences that allow the individual to identify as a certain kind of mathematics user. The participants in this study identified themselves as mathematicians. All participants communicated that being mathematically capable was part of the mathematical identity they had formed of themselves. Situations where this identity was challenged were recounted by nine of the twelve participants. As these instances were revealed, a pattern emerged among the stories.

In the experiences that were shared, after participants moved into their adult lives, either as an undergraduate or in their early teaching careers, participants came to a moment where their procedural understanding of mathematics failed them. This failure wasn’t an inability to solve a single math problem, but came in the form of recognition that what they saw as a strength in themselves was not enough. Olivia shared how she quickly became aware that her procedural understandings were not enough to support the students in her Remedial Math 7 class:

> Olivia: I thought I was a good math student, but now I realize I wasn't; I was a good memorizer, and regurgitator. I didn't realize that until I became a math teacher. If you show me how to do it a couple of times, I can repeat it. But I struggled with the application.
>
> CH: Do you have a clear memory of that realization?
>
> Olivia: Yep, it was my first job. When I used a curriculum, I was unfamiliar with. It wasn't like your traditional textbook but a write-in, workbook-type curriculum. It was very scripted. But the way they presented working with fractions and solving equations was different from what I remembered learning, it involved [using] manipulatives. I would call my [mathematical] learning what people think of as traditional or old school, so that made me realize that I needed to learn how to better understand the relationships between numbers to educate my students.

The inability to make sense of the manipulatives that were supposed to be tools to support students in developing their mathematical understandings was a key moment for Olivia. This moment, illuminated the need for Oliva to seek opportunities to build her understanding of number relationships. Andrea also shared that, although she identified as a strong mathematics student, she could identify times when her procedural mathematics knowledge failed her:

> Once I became a teacher, I realized how much my teachers taught me how to do a problem…A lot of the teachers that I had just avoided the word problems, or it was, okay, here's your 20, drill and kill type.

As she continued to share her experiences, she identified that this omission of word problems really impacted her when she entered college: "And when I got to college, I did a math minor. And I got to parts of calculus, where I broke the spine on that book real quick. Because it was all application." Andrea shared how this experience and her observation that her students were having struggles demonstrating their ability to solve application problems has informed one of her goals as a teacher:

> My professional goal is finding more real-life applications. For every unit, there's got to be more [real-life application problems] that are accessible to sixth grade, or that they [sixth grade students] could relate to. That's just my goal every year. So, every year when I get out our new unit, it's *okay, what can I add to it this year?* And I think that I'm continuously adding to things, but in a way that is making math more real. And more of a focus on problem solving, not drill and kill.

For participants who experienced this failure of their mathematics knowledge, this recognition placed many participants on a path that allowed them to identify what they were missing in their mathematical understanding, and then work to develop that as a part of their knowledge, in turn allowing them to maintain their identity as mathematicians. Neil describes the anger and frustration that came when his procedural mathematical understandings were not enough to complete his post-graduate, calculus-based Physics II class:

> I originally wanted to be a science teacher. And as I was in grad school, I couldn't pass calculus-based physics II because I kept making algebra mistakes, really basic algebra mistakes. And so, it was holding me back from completing some college courses, even though I had passed calculus. And so, I was pissed off. I mean, I was angry at the system, that I could make it through college and be working on my postgrad and not understand

> the basics of math. So, I went back and started taking math education classes for elementary school-aged kids. And that's where I fell in love with math, because I was like, I didn't know how much I didn't know. And when I was learning, I was like, this is a shame that someone like me can go through and not understand what's going on. So, I wanted to teach at the elementary or middle school level so that kids could get a real firm understanding of what they're doing mathematically. That's why I decided to be a math teacher. So, I gave up science altogether because I just fell in love with understanding math.

As participants described their reconciliation with the moment that their understanding failed them, they all came back to classroom practices. The way that they developed and expanded their understandings and rebuilt their identity as a mathematician, is reflected in the classroom practices they shared in this study. For them, this experience had placed a spotlight on the procedural practices that are a mainstay of their traditional mathematics education experience and pushed them to think about how to keep their students from having similar experiences. Alyssa spoke to this specifically:

> I think I had good teachers, but I understood it from the first example. The other examples were for somebody else, I still listened because I followed all the rules. But then I was done with everything quickly. But then I didn't know what I was doing when I got to college, where they expected me to think for myself and put together concepts. "When I was like, but what process do I follow for that problem?" And, they're like, "Well, you have to figure out what kind of problem it is first," "What do you mean, you're not going to tell me what kind of problem it is?" (pause) So, I'm fighting against that all the time, I don't want my students to feel lost when they get to those situations.

For the participants in this study, these experiences of identity reconstruction and reflection have provided an anchor for how they think about the instructional practices they use in their classrooms. Their desire being to build learning experiences that keep students from not only developing procedural understandings but also avoiding an experience where their students' mathematical understandings would fail them.

When Am I Ever Going to Use This?

The idea that a teacher's choice in instructional practices is driven by an individual's belief in the purpose for learning mathematics was identified during the review of the data in this study. Students often do not see a connection between mathematics and their lives. While students question the purpose of other secondary school subjects, the frequency in which students ask this about mathematics makes it an outlier. This coupled with the dislike, and anxiety that is felt by many students as they learn mathematics, often leaves students asking, "When am I ever going to use this?" How a teacher views the content that they teach impacts the ways that they respond to this inevitable question.

Two Types of Responses

Why do we learn algebra? Why do students have to know the quadratic formula when they can Google the answer? Inquiries like these, questioning the purpose behind mathematics content, often arise in mathematics classrooms. As a part of the interview, participants had the opportunity to share their experiences as students of mathematics as well as mathematics educators. In these discussions all participants spoke to what they believed was the purpose of learning and teaching mathematics. These beliefs fell into two categories. Participants in the first category described mathematics knowledge as a pursuit or a tool for life; an important part of the skills that students need to engage with the world. Participants in the second category shared that learning mathematics served more as a means to an end.

Mathematics as a Tool for Life. Participants shared that while some mathematical skills are essential for surviving outside of school, there was also a belief that mathematics served as a tool to interact with both the academic and non-academics parts of the world. For these participants, mathematics served as an important tool for supporting students in the development of thinking, communicating, and problem-solving skills that go far beyond the formulas and functions that exist in textbooks. Midge described this when she talked about the teaching that goes on in her classroom: “I really do feel this is teaching, that these are life skills, more so than math.” Midge and other participants described their approach to teaching mathematics as one that exposed students to mathematics course work that was built on more than facts and procedures.

Mathematics as a Means to an End. The participants in this category held the belief that the bulk of secondary mathematics topics had little impact for individuals outside of school and that mathematics courses served more as a way to demonstrate that an individual was ready for the next step or challenge that they were working toward. Meggin highlighted this when she shared how she responds to students when they ask, “When am I ever going to use this?”:

> I taught pre-calc and I taught calculus, and I got the question a ton less in those classes. I think those students understood that calculus itself wasn’t going to be applicable unless you are going into some kind of engineering field, but that they needed it for some kind of prerequisite and they were also proving to colleges that they could take a rigorous course and do well.

When Jeff discussed how he responded to student's who ask the question "When am I ever going to use?" His focus was on the problems that were in the packets he had given the students. His response focused on telling students what they could solve once they completed the practice he provided:

> Well, here's a problem. Or here's a series of problems. This is when you use this type of math, this is why we use this, why people find the slope of the line, they're trying to solve this problem.

Jeff's focus was on showing the students the types of problems that skill was useful for solving, but not engaging the students in the act of problem solving. These problems that he highlighted could be found in the practice packets, that the Algebra 1 teachers in his department had created. The practice in these packets resembled those found in more traditional textbooks. His response highlights his focus on completing course work versus a connection outside of the classroom.

Connections to Teaching Practices

Participants in Category 1, who saw math as an opportunity to develop students' reasoning abilities, embraced student-centered teaching practices differently. These participants saw these types of practices as ways to build the capabilities that would serve students outside of a math classroom. Sarah discussed how the drill and kill that she had experienced as a student just didn't align with reality: "How can I be a problem solver and a mathematician and not someone who finds answers? Who just does the same process over and over again?" Many participants shared how they saw a connection to their beliefs about the purpose of learning mathematics and how SCIP aligned with their larger view of teaching and learning. Matt spoke to this when he shared:

> As a learner of math, whatever the level may be, it's much more about math is all these things, math is the math practices, you know, making sense of problems, persevering in solving them. That's math, you know, constructing viable arguments and critiquing the reason of others… I tell the students, this is math guys, yes, there's the algebra, and we're going to do the algebra. And there's some things you should know in the algebra, but these are the skills, I don't care what you go into. These are the skills of life.

Alyssa also highlighted that her belief regarding why we learn mathematics connected to her instructional goals and practices:

> Not all students are going on to be mathematicians as a career. Trying to help them with the bigger picture of why is it meaningful to know how to reason and critique is a much better fit for me. I've had to find my why, to help them with the why of the mathematics.

Alyssa and Matt's comments bring together the ideas that participants in the first category shared. These participants saw mathematics as purposeful in its own right, but at the same time, they felt that the ways that students learn mathematics provide additional skills that take them beyond basic skills or jumping through hoops. These beliefs and skills that exist in addition to mathematical content appear to serve as a catalyst for participants, in this first category, to engage in more student-centered teaching practices.

Connecting to Classroom Observation Data

As a part of this study, participants allowed me to observe them facilitating a mathematics lesson in between the first and second interviews. For the classroom observation portion of this study, there was an alignment between the beliefs that participants shared and the instructional practices that were present in the lesson that was observed. Those participants whose beliefs fell into Category 1, that mathematics also served as a tool to interact with the world outside of school, shared lessons with either a strong use of SCIP or at a minimum a balance between teacher-centered and student-centered practices. Participants whose beliefs fell into Category 2, learning mathematics as a means to an end, shared lessons where a significant reliance on teacher-centered instructional practices were observed. In their lessons and interviews, the focus was showing students the skills they needed to master, followed by opportunities to practice those skills. During the classroom observations as students worked on these practice problems, there was limited discussion that was mostly teachers directed or involved students verifying, with the teacher, if they had completed the procedure correctly.

Shifts in Instructional Practices are Not Done in Isolation.

“Isolation is the enemy of Improvement”---Ingvi Hrrannar Òmarsson

The necessity of collaboration was a theme that existed in every participant’s story. Regardless of the level of implementation of SCIP, every participant identified the benefits of having colleagues or systems in place to support them so that their work to understand and implement SCIP was not done in isolation. While many participants had many different examples of the impact of opportunities to collaborate on their instructional practices, working together within a department or among a group that taught common courses was specifically addressed by every participant in the study. Jack shared his belief on collaboration and the impact that colleagues have on his teaching practices during his interview: “Yeah, as a general concept, anytime you’re teaching, and you’re working with other educators, especially good ones, you start to see what they do. And you kind of want to mimic them a little bit.” Even those participants who were using SCIP on a limited basis identified how a department’s expectations pushed them to continue to develop these practices. Meggin shared how knowing that others were struggling, encouraged her to stay the course:

> And then my colleagues, they're doing it too. And we're all at the same exact place. We're all feeling the exact same frustrations. … When everybody else is going through the exact same thing, then your kind of like, alright, well, I'll keep going.

This quote highlights how the existence of a group goal and opportunities to engage with others doing the same work can provide the opportunity to take risks and engage with something outside of a teacher's own classroom experiences and strengths as an instructor.

Where Do Teachers Find Opportunities to Collaborate

Having a collaborative department or professional learning community (PLC) provided participants who were initially skeptical about a practice to see it in action as a spectator, followed by an avenue for collaborative support once their colleagues shared their experiences. Andrea shared how this has played out in her PLC:

> You have these people who go off and they try something new. … And all of a sudden people are like, oh, well that is kind of cool. Okay, so gee, you are outscoring me now on state assessments because your kids can solve those problems. And mine can't. Maybe I'll taste your Kool-Aid. I'll see what it's like.

The collaborative nature of Andrea's PLC provided her with the opportunity to benefit from the willingness of others in her group to try something new. Without that exposure to the innovation of others in her PLC, she may not of tried a new instructional practice.

While participants identified having a group to collaborate with around instructional practices as an important support, many participants also identified that collaboration outside of their building colleagues was one of many places that they engaged in collaborative experiences. All of the participants in this study had connections to entities that provided instructional support outside of their building, either in the form of an intermediate school district (ISD) or due to their employment in a larger school district. These entities provide opportunities for teachers across several schools to come together and learn about instructional practices that can support the learning of students in their classrooms. Eleven of the 12 participants in this study indicated that participating in learning opportunities provided by these entities had an impact on the instructional practices they utilized in their classrooms. Matt identified the role that the ISD played in his development around the practice of posing purposeful questions:

> So, we had a chance to be at the ISD learning about it, [purposeful] questioning and formative assessment. Those were themes, those had been themes over the years. When I think of anything that I've done, either at the district level or county level. Yeah, having a strong ISD has helped in that.

These collaborative experiences highlighted by participants focused on a group of teachers working to understand an instructional practice that was being used in their classrooms. Regardless of whether it happened at school or outside of school, learning with others was important. Left to do this learning alone participants were more likely to implement practices at a superficial level or give up a practice when faced with hinderances in their use of the practice.

Structures That Support Collaboration

In addition to having schools or ISD's, that supported the understanding and development of instructional practices, several participants identified a deeper level of understanding happened when learning was done over an extended period of time. This long-term experience provided the opportunity for participants to really dig in and deepen their understanding, while also reflecting and refining the practice as they went. Alyssa highlights this as she described what learning experiences supported her in developing the student-centered practice of facilitating meaningful discourse:

> So that cycle of, you know, quality PD [professional development], coming back to my classroom, maybe talking to others, but trying some things and then having the opportunity to come back to do more PD, [even] if it's just discussing with other teachers. Some of the ISD's, eight-part series or four-part series have been critical to my learning, because I'm able to try it.

The benefits of learning that is organized over a long time was identified as a key piece to implementing instructional practices. Coupling this benefit with the advantage attending with colleagues who you can do this work regularly can increase a participant's ability to synthesize and internalize the learning they are engaged in. Angela reflected on a learning series at her ISD titled Algebra for All, which she stated was the first learning experience that supported her in implementing SCIP:

> And then a few of us from the high school did it. And it was, I think, a two-year series that we did. But it was, that whole, now you have a team of people in your building who are drinking the same Kool-Aid, you know, who will work together. So, you're not the only one. And then you know, when one of those people, like stop teaching, and the next team member would come in, we'd be like, okay, so now we got this, and then that team member would bring another perspective, and then you could kind of spread it around.

Other participants spoke to what Angela highlighted, the effects of attending these long-term learning opportunities with colleagues provided the opportunity to create a community that supported each other. This support was with the implementation of the practice as well as continuing the legacy of that learning, even when the membership in that group changed over time.

While the building level is a place where most participants first sought out collaboration, if it did not exist in their department, they sought outside resources. All participants had access to an ISD or district-wide learning opportunities, but in addition to those, seven of the 12 participants identified social media tools (i.e., Facebook, Twitter, and blogs) as a way to interact with others as they tried new instructional practices. In addition to social media, opportunities to learn virtually were also identified as a means to engage in collaboration. Jenny shared that, for her, a positive of the COVID pandemic was the increase in opportunities to learn and collaborate with others about instructional practices online:

> Virtual meetings have increased the number of opportunities I can have because there isn't travel time, and there isn't lost time to attend things like that…Now, we can be given a hyper doc where we can watch the videos and read things on our own time. And then, when we come together, share that thinking, grow that thinking, deepen that understanding, ask our questions, and learn from others.

Social media can serve as a tool for teachers to find opportunities to collaborate. There are many road blocks to collaboration for teachers, lack of colleagues, restrictive secondary school schedules and time demands of other teaching responsibilities, to name a few. Participants found that when they were unable to find opportunities to collaborate when needed social media and digital options could serve as a surrogate.

Frustrations When Collaboration and Learning Opportunities Are Unavailable

While all participants shared the belief that collaboration was key to supporting their work in implementing SCIP, several participants mentioned decreased access to these opportunities over the past few years. In the early 2000s, many districts had to deal with reductions in school funding, that impacted staffing as well as resources to support teachers in engaging in professional development. These same school districts are now struggling with shortages in classroom and substitute teachers due to the impacts of the COVID pandemic. Participants indicated that they feel they have less access to the types of experiences that support their growth as educators. Neil, a teacher who demonstrated significant use of SCIP, described a frustration as he reflected on his current state of instructional development:

> I just don't feel like I'm finding these things [opportunities to learn new instructional practices] anymore. Maybe it's because I'm in Pine County. I mean we haven't had a math meeting in 5-7 years. I feel like I'm getting worse. I'm not growing.

Neil's response highlighted not only the importance of collaboration and opportunities to grow as an educator, but the impact that the absence of those opportunities can have.

I Never Learned It This Way

The final theme from my research is that modeling SCIP allow teachers with procedural backgrounds to connect the practices to their learning experiences. As teachers work to make sense of student-centered teaching practices, they are often in a place of disequilibrium because these practices do not coincide with their educational experiences, specifically the mathematics instruction they encountered in school. All participants in this study identified their experiences while a mathematics student as very traditional or teacher-centered. To make sense of new learning, we try to align new knowledge with something that we already understand; however, with complex concepts or alternative understandings, we may not have the prior knowledge to build upon (Oden & Russ, 2018). Participants in this study identified that significant support for the development of their knowledge regarding the utilization of student-centered teaching practices came from experiencing them as a student. This is a significant point, since none of the participants identified having student-centered classrooms as a part of their k-12 education. These experiences came from learning opportunities that modeled the practices, in real time, while providing the participants the opportunity to learn. Participants identified these learning experiences as the chance to be involved with the practices as a student, while also being able think through them as a practitioner and facilitator. Olivia shared that when her school adopted a new math curriculum, they did a significant amount of research before deciding on a program. Additionally, prior to officially adopting the curriculum, they piloted one unit from the curriculum to verify that it was aligned to their school district and department standards. The success of the pilot encouraged them to adopt the program; yet, as she explains, the instructional practices that were highlighted in the program took on a new and deeper meaning when she experienced them being modeled as a part of the training that was included with the official adoption of the textbook:

> We had talked to other school districts; we knew we liked the questions and the fact that it was more; I guess the phrase is student-centered. The teacher is more of a facilitator, bringing forth the ideas they [the students] have. We liked all that. And it was okay when we piloted, but to get the training, it made more sense. After the training, we saw what it could be compared to what we had implemented for a unit [during the pilot].

This opportunity to see these SCIP modeled was indicated by many participants as the necessary piece to being able to visualize and implement that practice in their classroom. As teachers had the opportunities to experience the student-centered teaching practices as a student, they got the benefit of both lenses: the ability to experience learning in this different way, and see the teacher moves modeled by an experienced and knowledgeable educator. Jack’s school district recently sent him to training in support of the summer school program that they were adopting. The program his district adopted, focused on supporting students in making sense of problems and understanding the multiple ways that students can use to solve different math problems by utilizing SCIP. As Jack reflected on that training, he talked about working in small groups to solve problems and how that supported him. Despite the fact that he does not always appreciate the opportunity to work in groups on mathematics content, he realized that it provided a valuable opportunity to understand the thinking that his students would bring to his classroom:

> Where I did appreciate it, though, was that there were certain problems where they said, "We want you to come up with as many strategies as possible to solve this problem." Because the goal of the program is to provide students the opportunity to share a variety of strategies so that they can all know their strategy is valuable. And so that was helpful because my brain typically goes straight to what is the quickest mathematical way to get things done. Being able to listen to other team members share strategies that they used, or even if they didn't use them just to be able to brainstorm together what other students might come up with. That was helpful, because I feel like a lot of times other people are a little more creative than I am in terms of thinking outside the box and coming up with a variety of strategies.

Jack had not had a student experience that valued multiple methods, and he indicated that his experience as a student was traditional: "All of the math classes I've ever taken from middle school through college have always been teacher-centered, always lecture." Yet he believed that these opportunities to have this type of thinking modeled helped him to see the creative solutions that he could have easily overlooked if he stuck to the mathematical processes he had experienced as a student. Other participants expressed the benefits of seeing problem-solving in action as a means of deepening their mathematical understandings. Sarah specifically stated:

> The really cool part about when you're modeling it with a bunch of teachers that are all math teachers, you're sitting there in the room doing, I remember a CPM (College Preparatory Mathematics Curriculum) training we did on geometry. And everybody at my table was an algebra teacher, except for myself. So, I'm doing it the same old geometric way. And there's an Algebra 2 teacher doing it using the Algebra 2 methodology and I'm like, oh, my God, I learned so much. Because, we all have different experiences. And so that really brought a conversation about, we have all these kids who have different experiences at the table. And so, allowing them space to think so that they can all maybe do it in different ways.

Not only did these experiences enlarge Sarah's mathematical toolbox for solving that geometry problem, they also added to her understandings of why approaching instruction using SCIP can benefit the students in her classroom.

The Examples Matter

A notable detail that was highlighted regarding the modeling of instructional practices for participants in this study was the importance of having student-centered teaching practices modeled using math content. Teachers often see teaching practices modeled during meetings or professional development sessions, but for many reasons, those practices are modeled using non-mathematical content. Participants in this study identified the necessity of experiencing these practices within a mathematical context. Alyssa highlights some of the struggles with non-math examples and the impact modeling with mathematical tasks has had on her as a teacher:

> Seeing those strategies being used on me with mathematics tasks, that's been important too, because I feel like in general PD, it's never math. It's never a math task. It's always, "Think about how you are as a teacher," and I'm like, yes, but how do I do that with a math concept. I like what you're doing, and I'm benefiting from it. But now how do I translate it? So that modeling that has happened, where we do the math, the students would, and we talk about it, like, we were students, and the explicit, try and think like a student, try and talk like a student might. That has been phenomenal for me, in terms of what has helped me to learn how to do it with my students.

Participants repeatedly identified that opportunities where student-centered practices were modeled through a mathematics classroom lens were key to helping teachers bring these practices into their classrooms. Participants shared that they felt this allowed them to shift from looking at the practice through the broad lens of pedagogy to looking through the focused lens of mathematical content knowledge.

Summary

This chapter described four themes that emerged as a result of the research conducted for this study:

- Shifts in instructional practices are prompted by disequilibrium between procedural mathematical knowledge and an individual's identity.
- Instructional practices are driven by an individual's belief in the purpose for learning mathematics.
- Shifts in instructional practices are not done in isolation.
- Modeling student-centered instructional practices allows teachers with procedural backgrounds to connect the practices to their learning experiences.

These themes identify significant experiences shared by participants in this study while highlighting key ideas for consideration in addressing the research questions that are a part of this study. In the next chapter, these four themes will be utilized as a part of the discussion around the research questions this study was built to address as well as the findings and analysis of the data that resulted from this study.

Chapter Five: Conclusions, Discussions, and Implications

As I analyzed the data provided by the participants in this study, I engaged in a recursive process utilizing iteration, constant comparison, and theoretical sampling. This study examined the learning experiences of secondary mathematics teachers to determine the impacts these experiences have on how they make sense of the instructional practices they utilize. This grounded theory study was conducted over the 2020-2021 and 2021-2022 school years and was guided by the following research questions:

1. How do teachers understand the student-centered instructional practices they implement in their classrooms?
2. How do teachers experience the implementation of student-centered instructional practices?

The data is arranged around four themes that illuminate participants' experiences and provide a foundation for the discussion of the findings in this study. The first theme speaks to experiences that increase the interest in adopting student-centered instructional practices (SCIP). The remaining themes identify supports that encourage the development of these practices as a regular part of a participant's instructional repertoire.

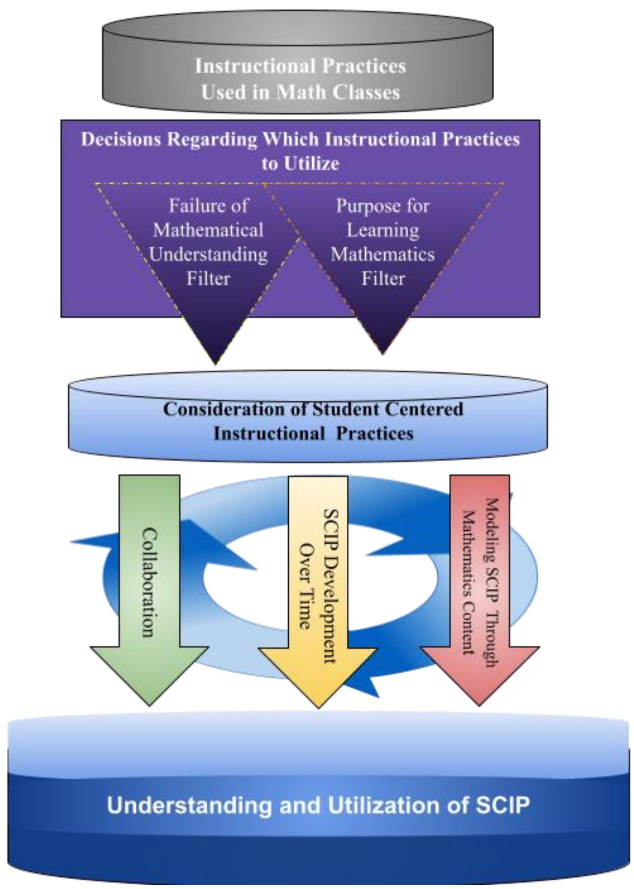
Summary of the Study's Findings

In this grounded theory study, participants shared experiences as a student and a practitioner of mathematics that impacted their use of SCIP. These experiences were part of creating an individual's mathematical identity and, in turn, their identity as an educator. These identities influence how participants engage with the instructional practices they choose for use in their classroom and the philosophy that drives their purpose for teaching and learning mathematics. For participants who utilized SCIP readily, two common experiences existed in the shared narrative. First, most participants in this study who used SCIP experienced a time when their mathematical identity underwent reconstruction due to a realization that their mathematics knowledge wasn’t enough. The reconciliation between their learning experiences and how their mathematical understandings failed them allowed participants to look beyond their student experiences as the “gold standard” for instructional practices and consider SCIP. As participants talked about the SCIP they utilized in their classrooms, the mathematics failure moment was a filter through which experiences that seemed uncharacteristic for a mathematics classroom could be run to remove initial doubts revealing possibilities for use. The second common narrative among participants who utilized SCIP regularly was a belief that mathematics served as a pursuit or a tool for life. This purpose for learning mathematics provided participants a lens for examining SCIP as a critical component to helping students achieve these pursuits and not as another way to “teach” math. A pursuit helps a student attain larger goals than just content and academic mastery and involves the work of developing the self in ways that extend the content (Muhammad, 2021). While these narratives were present for many participants, they were not mutually inclusive. Experience with just one of these narratives was enough to provide participants the necessary filter to consider SCIP as a means to impact mathematics learning in their classrooms.

Once participants could see SCIP in a way that did not directly conflict with their individual experiences and beliefs, their engagement in developing these practices began to increase. This study identified three essential supports that advanced the development of these SCIP. The first support was collaboration. The second support was that the development of SCIP should be done over time, allowing for reflection, revision, and refinement during implementation. The third support was that modeling these practices needed to be done utilizing mathematics content, allowing secondary math teachers to experience these practices as both students and teachers creating the prior knowledge required to build their understanding. Figure 2 shows how the experiences and supports identified as a result of this study combine to support secondary mathematics educators in considering and developing SCIP as a part of their instructional repertoire.

Figure 2

Process for Consideration and Development of Student-Centered Instructional Practices



The model in Figure 2 starts with all the instructional practices a teacher can consider. While these instructional practices include SCIP, the teacher-centered instructional practices experienced as a student are often in the forefront as those are the instructional practices that secondary mathematics educators have the most experience and understanding around. As secondary mathematics teachers make decisions about which instructional practices to utilize, the purple triangles are the filters that allow teachers to set aside other teaching practices to consider SCIP. The light blue cylinder represents the awareness of SCIP that exists before a teacher's engagement to make sense of and incorporate them into their instructional repertoire. The arrows show how collaboration, long-term learning, and modeling of SCIP through mathematics move SCIP awareness to deeper levels of understanding and utilization. This depth of understanding and increased utilization is represented by the deeper multi-colored cylinder. The circular symbol behind the arrows indicates that flow between the three supports can happen.

Discussion of the Study's Findings

SCIP impact student learning positively in mathematics classrooms (NCTM, 2014, 2020). SCIP are practices that place the teacher in the role of a facilitator while emphasizing the student's engagement in problem-solving and inquiry, creating opportunities for students' interactions and discourse that support the development of mathematical concepts and procedures (NCTM 2020). When someone describes a secondary mathematics classroom, they describe a teacher-centered one. In these stereotypical recollections, you hear descriptions where the math teacher works on an example at the board and explains how to do each step while students write the step in their notebooks. Next, the teacher provides a problem, expecting the students to mimic the work just modeled for the class independently. This process is repeated for a few nuanced versions of the skill taught that day and ended with the expectation that students complete additional practice or homework problems that evening. This teacher-centered approach is prevalent in mathematics classrooms (NCTM, 2014, 2020) and is often the only instructional practice that math teachers have ever experienced as students. As a practice, teachers are influenced by and directly replicate the instructional practices they experienced as a student in their classrooms (Elliot et al., 2013). These teacher-centered practices become the “gold standard” by which mathematics lessons are designed. Many mathematics teachers have not benefitted from learning mathematics in a student-centered fashion, leading to a disconnect between the instructional practices that a teacher has a working knowledge of and the student-centered practices they are encouraged to incorporate into their mathematics instruction. How do mathematics teachers utilize SCIP regularly in their instruction, especially when their identity as a mathematician has a foundation built from success with teacher-centered practices? This study took a closer at the experiences of twelve secondary mathematics teachers to gain insight into this question. This study found that participants who indicated regular use of SCIP in their classrooms identified either a significant shift in their mathematical identity as an adult or viewed the purpose of learning mathematics as a pursuit that leads beyond the attainment of skills and concepts.

Mathematics Failure and Consideration of Student-Centered Instructional Practices

Participants in this study identified moments where they experienced a failure in the mathematical knowledge they developed as a student. This failure in mathematics knowledge was an anchor point that influenced their desire to implement SCIP. Neil summarized this experience for participants when he stated:

> I originally wanted to be a science teacher. And as I was in grad school, I couldn’t pass calculus-based physics II because I kept making algebra mistakes, really basic algebra mistakes. And so, it was holding me back from completing some college courses, even though I had passed calculus. And so, I was pissed off. I mean, I was angry at the system,

> that I could make it through college and be working on my postgrad and not understand the basics of math. So, I went back and started taking math education classes for elementary school-aged kids. And that's where I fell in love with math, because I was like, I didn't know how much I didn't know. And when I was learning, I was like, this is a shame that someone like me can go through and not understand what's going on. So, I wanted to teach at the elementary or middle school level so that kids could get a real firm understanding of what they're doing mathematically. That's why I decided to be a math teacher. So, I gave up science altogether because I just fell in love with understanding math.

The disconnect between what participants needed to do mathematically and their mathematical understandings impacted their mathematical identity. This disconnect serves as a boundary experience. Boundary experiences occur when a person encounters an instance or situation where they cannot perform in a manner they expect based on their experiences and knowledge, requiring the individual to see themselves in a new light (Geijsel & Meijers, 2005). The work done by participants to reconcile their mathematical identity created a lens for viewing teaching practices in a manner that supports reflection and consideration of new approaches, specifically SCIP. Emotion is an essential factor in the sense-making process that occurs following a boundary experience, fueling the reconciliation required by the individual as they work to see themselves in this new context (Geijsel & Meijers, 2005; Ganon-Shilon & Schechter, 2016). The emotion attached to the boundary experience, created by the failure of a participant's mathematical knowledge, set the stage for the sense-making that took place as the next step for participants.

Sense-making theory (SMT) states that sense-making is grounded in identity construction (Weick et al., 2005; Weick, 1995; Dervin, 1998). For participants in this study, recognizing these deficiencies in their mathematical understandings required a shift in their mathematical identity to assuage the feelings that resulted from the incident. The efforts in identity construction that resulted from reconciliation with the failure of their mathematical knowledge led to a new mathematical identity that was open to consideration of SCIP as a tool in their instructional repertoire. Alyssa highlighted how she thinks about her knowledge failure when making instructional decisions: “So, I’m fighting against that all the time. I don’t want my students to feel lost when they get to those situations.” Her goal is to ensure that her students do not encounter a failure moment like hers, where they cannot utilize the mathematics they have learned. These moments of mathematical failure and identity reconstruction are the exacted cues, familiar structures, and experiences that Weick (1995) identifies as one of the seven key properties of sense-making. These cues serve as the reference point that ties elements together and evoke the capacity of the sense-maker to engage in the actions necessary to set sense-making into motion (Weick, 1995).

Purpose for Learning Mathematics and Consideration of Student-Centered Instructional Practices

The view that learning mathematics serves as a pursuit that goes beyond learning mathematical skills into developing key habits of mind and intellectual capabilities that benefit students, outside of solving equations and factoring quadratics, is another inroad to considering SCIP. How participants saw the purpose for learning the mathematics they were teaching created a pathway for consideration and adoption of SCIP as a part of their instructional repertoire. Instructional decisions are influenced by teacher beliefs (NCTM 2020). Teachers with well-developed mathematical knowledge for teaching (MKT) often have habits of mind that move beyond a focus on procedural problem-solving (Ball et al., 2008).

Participants who described the purpose of learning mathematics as a pursuit regularly referenced the eight standards for mathematical practice during their interviews. Matt shared his connections to the standards for math practice when he said:

> As a learner of math, whatever the level may be, it's much more about math is all these things, math is the math practices [standards for mathematical practice], you know, making sense of problems, persevering in solving them. That's math, you know, constructing viable arguments and critiquing the reason of others…. I tell the students, this is math guys, yes, there's the algebra, and we're going to do the algebra. And there's some things you should know in the algebra, but these are the skills, I don't care what you go into. These are the skills of life.

The standards for mathematical practice "describe varieties of expertise that mathematics educators should seek to develop in their students at all levels. These practices rest on important 'processes and proficiencies' with longstanding importance in mathematics education" (National Governors Association Center for Best Practices & Council of Chief State School Officers, 2010, p.6). The eight standards for mathematical practice as identified by the Common Core State Standards are as follows:

- Make Sense of Problems and Persevere in Solving Them,
- Reason Abstractly and Quantitatively,
- Construct Viable Arguments and Critique the Reasoning of Others,
- Model with Mathematics,
- Use Appropriate Tools Strategically,

- Attend to Precision,
- Look for and Make Use of Structure, and
- Look for and Express Regularity in Repeated reasoning.

These practices are engrained in how students engage and think about the mathematics they are presented. Participants who viewed mathematics learning as a pursuit saw a connection to what they wanted students to know, be able to do, and the eight standards of mathematics practice.

The connection of these standards for mathematical practice with the content standards that were a part of participants' course creates opportunities for consideration of SCIP. Teaching mathematics in a way that engages students with mathematical concepts and aligns with the belief in the pursuit of mathematics left teachers looking to move beyond the teacher-centered teaching practices they experienced as a student and develop SCIP. Helping students engage in the pursuit of mathematics, where they can develop mathematical skills and key habits of mind, requires teachers to deepen their MKT. The work of developing SCIP deepens MKT in the domains of knowledge of content and teaching and knowledge of content and students.

From Consideration to Utilization: Supports for Developing Student-Centered Instructional Practices

The journey to adopt, develop, and use SCIP as a regular part of classroom instruction involves repeated engagement with sense-making and identity development. The development of SCIP required participants to understand instructional practices they had not experienced as mathematics students. Participants shared their journey to understand and use SCIP, illuminating key themes and ideas regarding the supports that benefitted the development of their understanding and use of these instructional practices. The first support was the need for collaboration; participants repeatedly discussed the difficulty of adopting SCIP, especially when left to do that work in isolation. Participants shared that their understanding and use of student-centered practices were directly affected by their opportunities to collaborate with others. The second support was that learning these instructional practices needed to happen over time. This period creates a chance to revise and implement these instructional practices progressively. The third support was modeling SCIP through mathematics content. The mathematical content allowed participants to gain experience with the practice as mathematics students and a facilitator of mathematical learning.

Collaboration

Collaboration is defined as two or more people working together toward a common goal (Thousand et al., 2007). Every participant in this study identified collaboration as a powerful tool to support their work in developing new instructional practices. Dufour (2004) defines a collaborative team as a group of team members who work together to make public what has traditionally been private, allowing teachers to improve practice. The act of sense-making is the process that individuals utilize to examine the underlying phenomenon in a situation, to resolve a gap or inconsistency in their understanding (Dervin, 1983; Dervin, 1998; Odden & Russ, 2018; Ganon-Shilon & Schechter, 2016). As mathematics teachers work to define and understand how and when to utilize an instructional practice to support the learning of mathematics in their classroom, they are engaging in sense-making. Weick (1995) states that sense-making is grounded in individual and social activity. These opportunities to collaborate are moments where teachers can engage in the social activity necessary to develop their understanding of the SCIP. Odden and Russ (2018) share that sense-making involves a dialogue between construction and critique; collaborative teams, sometimes referred to as professional learning communities (PLC), allow opportunities for teachers to engage in the construction and critique necessary to develop an instructional practice. Andrea shared how this construction and critique existed within her PLC:

> You have these people who go off and they try something new… And all of a sudden people are like, oh, well that is kind of cool. Okay, so gee, you are outscoring me now on state assessments because your kids can solve those problems. And mine can't. Maybe I'll taste your Kool-Aid. I'll see what it's like.

For Andrea, her PLC provided the place to construct and critique her understanding of the instructional practices that others were implementing, and then continue the sense-making process as she started to try the practices in her classroom. Participants repeatedly identified collaborative experiences that allowed them to engage in construction and critique around SCIP.

A PLC at a building or department level is a great place to collaborate; unfortunately, truly collaborative PLCs do not always exist in school buildings (Dufour, 2004). For some participants in this study, finding a team to collaborate with proved difficult. Jeff shared that, while he would like the opportunity to engage with a collaborative PLC, in his 27 years in education, he is still waiting to find one:

> I know that I feel like I'm pretty solid with the PLC process, but you need collaborators. And that's been the struggle most of my career, teachers not really understanding the process and wanting to do that collaborative piece where they talk about their particular teaching strategies and how effective those strategies were with their students and, you know, us deciding, you know, together what kind of strategies we want to use to get across to the kids, so they get the content that's been my dream, I've never seen it happen.

Participants in this study who could not find a collaborative group that focused on learning SCIP demonstrated the use of SCIP that was more targeted on the teacher's role, limiting the student aspect of the SCIP. This focus left the implementation lacking the depth and student ownership evidenced by participants who identified working with a collaborative team.

School buildings are not the only place to seek out collaboration. Participants in this study utilized their access to resources via professional development teams within their school districts, intermediate school districts, professional organizations, and online offerings. Some participants who did not have access to collaborative teams within their building sought out these resources to engage in opportunities for collaboration. By looking for collaboration outside the building, participants could participate in various collaborative experiences and find opportunities to develop their SCIP. Participants were required to utilize time outside of the work day to participate in these experiences. This use of personal time impacted the amount of time spent engaging in these experiences, often limiting the frequency of engagement. Participants with collaborative teams and the ability to participate outside of the building learning were able to engage in multiple opportunities to make sense of SCIP and amplify their practice through the creation and critique with their peers.

Long Term

The second support was developing SCIP knowledge over time. Participants highlighted that engaging with SCIP development over a more extended period created an opportunity to revise and implement the SCIP in sustained chunks allowing for reflection and revision. Sense-making is an intertwined three-part process that enables an individual to infer meaning in a situation through creation, interpretation, and enactment (Ganon-Shilon & Schechter, 2016; Weick, 1995). Creation is the identification of the event that does not align with expectations in that situation; interpretation is where the individual tries to explain or interpret the event, and enactment is the use of the explanation to return to a state of alignment with an individual's understanding (Ganon-Shilon & Schechter 2016). As Alyssa reflected on the learning that helped her develop SCIP, this three-part process is a part of the long-term learning opportunities she described:

> So that cycle of, you know, quality PD [professional development], coming back to my classroom, maybe talking to others, but trying some things and then having the opportunity to come back to do more PD, [even] if it's just discussing with other teachers. Some of the ISD's eight-part series or four-part series have been critical to my learning because I'm able to try it.

In the statement, Alyssa describes her engagement with the three processes. Creation was the learning via quality PD and taking it back to her classroom. Back in her classroom, she accessed interpretation as she tried the practices and brought her experiences back to the group. Her opportunity for enactment came in her reflection and continuous learning cycle until she achieved successful implementation. She mentioned the eight-part or four-part series involved working with the same teachers over multiple sessions. The creation, interpretation, and enactment process happened for Alyssa across the whole series and between sessions as she engaged with the ideas shared across sessions. The long-term learning experiences that many participants shared in this study illuminate the necessary support in allowing secondary mathematics teachers to make sense of the SCIP in a manner that encourages the utilization of SCIP to deepen their understanding of the practice.

Sense-making theory (SMT) is a conceptual framework that allows us to think about how teachers make sense of the instructional practices they utilize in their classrooms. Weick (1995) identified seven properties of sense-making. As participants described their engagement in long-term learning focused on different SCIPs, these seven sense-making properties were woven throughout the discussion. Access to these sense-making properties increased the likelihood that what participants need to make sense of the SCIP they are working to incorporate into their practice is available when they participate in this work.

Modeling

Participants in this study identified that the ability to experience a SCIP in action was essential to supporting the development of those practices as a part of their instructional repertoire. Alyssa communicated this when she stated:

> Seeing those strategies being used on me with mathematics tasks, that's been important too, because I feel like in general PD, it's never math. It's never a math task. It's always, 'Think about how you are as a teacher', and I'm like, yes, but how do I do that with a math concept. I like what you're doing, and I'm benefiting from it. But now how do I translate it? So that modeling that has happened, where we do the math, the students would, and we talk about it, like, we were students, and the explicit, try and think like a student, try and talk like a student might. That has been phenomenal for me in terms of what has helped me to learn how to do it with my students.

Sense-making requires building from prior knowledge (Warren et al., 2001). The modeling of SCIP is vital for mathematics teachers. These practices are nuanced and not something many secondary mathematics teachers experienced as students. The lack of experience as a student with SCIP indicates the foundation teachers are building their understanding upon is a fragile base. To make sense of new learning, we try to align new knowledge with something we already understand. These experiences where SCIP is modeled create the foundation that allows for the building of a connection of something we know as a student to an understanding of these practices as a teacher.

The modeling of these SCIP for secondary mathematics educators through mathematics examples and lessons provides an opportunity for teachers to build their MKT. This modeling of instructional practices specifically supports the development of specialized content knowledge and knowledge of content and teaching. When Alyssa stated: “I’m like, yes, but how do I do that with a math concept. I like what you’re doing, and I’m benefiting from it. But now how do I translate it?” she was referencing how hard it can be to translate general pedagogical knowledge into MKT. Participants repeatedly shared this difficulty. The opportunity to see SCIP modeled allows access to the properties of SMT that will support the development of SCIP into MKT. The modeling of SCIP through mathematics content allows the sense-maker to engage in ongoing and social opportunities to learn. Those sense-making aspects happen while developing plausibility for the sense-maker and incorporating this student learning experience into their identity as a learner. A sense-maker, having engaged in this learning experience, can think retrospectively about their experience and then apply that to their enactment in their classroom. This experience of modeling instructional practices through mathematics content provides a “one-stop shop” for sense-making experiences that support the development and implementation of SCIP. Couple this experience with the other two supports discussed and an environment rich with the necessary opportunities to develop SCIP is available.

Sense-making requires building from prior knowledge (Warren, et al., 2001, Oden & Russ, 2017). Dervin (1983) identifies this process as a crucial part of sense-making. For participants in this study, experiencing these instructional practices as a student and reflecting on how to utilize them in their classroom setting creates an opportunity to align new knowledge with something they already understand, shifting the participant from the role of information attainment to interpreting the situation on their terms. People play a role in creating their environment, their actions become the constraints, realities, and opportunities they must address (Weick,1995). The modeling of SCIP supports teachers in identifying the plausibility of those practices by seeing them in a situation similar to the one they would utilize. In addition, modeling these practices provides the teacher with information and experiences that can support them in creating an environment where the opportunities to use the practice outweigh its constraints, while also providing a social setting for sense-making to occur. Engaging in SCIP modeled through mathematical content allows several touchpoints for interaction that would enable secondary mathematics teachers to make sense of these practices.

Implications of the Themes

The purpose of this study was to gain a deeper understanding of how secondary mathematics teachers understand SCIP to support their classroom implementation. This study's findings provide considerations for instructional leaders as they look to support secondary mathematics teachers in developing SCIP in support of mathematics learning. For this discussion, an instructional leader is any person who can impact the instructional knowledge or opportunity to gain instructional knowledge for a secondary mathematics teacher. Instructional leaders could be any of the following: building administrators, district administrators, professional development coordinators, content coordinators, department chairs, state and county level content specialists, and instructional coaches. Activation of prior knowledge is essential to building a schema that supports the development and retention of conceptual knowledge needed to make sense of instructional practices. For secondary mathematics teachers who experienced traditional mathematics instruction as a student, there is no prior knowledge of SCIP to frame their utilization of these practices as an educator. These secondary mathematics teachers who experienced traditional mathematics as a student often experience disequilibrium with SCIP, as they are counter-intuitive to the experiences that developed their mathematical identities. The instability teachers experience as they try to incorporate SCIP can lead to inadequate or non-use of SCIP. This study highlights key experiences that supported secondary mathematics teachers in developing SCIP, as a part of their instructional repertoire, despite a teacher-centered instructional background.

An idea that conflicts with a personal experience can be easier to engage with when there is another experience that can plausibly explain the concept. For participants in this study, the experiences that allowed for the plausibility of SCIP fell into two categories. One was an assault on their mathematical identity due to a failure in their mathematical understanding, and the other was the view that learning mathematics was a pursuit that would increase a student's mathematical knowledge and provide tools for life outside the walls of education. Those participants who experienced a failure in their math understandings had visceral recollections of those moments. These recollections impacted the decisions regarding the design of their mathematics instruction. Creating an experience of failure for every mathematics educator is not feasible, but providing opportunities to share personal math stories with colleagues provides knowledge that all can use as a filter for considering SCIP. When secondary mathematics educators are given opportunities to engage with these stories, those stories become a part of the narrative considered when thinking about mathematics experiences.

Seeing value in using SCIP and effectively using those practices to deepen student understandings of mathematics is very different. Participants in this study shared that their path to making sense and utilizing SCIP with efficacy involved opportunities to engage collaboratively with the SCIP. While many teachers are required to participate in teams or PLCs as a part of their professional responsibilities, these teams often fall short of true collaboration. Efforts from instructional leaders to support the development of collaborative opportunities within their buildings and learning communities will increase opportunities for secondary mathematics teachers to engage in the collaborative experiences identified by participants in this study. These collaborative experiences are instances that support the construction, critique, and reflection of the knowledge of SCIP that allows participants to engage in sense-making around SCIP.

Educators often have instructional practices modeled for them. As indicated in this study, modeling these practices through mathematics content is a necessary next step to support mathematics teachers as they adopt the practice. As instructional leaders consider how they provide professional development, making space to include modeling of practices through mathematical examples is a necessary component to the development of the prior knowledge needed to develop this practice as a part of their MKT.

As instructional leaders consider budget restrictions or the challenges of teacher and substitute teacher shortages, opportunities to engage in long-term learning experiences, as described by participants, need to be protected. These long-term learning experiences are designed to include all three supports for developing SCIP identified in this study. Limiting these learning experiences can be short-sighted, considering the days needed for the teacher to engage in the learning experience will be significantly shorter than the impact of the learning experience. These learning opportunities serve as the first ripple that impacts a collaborative team. Without them, a team can remain placid, lacking the movement needed to shift practice.

Encouraging secondary mathematics educators to embrace SCIP has been a challenge. Instructional leaders' decisions to build and reinforce the three supports of collaboration, long-term learning, and modeling for the educators will provide necessary opportunities for secondary mathematics teachers to transition from awareness to effective implementation of SCIP. Once done with the work of creating interest, the result of turning that interest into implementation becomes the next step.

Limitations

This study was conducted during the 2020-2021 and 2021-2022 school years. During this time, educators had to manage many health, safety, and emotional responsibilities in addition to the educational needs of students. Response to COVID has created health, safety, and emotional stressors that have become a regular part of participants' personal and professional lives. In addition to these stressors, virtual, hybrid, and social distancing requirements impacted the educational environments created by educators in this study. For some participants in this study, the interview and classroom observation phase coincided with the emotional turmoil that comes in the wake of a school shooting. While this shooting did not occur in schools where participants taught, the shooting did occur in the same county. This proximity to the tragedy impacted the classroom learning environments that participants were able to create. While gun violence and COVID are not new to educators, these traumatic events are the backdrop for the participant's discussions and need to be identified.

One limitation of this study was the inability to recruit participants with less than five years of teaching experience. Common reasons given for non-participation during the active recruitment phase of this study were fatigue and being overwhelmed. While recruiting participants is a challenge for many research studies, I believe that COVID and the tragedy of gun violence usurped the energy individuals had available to participate. The confidence that comes with experience and job security may have reduced a few stressors for those who did participate, leading to a participant pool that lacks the insight of novice educators. Participants with less than five years of teaching experience offer the perspective of those new to the teaching profession and the increased likelihood that they may have encountered student-centered teaching practices as secondary mathematics students. Input from participants with these experiences should be considered for future studies.

Many of the participants in this study consider themselves instructional leaders. The large number of participants who view themselves as instructional leaders is a limitation of this study. Data from mathematics educators that do not see themselves in this leadership role could provide additional information for use in supporting teachers in understanding and implementing SCIP.

Concluding Thoughts

I designed this study to understand why secondary mathematics educators were reluctant to engage in SCIP. For many secondary mathematics teachers, learning mathematics was a teacher-centered experience that directly contrasts with SCIP. This study showed that an experience or belief could provide a filter to process SCIP. This filter allows secondary mathematics educators to consider SCIP, which often contradicts what was “good enough” for them as a student. Moments shared by participants in this study focused on either a failure of mathematical knowledge or learning mathematics as a pursuit. These moments serve as a filter to remove the veil that obscures recollections of past experiences. Removing the veil allows for telling a story that shifts the focus from the benefits of teacher-centered instructional practices to consideration of SCIP. While impossible to create moments of mathematical failure for every secondary mathematics educator, we can create shared knowledge and stories that serve to illuminate these experiences when educators engage in conversations regarding their pursuits of learning mathematics. This work cannot be left to secondary mathematics educators on their own. Instructional leaders need to take responsibility for leading this work. With all that is asked of teachers regularly, too often, the “procedural” nature of education is allowed to prevent SCIP from staying at the forefront of discussions that impact student mathematics learning. Once teachers consider building their knowledge and understanding of SCIP, instructional leaders must support that learning if it is to transition from a basic level to the expertise necessary for utilization and implementation that highlights the mathematical brilliance that exists in every secondary mathematics student.

SCIPs are significant ways to support students in developing their mathematical knowledge. For many teachers, these practices are not a part of the secondary mathematics instructional experience upon which they have built their mathematical identity. These SCIP can be challenging to incorporate into a teacher’s instructional repertoire due to the misalignment with an educator’s own instructional experience creating a need to understand these practices as both an educator and a student. This study has identified two key experiences that support teachers in seeing the value of SCIP. The experiences are the failure of an individual’s mathematical knowledge in a way that causes identity reconstruction and the belief that learning mathematics is a pursuit meant to increase mathematical knowledge and develop key habits of mind. This study also identified three key supports for helping teachers build their knowledge and skill in utilizing SCIP once they considered the potential value added for their use. These three key supports for assisting teachers incorporate these practices into their repertoire are (a) collaborating with others, (b) engaging in long-term learning opportunities around SCIP, and (c) having SCIP modeled through mathematcal content.

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APPENDICES

Appendix A: IRB Exempt Status

EASTERN
MICHIGAN UNIVERSITY

University Human Subjects Review Committee

Apr 26, 2021 7:13:10 AM EDT

Carrie Heaney
Eastern Michigan University, Leadership and Counsel

Re: Exempt - Initial - UHSRC-FY20-21-178 Understanding Implementation: A Qualitative Examination of How Teachers Experiences Impact the Implementation of Instructional Practices

Dear Carrie Heaney:

The Eastern Michigan University Human Subjects Review Committee has rendered the decision below for Understanding Implementation: A Qualitative Examination of How Teachers Experiences Impact the Implementation of Instructional Practices. You may begin your research.

Decision: Exempt

Selected Category: Category 1. Research, conducted in established or commonly accepted educational settings, that specifically involves normal educational practices that are not likely to adversely impact students' opportunity to learn required educational content or the assessment of educators who provide instruction. This includes most research on regular and special education instructional strategies, and research on the effectiveness of or the comparison among instructional techniques, curricula, or classroom management methods.
Category 2.(ii). Research that only includes interactions involving educational tests (cognitive, diagnostic, aptitude, achievement), survey procedures, interview procedures, or observation of public behavior (including visual or auditory recording).
Any disclosure of the human subjects' responses outside the research would not reasonably place the subjects at risk of criminal or civil liability or be damaging to the subjects' financial standing, employability, educational advancement, or reputation.

Renewals: Exempt studies do not need to be renewed. When the project is completed, please contact human.subjects@emich.edu.

Modifications: Any plan to alter the study design or any study documents must be reviewed to determine if the Exempt decision changes. You must submit a modification request application in Cayuse IRB and await a decision prior to implementation.

Problems: Any deviations from the study protocol, unanticipated problems, adverse events, subject complaints, or other problems that may affect the risk to human subjects must be reported to the UHSRC. Complete an incident report in Cayuse IRB.

Follow-up: Please contact the UHSRC when your project is complete.

Please contact human.subjects@emich.edu with any questions or concerns.

Sincerely,

Eastern Michigan University Human Subjects Review Committee

Appendix B: Consent Form

RESEARCH @ EMU

Informed Consent Form

Project Title: Understanding Implementation: A qualitative Examination of How Teacher Experiences Impact the Implementation of Instructional Practices

Principal Investigator: Carrie Heaney, Graduate Student

Faculty Advisor: Dr. Rema Reynolds, Professor of Education Leadership

Invitation to participate in research

You are invited to participate in a research study. In order to participate, you must be a secondary mathematics teacher (grades 6 – 12), who currently teaches in a Michigan Public School. Participation in research is voluntary. Please ask any questions you have about participation in this study

Important information about this study

- The purpose of the study is to understand how secondary mathematics teachers make sense of the instructional practices they implement in their classrooms.
- Participation in this study involves participation in two interview sessions (approximately 1 hour in duration) and a classroom observation.
- Risks of this study include a potential loss of confidentiality.
- The investigator will protect your confidentiality by using a code to label data with identifiable information and storing all data in a password protected file.
- Participation in this research is voluntary. You do not have to participate, and if you decide to participate, you can stop at any time.

What is this study about?

The purpose of the study is to learn more about how mathematics teachers make sense of the student-centered instructional practices they use in their classroom.

What will happen if I participate in this study?

Participation in this study involves

- Completing two interview sessions with the investigator.
- Allowing the investigator to observe you teaching a math class in between interview sessions.

We would like to audio record your interview sessions for this study. If you are audio recorded, it will be possible to identify you through your voice. If you do not agree to be audio recorded, you may not be eligible to participate in this study

What types of data will be collected?

We will collect data about your experiences as a math teacher and how you develop and implement new instructional practices in your classroom. We will also ask you information about your ethnic origin, gender, and age.

What are the expected risks for participation?

The primary risk of participation in this study is a potential loss of confidentiality.

Are there any benefits to participating?

You will not directly benefit from participating in this research.

Benefits to society include understanding how mathematics educators how make sense of the student-centered instructional practices they use in their classroom.

How will my information be kept confidential?

We plan to publish the results of this study. We will not publish any information that can identify you.

We will keep your information confidential by using a code to label data with the code linked to identifiable information is a key stored separately from data. Your information will be stored in a password protected file on a password protected computer non digital files will be locked in a filing cabinet. All audio files will be destroyed after transcription.

We will make every effort to keep your information confidential, however, we cannot guarantee confidentiality. The principal investigator and the research team will have access to the information you provide for research purposes only. Other groups may have access to your research information for quality control or safety purposes. These groups include the University Human Subjects Review Committee, the Office of Research Development, federal and state agencies that oversee the review of research. The University Human Subjects Review Committee reviews research for the safety and protection of people who participate in research studies.

Storing study information for future use

We will store your information to study in the future. Your information will be labeled with a code and not your name. Your information will be stored in a password-protected or locked file and will be stored indefinitely.

We may share your information with other researchers without asking for your permission, but the shared information will never contain information that could identify you. We will send your de-identified information by email and only upon request.

What are the alternatives to participation?

The alternative is not to participate.

Are there any costs to participation?

Participation will not cost you anything.

Will I be paid for participation?

You will not be paid to participate in this research study.

Study contact information

If you have any questions about the research, you can contact the Principal Investigator, Carrie Heaney, at cheaney@emich.edu or by phone at xxx-xxx-xxxx. You can also contact Carrie's advisor, Rema Reynolds, at rreyono15@emich.edu or by phone at 734-487-2713.

For questions about your rights as a research subject, contact the Eastern Michigan University Human Subjects Review Committee at human.subjects@emich.edu or by phone at 734-487-3090.

Voluntary participation

Participation in this research study is your choice. You may refuse to participate at any time, even after signing this form, without repercussion. You may choose to leave the study at any time without repercussion. If you leave the study, the information you provided will be kept confidential. You may request, in writing, that your identifiable information be destroyed. However, we cannot destroy any information that has already been published.

Statement of Consent

I have read this form. I have had an opportunity to ask questions and am satisfied with the answers I received. I give my consent to participate in this research study.

Signatures

____

Name of Subject

____ ______________________

Signature of Subject Date

I have explained the research to the subject and answered all their questions. I will give a copy of the signed consent form to the subject.

____

Name of Person Obtaining Consent

____ ______________________

Signature of Person Obtaining Consent Date

Appendix C: Recruitment Letter

Study Recruitment Letter

Hello,

My name is Carrie Heaney and I am a graduate student at Eastern Michigan University. I am currently working on my PhD is Education Leadership and as a part of my program I am conducting research regarding how secondary mathematics teachers understand and implement the instructional practices they use in their classrooms.

Your experiences as a secondary mathematics teacher would provide valuable information and I would like to invite you to participate in this voluntary study. Participation is this study would involve participation in two interviews focused on your experiences as a mathematics teacher, lasting approximately 45 minutes to an hour, as well as allowing me to observe you teach a mathematics lesson between the first and second interview.

If you have questions or would like further information about this study, please contact me via email at cheaney@emich.edu.

Thank you for your consideration, if you would like to participate in this study, please complete this form, indicating your interest and providing contact information so that I may contact you to discuss your participation.

Thank You,

Carrie Heaney

Graduate Student
Eastern Michigan University
Ypsilanti, Mi, 48197

Study Interest / Request for Contact Form

By completing the information below, you are granting the researcher permission to contact your regarding your interest in participating in the study around how secondary mathematics teachers understand and implement the instructional practices they use in their classrooms.

Name:

Please provide the phone number or email address that you would like the researcher to use to contact you regarding this study.

Email Address:

Phone:

Thank you for your interest in participating in this study, I will be in contact shortly to discuss next steps.

Appendix D: Participant School Demographic Information

Table F1 - Study Participant School Race/Ethnicity

Pseudonym	American Indian Alaskan Native	Asian	African American	Hispanic	White	Native Hawaiian	Two or More Races
Angela	0.08%	2.25%	16.93%	3.39%	74.49%	0.0%	2.6%
Midge	0.2%	2.74%	12.17%	3.72%	78.08%	0.2%	2.94%
Olivia	0.08%	2.25%	16.93%	3.39%	74.49%	0.0%	2.6%
Jack	0.42%	8.15%	15.96%	8.66%	63.07%	0.25%	3.48%
Meggin	0.08%	2.25%	16.93%	3.39%	74.49%	0.0%	2.6%
Alyssa	0.32%	1.9%	2.28%	6.21%	87.94%	0.0%	1.9%
Matt	0.19%	2.44%	1.99%	6.68%	85.82%	0.0%	2.98%
Sarah	0.19%	2.44%	1.99%	6.68%	85.82%	0.0%	2.98%
Neil	0.4%	2.2%	1.0%	16.3%	75.3%	.01%	4.7%
Jeff	0.8%	6.5%	17.3%	25.7%	42%	0.6%	7.1%

Pseudonym	American Indian Alaskan Native	Asian	African American	Hispanic	White	Native Hawaiian	Two or More Races
Andrea	0.5%	4.9%	17.9%	35%	33%	0.3%	7.7%
Jenny	0.0%	1.19%	38%	4.99%	47.51%	0.0%	8.31%

Note. All Participant names have been changed to preserve anonymity.

Table F2 – Study Participant School Percent Economically Disadvantaged

Pseudonym	Economically Disadvantaged
Angela	17.87
Midge	17.87
Olivia	17.87
Jack	31.49
Meggin	17.87
Alyssa	13.74
Matt	19.87
Sarah	19.87
Neil	15.2
Jeff	42.6

Pseudonym	Economically Disadvantaged
Andrea	55.9
Jenny	66.03

Note. All Participant names have been changed to preserve anonymity.

Appendix E: Interview Protocol

Time & Date:

Interviewee:

[Initial Interview Introduction]

I want to thank you for your willingness to participate in this research study. The purpose of this research is to better understand the ways that teachers make sense of the instructional practices they use in their classrooms. Do you have any questions that you would like to ask prior to starting the interview? Then let's begin.

Initial Interview Prompts

1. Please, tell me about yourself, teaching experience, and what you currently teach.
2. How would you describe yourself as a math student?
3. Why did you choose to be become a math teacher?
4. How would you describe yourself as a math teacher?
5. How are the ways you teach math similar to and different from the ways you were taught math as a student?
6. Would you have liked your math class as a student?
7. What was the last instructional practice that you worked to make a part of your practice?
8. Tell me about a time you learned a new instructional practice? Something outside of your teacher prep program.

Share and this list of the 8 Instructional practices that are identified by NCTM as a framework for mathematics teaching

- Establish mathematical goals to focus learning
- Implement tasks that promote reasoning and problem solving
- Use and connect mathematical representations

- Facilitate meaningful mathematical discourse
- Pose purposeful questions
- Build procedural fluency from conceptual understanding
- Support productive struggle in learning mathematics
- Elicit and use evidence of student thinking.

11. How familiar are you with these practices?
12. Have you implemented any of these practices in your instruction?
13. I want to talk more in depth about one of these practices. Which one of these practices would you like to focus that discussion on?
14. Thinking about _____ (the practice identified by interviewee in previous question), when did you start learning about this as an instructional practice?
    a) What experiences have helped you develop this as a part of your instructional practice?
    b) Where have you found support in making sense of this instructional practice?
    c) Have you experienced success with the implementation of this instructional practice?
        a. How would you describe that success?
        b. What do you feel attributed to your success/lack of success with this practice?
    d) How has your view of this practice changed over time?
    e) How does this practice align with your experiences as a math learner?
    f) How does this practice align with those who you collaborate with?

[Thank participants for their responses. Confirm the classroom observation date, time, details.]

Classroom Observation Date: _________ Time: _________

Time & Date:

Interviewee:

[Post Observation Interview Introduction]

Thank you again for allowing me to visit your classroom. For this interview I'd like to talk about the instructional practices you used during the lesson I observed and talk about the ways you have learned to incorporate different instructional practices into your lessons.

Post Observation Interview Prompts

1. During the lesson I observed, I noticed you _____ (identify an instructional practice witnessed during the classroom observation), tell me how you developed that practice as a part of your teaching practice?
2. What makes you want to try a new instructional practice in your classroom?
3. What makes you continue using an instructional practice in your classroom?
4. What is something that you have learned this year that you feel you've grown in (or seen success with?)
5. When do you think you have been the most effective in implementing an instructional practice in your classroom? Why?
6. What types of PD best support you in learning and using a new instructional practice in your classroom?
7. Do you consider yourself a mathematician?

[Interview Conclusion]

Thank you again for sharing your classroom with me as well as taking the time to talk about the instructional practices you utilize in your classroom. I appreciate all that you have shared. Don't hesitate to contact me if you have any questions. Have a wonderful rest of the school year.

Appendix F: TRU Math Framework

TRU Math: Teaching for Robust Understanding in Mathematics[1]

Scoring Rubric

Release Version Alpha | REVISED July 31, 2014

This document provides the summary scoring rubric for the TRU Math (Teaching for Robust Understanding of Mathematics) classroom analysis scheme. TRU Math addresses five general dimensions of mathematics classroom activity, and one dimension that is algebra-specific. Each of these six dimensions is coded separately during whole class discussions, small group work, student presentations, and individual student work.

1. The Mathematics	2. Cognitive Demand	3. Access to Mathematical Content	4. Agency, Authority, and Identity	5. Uses of Assessment
The extent to which the mathematics discussed in the observed lesson is focused and coherent, and to which connections between procedures, concepts and contexts (where appropriate) are addressed and explained	*The extent to which classroom interactions create and maintain an environment of productive intellectual challenge that is conducive to students' mathematical development*	*The extent to which classroom activity structures invite and support the active engagement of all of the students in the classroom with the core mathematics being addressed by the class*	*The extent to which students have opportunities to conjecture, explain, make mathematical arguments, and build on one another's ideas, in ways that contribute to students' development of agency, authority, and their identities as doers of mathematics*	*The extent to which the teacher solicits student thinking and subsequent instruction responds to those ideas, by building on productive beginnings or addressing emerging misunderstandings*

Content Elaboration for Contextual Algebraic Tasks: - The extent to which students are supported in dealing with complex modeling and applications problems, which typically call for understanding complex problem contexts (most frequently described in text), identifying relevant variables and the relationships between them, representing those variables and relationships symbolically, operating on the symbols, and interpreting the results.

This document is a research tool; it is not intended for use in teacher evaluations. Detailed instructions regarding the use of this scoring rubric are provided in *The TRU Math Scoring Guide*. Information regarding the genesis, rationale, and applications of the TRU Math scheme can be found in the document *An Introduction to Teaching for Robust Understanding in Mathematics (TRU Math)*. Both documents, along with this scoring rubric and TRU Math coding sheets, are available at <http://ats.berkeley.edu/tools.html>.

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Summary Rubric

	The Mathematics	Cognitive Demand	Access to Mathematical Content	Agency, Authority, and Identity	Uses of Assessment
	How accurate, coherent, and well justified is the mathematical content?	*To what extent are students supported in grappling with and making sense of mathematical concepts?*	*To what extent does the teacher support access to the content of the lesson for all students?*	*To what extent are students the source of ideas and discussion of them? How are student contributions framed?*	*To what extent is students' mathematical thinking surfaced; to what extent does instruction build on student ideas when potentially valuable or address misunderstandings when they arise?*
1	Classroom activities are unfocused or skills-oriented, lacking opportunities for engagement with key grade level content (as specified in the Common Core Standards)	Classroom activities are structured so that students mostly apply memorized procedures and/or work routine exercises.	There is differential access to or participation in the mathematical content, and no apparent efforts to address this issue.	The teacher initiates conversations. Students' speech turns are short (one sentence or less), and constrained by what the teacher says or does.	Student reasoning is not actively surfaced or pursued. Teacher actions are limited to corrective feedback or encouragement.
2	Activities are at grade level but are primarily skills-oriented, with few opportunities for making connections (e.g., between procedures and concepts) or for mathematical coherence (see glossary).	Classroom activities offer possibilities of conceptual richness or problem solving challenge, but teaching interactions tend to "scaffold away" the challenges, removing opportunities for productive struggle.	There is uneven access or participation but the teacher makes some efforts to provide mathematical access to a wide range of students.	Students have a chance to explain some of their thinking, but the teacher is the primary driver of conversations and arbiter of correctness. In class discussions, student ideas are not explored or built upon.	The teacher refers to student thinking, perhaps even to common mistakes, but specific students' ideas are not built on (when potentially valuable) or used to address challenges (when problematic).
3	Classroom activities support meaningful connections between procedures, concepts and contexts (where appropriate) and provide opportunities for building a coherent view of mathematics.	The teacher's hints or scaffolds support students in productive struggle in building understandings and engaging in mathematical practices.	The teacher actively supports and to some degree achieves broad and meaningful mathematical participation; **OR** what appear to be established participation structures result in such engagement.	Students explain their ideas and reasoning. The teacher may ascribe ownership for students' ideas in exposition, **AND/OR** students respond to and build on each other's ideas.	The teacher solicits student thinking and subsequent instruction responds to those ideas, by building on productive beginnings or addressing emerging misunderstandings.

Whole Class Activities: **L**aunch, Teacher **E**xposition, Whole Class **D**iscussion

*On the score sheet, Circle one of **L / E / D** if the episode is primarily of that type. If a Launch is primarily logistical, some dimensions may be labeled N/A.*

	The Mathematics	Cognitive Demand	Access to Mathematical Content	Agency, Authority, and Identity	Uses of Assessment
	How accurate, coherent, and well justified is the mathematical content?	*To what extent are students supported in grappling with and making sense of mathematical concepts?*	*To what extent does the teacher support access to the content of the lesson for all students?*	*To what extent are students the source of ideas and discussion of them? How are student contributions framed?*	*To what extent is students' mathematical thinking surfaced; to what extent does instruction build on student ideas when potentially valuable or address misunderstandings when they arise?*
1	Classroom activities are unfocused or skills-oriented, lacking opportunities for engagement with key grade level content (as specified in the Common Core Standards)	Classroom activities are structured so that students mostly apply memorized procedures and/or work routine exercises.	There is differential access to or participation in the mathematical content, and no apparent effort to address this issue.	The teacher initiates conversations. Students' speech turns are short (one sentence or less), and constrained by what the teacher says or does.	Student reasoning is not actively surfaced or pursued. Teacher actions are limited to corrective feedback or encouragement.
2	Activities are at grade level but are primarily skills-oriented, with few opportunities for making connections (e.g., between procedures and concepts) or for mathematical coherence (see glossary).	Classroom activities offer possibilities of conceptual richness or problem solving challenge, but teaching interactions tend to "scaffold away" the challenges, removing opportunities for productive struggle.	There is uneven access or participation, but the teacher makes some efforts to provide mathematical access to a wide range of students.	Students have a chance to explain some of their thinking, but the teacher is the primary driver of conversations and arbiter of correctness. In class discussions, student ideas are not explored or built upon.	The teacher refers to student thinking, perhaps even to common mistakes, but specific students' ideas are not built on (when potentially valuable) or used to address challenges (when problematic).
3	Classroom activities support meaningful connections between procedures, concepts and contexts (where appropriate) and provide opportunities for building a coherent view of mathematics.	The teacher's hints or scaffolds support students in productive struggle in building understandings and engaging in mathematical practices.	The teacher actively supports and to some degree achieves broad and meaningful mathematical participation; **OR** what appear to be established participation structures result in such engagement.	Students explain their ideas and reasoning. The teacher may ascribe ownership for students' ideas in exposition, **AND/OR** students respond to and build on each other's ideas.	The teacher solicits student thinking and subsequent instruction responds to those ideas, by building on productive beginnings or addressing emerging misunderstandings.

Small **G**roup Work

If students are engaged in early brainstorming, the role of the teacher is to support students in exploring and justifying. This is the reason for "ORs" in the scoring.

	The Mathematics	Cognitive Demand	Access to Mathematical Content	Agency, Authority, and Identity	Uses of Assessment
	How accurate, coherent, and well justified is the mathematical content?	*To what extent are students supported in grappling with and making sense of mathematical concepts?*	*To what extent are all students supported in meaningful participation in group discussions?*	*To what extent do teacher support and/or group dynamics provide access to "voice" for students?*	*To what extent does the teacher monitor and help students refine their thinking within small groups?*
1	The mathematics discussed is not at grade level; **OR** discussions are aimed at "answer getting." Explanations, if they appear, are largely procedural.	Activities or teacher intervention constrain students to activities such as applying straightforward or memorized procedures.	Some students are disengaged or marginalized, and differential access to the mathematics or to the group is not addressed.	Teacher interventions, if any, either constrain students to producing short responses to the teacher **OR** do not address clear imbalances in group discussions.	Teacher actions are simply corrective (e.g., leading students down a predetermined path) and the teacher does not meaningfully solicit or pursue student thinking.
2	Discussions are at grade level but are primarily skills-oriented, with few opportunities for making connections (e.g., between procedures and concepts) or for mathematical coherence (see glossary).	Activities offer possibilities of productive engagement or struggle with central mathematical ideas, BUT students are either left unsupported when lost, OR the teacher's actions scaffold away challenges.	All team members appear to be doing mathematics, but some are not participating in group activities; the teacher does not support their engagement in student-to-student discussion.	At least one student has a chance to talk about the mathematical content, but the teacher is the primary driver of conversations and arbiter of correctness. Students are not supported in building on each other's ideas.	Teacher solicits student thinking, but subsequent discussion does not build on nascent ideas. Teacher actions are corrective in nature, possibly by leading students in the "right" directions.
3	Explanation of and justification for central grade level mathematical ideas is coherent.	Students are supported in engaging productively with central mathematical ideas. This may involve struggle; it certainly involves having time to think things through.	Everyone in the team contributes to group or subgroup mathematical discussions, **OR** teacher moves to have all team members make meaningful contributions.	At least one student puts forth and defends his/her ideas/reasoning **AND, EITHER** students build on each other's ideas **OR** the teacher ascribes ownership for students' ideas in subsequent discussion.	The teacher solicits student thinking, **AND** subsequent discussion responds to those ideas, by building on productive beginnings or addressing possible misunderstandings.

Student Presentations

*Some episodes are in essence a conversation between teacher and student presenter(s); some conversations that involves the whole class. Scoring in the rubrics corresponds to the presence of these two different participation structures: **C** for a teacher-presenter **c**onversation, and **W** for **w**hole-class involvement.*

	The Mathematics	Cognitive Demand	Access to Mathematical Content	Agency, Authority, and Identity	Uses of Assessment
	How accurate, coherent, and well justified is the mathematical content?	*To what extent are students supported in grappling with and making sense of mathematical concepts?*	*To what extent does the teacher support presenters or class in engaging with the mathematics?*	*To what extent are students the source of presented ideas and response to presented ideas?*	*To what extent is students' mathematical thinking surfaced and serve as grounds for conversation?*
1	Presentation is aimed at "answer getting" without addressing underlying reasoning.	Presentation and classroom discussion focus on straightforward or familiar facts and procedures.	**(C):** Presenter(s) need support/encouragement but do not receive it; **OR** **(W):** A significant number of students appear disengaged.	Presenter role is structured by teacher/text and student is narrowly constrained in response to teacher questions.	Student reasoning is not surfaced or pursued. Teacher actions are limited to corrective feedback or encouragement.
2	The mathematics presented is largely procedural; presenter(s) are not expected to explain their ideas or supported in doing so.	Presentation offers possibilities of conceptual richness or problem solving challenge, but teaching interactions tend to "scaffold away" these possibilities, resulting in a focus on straightforward or familiar facts and procedures.	**(C):** Teacher encourages presenters but does not provide effective scaffolding; **OR (W):** The presentation evolves into whole class activity. There is uneven participation and the teacher does not provide structured support for many students to participate in meaningful ways.	Presenters have the opportunity to demonstrate individual proficiency, without being tightly constrained by text or teacher. **BUT,** the discussions do not build on students' ideas. (*To qualify as an *idea*, what is referred to must extend beyond the tasks, diagrams, etc., that students were given.)	In presentation and discussion the teacher refers to student thinking, perhaps even to common mistakes, but specific student ideas are not built on (when potentially valuable) or used to address challenges (when problematic).
3	The mathematics presented is relatively clear and correct, **AND** either includes justifications or explanations **OR** the teacher encourages students to focus on central mathematical ideas and explaining and justifying them.	The teacher's hints or scaffolds support presenters and/or class in "productive struggle" in building understandings and engaging in mathematical practices.	**(C):** Teacher supports presenters (if needed) in engaging, **OR (W):** The presentation evolves into whole class activity in which the teacher actively supports broad participation and/or what appear to be established participation structures result in such participation.	Student presentations result in further discussion of relevant mathematics, **OR** students make meaningful reference to other students'/groups' ideas in their presentations. (*To qualify as an idea, what is referred to must extend beyond the tasks, diagrams, etc., that students were given.)	In presentation and discussion the teacher solicits student thinking and responds to student ideas by building on productive beginnings or addressing emerging misunderstandings.

Individual Work

Student seat work is coded as N/A unless the teacher is actively circulating through the classroom and consulting with students on an ongoing basis. Note that with a stationary camera it is impossible to see individual student work. Hence, unless there is evidence from the conversation, one cannot discern student errors.

	The Mathematics	Cognitive Demand	Access to Mathematical Content	Agency, Authority, and Identity	Uses of Assessment
	How accurate, coherent, and well justified is the mathematical content?	*To what extent are students supported in grappling with and making sense of mathematical concepts?*	*To what extent is there equitable access to meaningful participation for all students?*	*To what extent are students the source of presented ideas; do students respond to presented ideas?*	*To what degree does the teacher monitor and help students refine their thinking as he or she circulates through the class?*
	May be N/A if there are insufficient data; or…	May be N/A if there are insufficient data; or…	May be N/A if there are insufficient data; or…	May be N/A if there are insufficient data; or…	May be N/A if there are insufficient data; or…
1	Materials are aimed at "answer getting" without addressing underlying reasoning.	Materials demand no more than applying familiar procedures or memorized facts.	A significant number of students appear disengaged and there are no overt mechanisms to support engagement.	Teacher shows or tells students how to do the mathematics, possibly correcting student work. Student ideas are not elicited or built upon.	Teacher actions are limited to corrective feedback or encouragement.
2	Materials for student work provide some affordances for coherent mathematics, but teacher support is minimal and does not exploit them.	Materials offer possibilities of conceptual richness or problem solving challenge, but teaching interventions tend to "scaffold away" the challenges.	Students appear to be working, but there are no clear mechanisms for students who want or need support or attention to receive it.	One-on-one interactions give students the opportunities to talk about their ideas and/or provide access to varied ways to engage in the mathematics.	Individual interactions provide opportunities for students to discuss their thinking, and teacher responses address such thinking explicitly (not simply correcting student work).
3	The teacher's interventions with individual students support a coherent and connected view of the mathematics.	The teacher's hints or scaffolds support students in "productive struggle" in building understandings and engaging in mathematical practices.	Teacher's and/or surrogates' attention is clearly and widely available for those students who want it, resulting in access to the mathematics.	A score of 3 is not coded *unless* the student has ample opportunity and agency to develop his/her idea interacting with the teacher, **OR** the teacher takes the student idea up for class discussion right after individual work ends.	The teacher solicits student thinking and subsequent discussions respond to those ideas, by building on productive beginnings or addressing emerging misunderstandings.