Mathematics Teachers' Perceptions of, and Strategies for, Implementing Inquiry-Based Teaching and Learning

By

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Abstract

Inquiry-based mathematics is based on principles of reform mathematics that aim to enhance students' problem-solving skills, giving them opportunities to generate ideas, formulate their own questions, and develop strategies in order to justify answers (Manouchehri, 1997; National Council of Teachers of Mathematics, 1989). This research study examines how mathematics teachers enact inquiry-based pedagogy in the intermediate classroom and the outcomes associated with student learning.

Three experienced Ontario intermediate mathematics teachers were interviewed for this study using face-to-face semi-structured interviews. Interviews focused on exploring how teachers implement inquiry-based practice in the mathematics classroom in order to understand best practices associated with this style of teaching. The analysis of the data collected and the relevant literature on this topic reveal teachers' conceptualizations and the strategies they implement when using inquiry to teach mathematics. Various themes emerged that relate to how mathematics teachers enact this inquiry-based pedagogy in their classroom including instructional approaches in inquiry and the challenges that teachers experience. The results indicted that it is the students who drive the inquiry while the teacher facilitates.

Keywords: Inquiry-Based, Mathematics, Constructivism

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Chapter 1: Introduction

1.0 Research Context

Constructivism is a teaching approach that encourages inquiry-based thinking, different from traditional mathematics teaching. Instead of delivering content, teachers create opportunities for students to enhance their critical thinking and problem-solving skills through more open-ended tasks. Incorporating constructivist activities in the mathematics classroom is becoming more common practice for teachers. The teacher's role is important, as they are the facilitators that guide the students during activities rather than lecture (Cobb, Wood, & Yackel, 1993). It is the teacher's responsibility to create a learning environment that encourages exploration and inquiry while also considering the individual needs of their students (Simon & Schifter, 1991). A major concern emerges in the practice of constructivism in the mathematics classroom, as teachers must be able to provide effective inquiry-based math lessons in order to enhance students' conceptual understanding (Chapman, 2011). However, research has found that teachers struggle to implement *effective* constructivist strategies in mathematics classrooms (Simon & Schifter, 1991; Chapman, 2011).

Professional development programs are designed to prepare teachers to implement constructivist practice in their classrooms successfully and effectively. Programs provide the guidance and support needed to increase teachers' confidence in using constructivism in their mathematics classrooms (Simon & Schifter, 1991). However, research has found that teachers are still apprehensive in regards to facilitating mathematical inquiry and some do not know *how* to properly implement inquiry-based lessons in the classroom (Simon & Schifter, 1991). Research has found that teachers are uncomfortable with becoming a facilitator as they might lack the conceptual background knowledge necessary to effectively implement inquiry-based activities in their classrooms. Teachers committed to constructivist pedagogy hesitate to label a students' answer as right or wrong – instead, they must be able to accept the uncertainty and freedom associated with constructivism (Simon & Schifter 1991; Burns, 2007).

Although constructivism in the mathematics classroom has been an extensively debated topic throughout the literature, questions remain as to whether this style of teaching is successful in an intermediate context. In primary classrooms, research studies have shown that students learning mathematics through constructivist approaches were actively involved in the learning process and developed greater understanding of mathematical concepts (Brewer & Daane, 2002; Cobb, Wood, & Yackel, 1992). As mathematics becomes more challenging in the intermediate grades however, inquiry-based tasks become more complex as well (Burns, 2007). Ultimately, it is beneficial to understand how teachers are implementing constructivist practices successfully to support students and guide them in the learning process.

1.1 Research Problem

Constructivist approaches allow students to engage in deeper learning and collaborative discourse with their peers. In mathematics, constructivism encourages students problem solve and build meaningful knowledge that is complex, powerful, and conceptual (Cobb, 1988). Although research shows constructivist approaches can have these benefits for students (Simon, 1986; Cobb, 1988; Cobb, Wood, & Yackel, 1993), it also shows that teachers experience challenges with how to implement it effectively when they themselves were educated through outcomes-based approaches that prioritized answers, not mathematical thinking (Simon & Schifter, 1991; Steffe, 1990; Burns, 2007; Chapman, 2011). Teachers need to know how to use constructivism effectively in order to create learning environments where students can construct their own knowledge and engage in higher-order thinking (Steffe, 1990).

1.2 Research Purpose

In view of this problem, the purpose of my research is to learn how intermediate mathematics teachers implement an inquiry-based approach in order to share best practices and strategies with the education community. I want to learn how mathematics teachers can effectively employ constructivist strategies to engage students through inquiry-based learning.

1.3 Research Questions

The main question guiding this research study is: How is a sample of intermediate mathematics teachers enacting inquiry-based pedagogy?

Subsidiary Questions:

- How do mathematics teachers conceptualize inquiry-based approaches in theory and in practice?
- What experiences, resources (e.g. books, manipulatives, websites), and factors support these teachers' confidence and competence to teach math through inquiry-based pedagogy?

- What are some barriers that these teachers encounter and how do they respond to them?
- What do these teachers observe in terms of students' mathematical understanding and engagement?

1.4 Background of the Researcher

As someone who experienced difficulties in mathematics as a student, I believe in the importance of teaching math in an engaging way. My intermediate math teachers taught using traditional methods, delivering the content as students copied information in their notebooks. I memorized abstract concepts and formulas because I did not learn how to conceptually understand the content. As a result, I failed many math tests because I did not have additional support in class to enhance my problem-solving and critical thinking skills.

I avoided math throughout university and the thought of teaching it in the future worried me. However, my passion for teaching overshadowed my math anxiety as I still applied to many junior/intermediate consecutive education programs. In my first practicum, I was tasked with teaching Grade Seven students a unit on measurement. I did not expect to teach math so soon, especially using inquiry-based strategies. My associate teacher advocated inquiry-based mathematics, creating problem-solving activities that enhanced his students' conceptual understanding. He wanted all of my math lessons to be designed as guided inquiry in order to support his students' needs. As I never excelled in math, I believed I did not have enough background knowledge to incorporate inquiry-based pedagogy in my math lessons effectively. When students asked me questions regarding the open-ended tasks I assigned them, I would have difficulty answering. I did not know *why* two parallelograms helped students find the formula for area of a trapezoid or how to explain that one square metre equated ten thousand centimetres. Developing these inquiry-based tasks made me realize how much background knowledge is required to effectively teach students through inquiry-based pedagogy. Although students construct their own knowledge, they still must be supported and guided during the process.

My experiences in my practicum contributed to my growing interest in inquiry-based pedagogy and impelled me to study how intermediate teachers are incorporating this method of teaching in their classrooms. It is important to me that I teach math in an engaging way, supporting students throughout the process. I saw my associate teacher use constructivism and inquiry-based practice successfully so I know it can be used effectively to teach math. However, I am concerned that not all teachers are as confident in implementing inquiry-based activities. I would like to learn from teachers how use constructivism and inquiry-based activities effectively so I can better support and engage my future students in mathematics.

1.5 Overview

To respond to the research questions I have conducted a qualitative research study using purposeful sampling to interview three teachers about their strategies for effectively integrating constructivist practice in the intermediate mathematics classroom. Chapter 2 contains a review the literature in the area of constructivism, looking particularly at professional development programs, teachers' attitudes and beliefs toward constructivism, and the challenges of constructivism in the math classroom. Chapter 3 provides the methodology and procedure used in this study including information about the sample participants and data collection instruments. Chapter 4 identifies the participants in the study and describes the data as it addresses the research question. In Chapter 5, I present an analysis of the interview data, discuss limitations of the study, conclusions, recommendations for practice, and further reading and study. References and a list of appendices follow at the end.

Chapter 2: Literature Review

2.0 Introduction

As mathematics education has encountered a paradigm shift from traditional to reform practice, many teachers are tasked with creating engaging constructivist lessons that enhance students' conceptual knowledge (Simon & Schifter, 1991). In this chapter I review the research in the area of constructivism in mathematics education, beginning with the theoretical framework and pedagogy of constructivism. The scope of this literature review is expanded to include research that examines traditional versus reform mathematics, professional development programs, the teachers' role in constructivist classrooms, the constructivist classroom environment, teachers' beliefs and attitudes toward constructivism, and the challenges of implementing constructivism in the mathematics classroom.

2.1 Theoretical Framework

Inquiry-based learning is based on constructivist learning theories. Constructivism is a philosophical perspective of learning that is rooted in the early theoretical and empirical work of Piaget (Simon & Schifter, 1991). The core idea is that learners construct their own knowledge and meaning in relation to their actions and experiences – it is always contextual, never separated from the knower (Wheatley, 1991). According to Piaget (1967) knowledge does not attempt to produce a copy of reality but, instead, serves the purposes of adaptation in which learners can produce coherent, non-contradictory conceptions to solve problems presented by the environment. Piaget's model of constructivism further theorizes that learning occurs through assimilation or accommodation. Assimilation occurs when new information is incorporated into existing knowledge or schemas based on previous experiences. On the other hand, accommodation involves modifying existing schemas as a result of new information or experiences. In line with constructivist theory, Piaget's concept of disequilibrium is the foundation for learning (Dethlefs, 2002).

Disequilibrium creates an imbalance between new information and what is already understood. Prior knowledge must be adapted because new information conflicts with what is known to cause disequilibrium. Engaging in constructivist tasks causes either equilibrium or disequilibrium and as a consequence, learners must assimilate or accommodate new information (Piaget, 1967; Dethlefs, 2002). Furthermore, meaningful learning experiences occur as learners develop complex cognitive structures that assimilate and accommodate incoming knowledge (Dethlefs, 2002).

Constructivism is consistent with Dewey's (1963) "experiential education" where educational programs connect to real life experiences. Experiential learning is based on three assumptions: learning is enhanced when students are personally involved in the learning experience; knowledge has to be discovered by the learner if it is to have significant meaning to them; and a person's commitment to learning is highest when they can create their own learning goals and are able to actively pursue them within a given conceptual framework (Dewey, 1963; Maher & Alston, 1990).

More recent research has highlighted the importance of constructivism as it applies to the real world. According to Checkley (2006) the constructivist math classroom builds students' understanding and prepares them for real life situations.

Beyond the theoretical framework, general agreement about constructivist learning exists in the literature, operationalized in many different ways.

2.2 Constructivism and Mathematics Pedagogy

In line with these theoretical perspectives, Kilpatrick (1987) believed constructivism "seems to be having an especially strong impact on the thinking and activities of mathematics educators" (p. 5). He describes two hypotheses of constructivism: knowledge is actively developed by the learner and passively received by the environment; coming to know is an adaptive process that organizes one's experiential world – it does not discover an independent, pre-existing world outside the mind of the knower. Mathematics educators generally accept the first hypothesis, as teachers allow students to construct meaning and consolidate their thinking through reflection (Lerman, 1989). Educators who accept both hypotheses have been called "radical constructivists" – those who advocate this theory believe that knowledge is constructed through discovery learning, learning in complex situations, and learning in social contexts (Anderson, Reder, & Simon, 1998)

Constructivism is an alternative paradigm to instruction in the realm of mathematics. A fundamental goal of mathematics instruction is to help students build meaningful knowledge that is complex, powerful, and conceptual and thus, the teacher's role is to facilitate profound cognitive restructuring and sophisticated understanding of concepts (Simon, 1986; Cobb, 1988). However, teachers must adopt the curriculum reform and become facilitators in the learning process to successfully implement constructivism in the classroom (Kamii, Lewis, & Jones, 1991). Not all educators are comfortable with constructivism and the transition from traditional pedagogy to reform-oriented practice can be an overwhelming responsibility (Steffe 1990; Simon, 1995; Burns, 2007).

2.3 From Traditional to Reform Mathematics

Mathematics instruction is evolving to encompass reform-oriented practices that include active construction and teaching as facilitation rather than content-based transmission (Simon & Schifter, 1991; Cobb, Wood, and Yackel, 1993; Manouchehri, 1997; Hills, 2007). The teacher encourages exploration and discussion through a mathematical community focused on student-centered learning (Simon & Schifter, 1991). This shift toward more active learning in mathematics is explained through the National Council of Teachers of Mathematics standards (NCTM).

2.3.1 NCTM standards. The Board of Directors of the National Council of Teachers of Mathematics in the United States established the *Curriculum and Evaluation Standards for School Mathematics* (1989) outlining reform practices for mathematics classrooms. This document proposes a new vision of mathematics teaching different from traditional mathematical learning where knowledge is delivered to students who passively receive it. Cooney and Brown (1985) argue that a theory in mathematics education must be able to improve teaching and learning of mathematics. Reform-based mathematics is based on constructivist principles aiming to enhance students' problem-solving skills, giving them opportunities to generate ideas, ask questions, develop strategies, and justify answers (Manouchehri, 1997). In line with these principles, the

Professional Standards for School Mathematics outlined by the NCTM, envisioned teachers' responsibilities in four areas: selecting appropriate mathematical tasks to achieve set goals, facilitating classroom discourse in a way that promotes student understanding, creating a classroom environment to support the teaching and learning of mathematics, and analyzing student learning in order to make ongoing modifications and instructional decisions (p. 5). Teachers must accept these responsibilities if constructivist mathematics teaching is to be used effectively.

According to the NCTM, teaching reform mathematics curricula has been a slowly evolving process within the past decade. Teachers are gradually implementing constructivist math textbooks into classroom teaching, discarding traditional textbooks that advocate computation through repeated problem-solving tasks (Hills, 2007). Without these significant curriculum changes, the majority of teachers would not be able to implement constructivist teaching practices successfully. The NCTM standards guide teachers toward developing deeper, more sophisticated open-ended lessons that aim to actively engage students in mathematics (Manouchehri, 1997; Hennessy, Higley, & Chesnut, 2012).

2.3.2 Professional development programs. Cooney (1988) stated that, "One of the central issues facing our profession is how the NCTM (1989) Curriculum and Evaluation Standards for School Mathematics can influence mathematics teacher education programs…. the task that lies ahead is both significant and awesome" (p. 352). In line with Cooney (1988), the Educational Leaders in Mathematics (ELM) Project designed a professional development program addressing three goals:

1. Design an innovative program for pre-service teachers of mathematics formed on the basis of recent research and theoretical work,
2. Analyze how outcomes of this program affect teachers' thinking and practice,
3. Study the effects of this program on the students of the participating teachers.

According to Simon and Schifter (1991) many professional development programs simply expose prospective teachers to instructional strategies and materials, often providing inadequate preparation to teach reform mathematics successfully. Furthermore, the ELM inservice intervention provides opportunities for teachers to examine the nature of mathematics and the process of learning mathematics through programs that enhance mathematical understanding and promote conceptual development. This program provides the supervision and support needed to increase teachers' confidence in implementing constructivism into classroom practice. Teachers' mathematical abilities were further developed as they had the opportunity to construct meaning and conceptualize content through discussion – a necessary component of a constructivist classroom (Simon & Shifter, 1991).

A more recent professional development program functions on the same principles but emphasizes the importance of agency in terms of teaching mathematics. Chapman's (2011) quantitative study of a self-directed, practice-based professional development program exposed teachers to questioning techniques designed to enrich student thinking. Participants included fourteen practicing teachers with representation from grades one to six. Teachers engaged in meaningful practice throughout the study, probing student thinking through questioning and gaining an understanding of how to observe students' problem-solving behavior. Through this self-directed professional development program, teachers became more confident in their ability to provide effective constructivist math lessons to students. According to Bruner (1996), "Agency implies not only the capacity for initiating, but also for completing our acts, it also implies skill or know-how" (p. 36). Applying the notion of agency to self-directed professional development programs gives teachers the authority to make their own decisions, crafting their teaching methods in terms of goals, activities, process, and outcome (Bruner, 1996; Chapman, 2011). In this study and in many similar professional development programs, teachers gained the skills and background knowledge necessary to facilitate constructivist mathematics lessons more confidently and effectively (Simon & Schifter, 1991; Simon & Shifter, 1992; Chapman, 2011). These professional development programs showcase new directions for how educators can facilitate students' learning in the mathematics classroom.

2.4 The Application of Constructivism in the Mathematics Classroom

Constructivism in the mathematics classroom has been considered as an instructional practice as early as 1987 as a way to counteract the obstacles in traditional mathematics teaching. Schön (1987) advocated that teachers should engage in practices that focus on the learning process rather than answers. The issue is, how is this kind of teaching developed? What kinds of environments are appropriate for teachers so they can exercise effective constructivist practice? These questions are answered throughout the literature on constructivism.

2.4.1 Teacher's role. The teacher's role is important, as they are there to facilitate rather than deliver content. Cole and Wasburn-Moses (2010) emphasized that constructivist pedagogy and inquiry-based teaching is a student-centered approach that underscores collaborative learning rather than content delivery. Cobb, Wood, and Yackel (1993) argued that the teacher has a duel role of cultivating students' conceptual knowledge and encouraging students to share their knowledge through collective discussion. In order to do this, teachers' responsibilities also involve planning. According to Simon (1995) the planning of instruction through constructivist principles is problematic for teachers. Brousseau (1987) claimed that students must have freedom to construct a response to a mathematical situation on the basis of their prior knowledge of the context and their developing mathematical understanding. However, if the situation *leads* the students to make a certain response, no real conceptual learning takes place (Brousseau, 1987; Simon, 1995 – translation). As Brousseau (1987) further stated, "If the teacher has no intention, no plan, no problem, or well-developed situation, the child will not do and will not learn anything" (p. 8; Simon 1995).

Ball (1993) and Steffe (1991) have also conducted investigations pertaining to teacher planning. Steffe (1991) emphasized that teachers' plans must be informed by the mathematics *of* the students and relate to what students already know. Similarly, Ball (1991) believed constructivist teaching to be an ongoing inquiry into content and students' thinking and into ways that contexts can be structured to enhance learning experiences. Further research is needed in order to understand the pedagogical discourse in reform-oriented (constructivist) mathematics teaching (Simon, 1995).

2.4.2 Creating a constructivist environment. In order for students to excel in constructivist mathematics classrooms, teachers must create environments designed to optimize learning. The literature suggests that a constructivist environment is either the creation of the teacher or the creation of the teacher *and* student (Pirie & Kieren, 1992; Fosnot, 1996; Hennessy, Higley, & Chesnut, 2012). Fosnot (1996) built on Piaget's theories and described constructivist classrooms as environments where students actively construct their own knowledge and meaning through processes of disequilibrium, reflection and dialogue. According to Fosnot (1996), teachers must foster student learning and enhance their understanding by providing students with investigations that challenge their current conceptions, explore multiple solutions, test various hypotheses, and justify answers. Therefore, it is the teachers' intentions that determine the constructivist nature of teaching, deliberately creating an environment conducive to inquiry-based learning (Pirie & Kieren, 1992). In support of creating constructivist environments, von Glasersfeld's (1990) beliefs align with Fosnot's assertion:

> "The task of education … becomes a task of first inferring models of the students' conceptual constructs and then generating hypotheses as to how the students could be given the opportunity to modify their structures so that they lead to mathematical actions that might be considered compatible with the instructor's expectations and goals" (von Glaserfeld, 1990, p. 34)

It is the constructivist classroom environment that the teacher creates which determines whether students will engage in meaningful mathematical knowledge development in line with the teacher's expectations and goals.

More recent literature emphasized the role of the teacher and student in creating and maintaining an effective constructivist classroom environment (Chapman, 2011; Hennessy, Higley, & Chesnut, 2012; Leiken & Rota, 2006). According to Hennessy, Higley, and Chesnut (2012), teachers and students actively construct meaning to each others' actions. The teacher reflects on student knowledge through interactions with students and hypothesizes what the student knows and what type of learning experiences would suit the student's background knowledge, enabling them to learn another concept successfully. However, the belief that teachers and students create a constructivist environment together has not always been supported in the literature. Cobb (1988) contended that even though students may complete a task successfully, it is not necessarily true that students have absorbed the knowledge the teacher believes he or she has transmitted. Instead, the students have found a way of performing the task in line with the teacher's expectations about the outcomes of constructivist instruction. Therefore, the constructions that students articulate align with those that the teacher believes they have made (von Glasersfeld, 1983). An evolution is present in constructivist instructional practice as more recent literature values teacher and student interaction as instrumental in enhancing the learning process (Chapman, 2011; Hennessy, Higley, & Chesnut, 2012).

2.4.3 Student outcomes. Brewer and Daane (2002) conducted a study that revealed student outcomes of constructivist learning environments. Primary students were observed in eight mathematics classrooms where teachers guided inquiries. They found that students were actively involved in the learning process, as they made their own decisions about appropriate problem solving strategies and questioned each other's solutions. Autonomy was encouraged as students had opportunities to think for themselves in an environment where they were responsible for much of their own learning (Brewer & Daane, 2002). Similar research studies have shown that students in constructivist classrooms have had a deeper understanding of mathematics and experienced more success than those in traditional mathematics classrooms because they were more actively involved in their learning (Cobb, Wood, Yackel, & Perlwitz, 1992). Students become actively involved, as they have opportunities to work collaboratively in a group setting and risk free environment where they feel comfortable questioning and exchanging ideas about math problems (Brewer & Daane, 2002).

2.5 Teacher's Beliefs and Attitudes Toward Constructivism

Through an empirical study, Stipek, Givvin, Salmon, and MacGyvers (2001) investigated teachers' beliefs and values about constructivism. The study was based on the premise that teachers' beliefs about teaching influence their constructivist teaching practices. As Stipek, et al. (2001) predicted, teachers who embraced more traditional beliefs about mathematics instruction had lower self-confidence and enjoyed mathematics less that teachers who adopted more constructivist views. Teachers who deviate from traditional mathematics instruction are able to diagnose and analyze students' misconceptions, providing appropriate intervention in line with constructivist principles. As Stipek et al. (2001) speculated, building teachers' confidence in mathematics involves strengthening their conceptual understanding and moving them toward more constructivist beliefs.

Research has found that teachers' beliefs are mainly acquired during their schooling years through their experiences in mathematics. However, Bush (1986) contended that social context is more influential in developing teachers' beliefs about mathematics. He believed that teachers already possess beliefs about teaching before they begin their teacher education program. It is common for teachers to revert to teaching styles familiar to those used by their past teachers (Brown, Cooney, & Jones, 1990). Therefore, it is concerning that teachers adhere to their prior beliefs because as Manouchehri (1997) concluded, "Teachers may not see the relevance of pedagogy courses to the process of learning to teach, and they may not attend closely to experiences and information in these courses" (p. 198). Modifying beliefs of mathematics that teachers have engrained in their practice is difficult. Professional education programs must be able to restructure teacher beliefs, teaching prospective teachers to explore different ways of solving problems so that they can effectively apply reform mathematics to their classroom practice (Manouchehri, 1997).

2.6 Challenges of Constructivism in Mathematics

Teachers face many challenges when confronted with the task of implementing constructivism into their classroom. Because constructivist teaching is open-ended, teachers are required to have extensive knowledge in order to engage students meaningfully. However, the literature suggests that student success depends greatly on teachers' knowledge and skills (Thompson, 1992; Simon, 1995; Leiken & Rota, 2006). The question remains contested in the literature: are teachers able to overcome the obstacles to constructivist practice?

2.6.1 Teacher anxiety. According to Simon (1991), teachers do not know *how* to properly implement constructivism in the classroom. Teachers who are unfamiliar with taking on the role as facilitator may experience discomfort and lack confidence in teaching students through constructivist methods. This discomfort may arise, as a constructivist teacher cannot label a students' answer as right or wrong – instead, it becomes an alternative conception. The teacher must be able to accept the uncertainty associated with constructivism, as students are free to explore mathematical concepts and generate their own solutions that may not always align with the teachers' ideas. Burns (2007) asserted that teachers do not feel comfortable with constructivist mathematics as they probably learned concepts through more algorithmic approaches. Burns (2007) suggested that a constructivist math textbook might help educators who are attempting to "teach what they do not truly understand" (Burns, 2007, p. 183). This more recent literature validates the current situation in constructivist classrooms – teachers have difficulty relinquishing their control.

2.6.2 Teacher inexperience. According to the recent literature, teachers encounter several obstacles to constructivism because they do not know how to use it as a basis for teaching (Simon & Schifter, 1991; Burns, 2007; Chapman, 2011). Constructivism in mathematics is a sophisticated practice that requires extensive background knowledge to conceptually understand difficult content. Beginner teachers who use this method and want their students to construct meaning, ask their students for ideas with the intention that at least one student will volunteer to explain it to others. However, Simon (1995) noted that if a group of students do not grasp a particular concept correctly, how do teachers intervene to encourage the development of that concept?

Therefore, teachers should be content specialists and according to Steffe (1990), "Using their own mathematical knowledge, mathematics teachers must interpret the language and actions of their students and then make decisions about possible mathematical knowledge their students might learn" (p. 395). Teachers' inexperience with constructivism prompted scholars to wonder whether professional development programs are providing enough support (Simon, 1995). Teachers must be able to see areas where students lack conceptual understanding and prescribe appropriate interventions to enhance knowledge. However, there are practicing teachers who lack the background to implement constructivism effectively, affecting students' learning experiences. Furthermore, teachers need to develop their own understandings first in order to engage students in meaningful learning (Steffe, 1990). Burns (2007) explained, "Teachers can't teach for understanding if they don't have a firm foundation of understanding themselves" (p. 5).

2.6.3 Constructivism is time consuming. According to Simon (1995), it is difficult to determine how much time is needed to teach a particular concept. When teachers use the constructivist approach in the classroom, they often overlook the complexity of tasks. Students need to have *time* to question, evaluate, and predict strategies for problem solving. The teacher's job is to construct a learning environment where the student seeks a response to the *milieu.* Whole class discussion is encouraged and allows the teacher to ask students questions to consolidate their thinking which can be time consuming (Simon, 1995). Steffe and Thompson (2000) agreed that constructivist teaching takes time, as the students and teachers need time to reflect, revise, and re-examine solutions. As there is less emphasis on teachers telling the answer in constructivist pedagogy, it is unlikely that a lesson will be completed in a single class session.

2.6.4 Diversity of response. Even though a teacher creates an initial goal and plan for instruction, it must be modified several times depending on how students respond during the study of a particular concept (Simon, 1995). According to Simon (1995), "A teacher may pose a task, however, it is what the students make of it and their experience with it that determines the potential for learning" (p. 133). Teachers see their students respond to the same problem in different ways, as they share their work with others – they have their own interpretation of the task and reveal their ideas about a mathematical concept (Pirie & Kieren, 1992). As Simon (1995) stated, "The only thing that is predictable in teaching is that classroom activities will not go as predicted" (p. 133).

According to Kuhlthau, Maniotes, and Caspari (2007), inquiry and constructivist pedagogy focuses on the learning *process*. Students generate different ideas and produce a variety of responses during the learning process that teachers monitor and evaluate in order to effectively support each student. Teachers have to think about *how* each student communicates, applies, and understands the material. As thoughts can sometimes be difficult to uncover, teachers use different strategies to assess student thinking, some examples include journals and/or conferences (Kuhlthau, et al., 2007).

2.6.5 Minimizing challenges. According to Steffe and Wiegel (1992), "The most basic responsibility of constructivist teachers is to learn the mathematical knowledge of their students and how to harmonize their teaching methods with the nature of that mathematical knowledge" (p. 17). In line with this view, Simon (1995) emphasized that teachers must accept that their goals and hypotheses about students' learning and understanding change continually and need to be modified in order to provide meaningful support. Teachers must communicate with and observe students to gain a new understanding of the student. Posing additional problems based on students conceptual difficulties will also provide the students with more practice in a way that aligns with the constructivist pedagogy. As Pelfrey (2006) emphasized, teachers should be responsive to student needs in order to effectively guide them throughout the learning process. According to Steffe and Thompson (2000), students can have a written record of solutions prepared that will be shared with a small group. Teachers must keep in mind that student responses might be revised throughout the consolidation process as they reflect on their thinking with their classmates. It is the teacher's priority to meet the needs of *all* students in the classroom.

According to Pirie and Kieren (1992), teachers must also be aware that not every student will be ready to move toward mathematics learning goals at the same time. Some students may not achieve this progress, as they develop understandings that are inconsistent with the teacher's conceptions. The teacher also must be aware that different people will hold different mathematical understandings and in order to implement constructivism successfully, the teacher believes in this difference of understanding and develops suitable interventions to reach a myriad of students. With this in mind, inquiry-based activities are most meaningful when they capture students' interests. Students are more likely to learn effectively in inquiry-based classrooms if the tasks challenge students to solve 'authentic' problems by constructing their own solutions (Hmelo-Silver, et al., 2006; Llewellyn, 2012; Whitehead, 2015). Whitehead (2015) echoed this belief and emphasized that learning can be sustained when students are actively engaged. Overall, the teacher must realize that students will be at various levels of learning and understanding and it is with this awareness that teachers can provide necessary support and plan effectively in order to create engaging tasks (Pirie & Kieren, 1992; Whitehead, 2015).

2.7 Conclusion

The literature has provided information on concepts of constructivism and constructivist instructional practice in teaching and learning mathematics. The literature has shown that although there have been some disagreements about constructivism, theorists and scholars have proven this theory to be beneficial in the mathematics classroom. After examining research particularly pertaining to constructivist pedagogy, professional development programs, and challenges I discovered that constructivism can be beneficial for students if implemented effectively. It has been suggested throughout the literature that more research is needed to help prospective teachers learn *how* to implement the best constructivist practices and I have yet to discover what teaching strategies work well with constructivist math activities.

In this study, I reveal and share the best strategies to integrate constructivist practice effectively into the intermediate mathematics classroom. As culled from the literature, the greatest advantage of the constructivist approach is students have the opportunity to take ownership of their learning experiences, engaging in meaningful activities to gain important skills that can be used in the school setting and beyond.

Chapter 3: Research Methodology

3.0 Introduction

This research study uses a qualitative research approach to investigate the ways in which intermediate mathematics educators use inquiry-based strategies to engage students. To gather qualitative data, semi-structured interviews will be conducted with practicing intermediate mathematics teachers. In this chapter I describe the research methodology and begin by reviewing the research approach, procedures, and data collection instruments, followed by an explanation on the participants I will recruit for this study. I explain data analysis procedures and review ethical considerations relevant to my study and will identify a range of methodological limitations and strengths affecting my research. Finally, I will conclude this chapter with a brief summary of key methodological decisions and my rationale for these decisions given the research purpose and questions.

3.1 Research Approach and Procedures

This research study is based upon qualitative research by first reviewing the literature, and then conducting semi-structured interviews with exemplary mathematics educators. Related literature was reviewed to identify areas that required further exploration, and to guide the design of interview questions. Qualitative research provides a unique tool for studying human experience and adds greater depth and contextual understanding of people’s perspectives (Kincheloe, 1991). According to Kincheloe (1991), “Qualitative research attempts to appreciate human experience in a manner empathetic to the human actors who feel it or live it" (p. 188). By conducting qualitative research, we examine all aspects of human experience and empower individuals to share their stories and have their voices heard to enrich our understanding of particular areas of interest (Kincheloe, 1991).

This research project is a qualitative study, drawing on characteristics of narrative and phenomenological approaches. This research study gathered information about educators' lived experiences in teaching inquiry-based mathematics with the aim of discovering the ways mathematics educators implement an inquiry-based program in their classroom. Moreover, this study focused on individuals' experiences around a phenomenon (i.e. teachers' experiences using an inquiry-based approach in mathematics). This study is also narrative in nature, as teachers had the opportunity to share their stories and explain the significance of their experiences (Creswell, 2013).

3.2 Instruments of Data Collection

I designed a semi-structured interview protocol as the primary instrument of data collection in this study and I conducted interviews with three consenting participants. These interviews were conducted in order to gather information on the ways educators implement an inquiry-based program in their math classrooms, exploring the best practices to support teachers in using this approach to teaching and learning effectively. Semi-structured interviews provided the opportunity to hear about peoples' experiences through a number of interviewer questions that were carefully prepared in advance but open-ended enough to allow the participant to elaborate or provide valuable information that was not anticipated by the researcher (Wengraf, 2001). The objective was to guide the participant in conveying their experiences as it related to the research purpose. The purpose of interviewing the participants is to find out about their practices, attitudes, and strategies in relation to the research topic (Galletta, 2013).

The interview questions aimed at understanding the best practices and challenges of incorporating inquiry-based strategies in the mathematics classroom as well as the perceived benefits this approach to teaching has for student success. As research studies emphasized the instructional strategies teachers implement through inquiry-based approaches and the associated benefits for students, interview questions include:

- What do you believe are some of the benefits of an inquiry-based approach to teaching and learning math?
- What are some of the core approaches, practices, and underlying philosophies guiding an inquiry-based approach to teaching and learning?
- What instructional strategies and approaches do you use to create opportunities for learning that are inquiry-based in your math classroom?

These questions allow for thorough discussion about the process involved in creating an inquiry-based mathematics program. Interview questions were designed with the purpose of investigating how mathematics teachers perceive and enact inquiry-based approaches in their classrooms in order to gain insight about best practices and effective strategies. After interviews were completed, they were transcribed, coded, and analyzed for themes in order to gain a comprehensive understanding of the ways in which mathematics teachers use inquiry-based approaches to teach students.

3.3 Participants

Here, I review the sampling criteria I established and the sampling procedures I used in order to recruit exemplary mathematics teachers to interview for this study. I also introduce my participants in this section, providing some information about their background experiences.

3.3.1 Sampling criteria. I believe that examining the practice of teachers who fulfill the sampling criteria provided me with a firm basis for designing an inquiry-based mathematics program that engages all students. I interviewed teachers who use inquiry-based practices consistently in order to learn about how this approach to teaching can be applied to classroom learning in a meaningful way to engage all students. In order to gain an understanding of their practices for inquiry-based mathematics teaching, I selected my participants according to the following criteria:

1. Teachers will have a minimum of five years of teaching experience
2. Participating teachers will have a minimum of three years experience teaching mathematics to intermediate students
3. Teachers will employ inquiry-based practice in their mathematics classrooms
4. Teachers will have demonstrated leadership and or expertise in the area of inquiry-based learning in mathematics education (e.g. have led professional development for colleagues, developed curriculum resources, have a graduate degree in this area)

It is important that participating teachers have experience teaching through inquiry as recent research emphasized that teachers play a greater role in structuring and guiding the inquiry, prepared for the possibility that the class does not have the requisite inquiry skills (Artigue & Blomhøj, 2013; Blair, 2014). Teachers who have been more expert in inquiry-based teaching have had professional development experiences in inquiry instructional practices, increasing their understanding and proficiency to implement inquiry-based practices (Marshall & Smart, 2013).

3.3.2 Sampling procedures. To locate and recruit these teachers I networked with other teachers, attended conferences, and returned to schools where I had my practicum placements, providing an overview of my research study. I provided the participant criteria and asked these individuals to distribute my information to teachers they believed fulfilled the criteria. In providing my information I ensured that teachers were volunteering to participate in my research study rather than feeling obligation to participate.

Purposeful sampling is employed to gain insight and deeper understanding about issues pertaining to the purpose of the study (Patton, 2015). Therefore, I used purposeful sampling when selecting participants, as I believed it to be important in strategically selecting participants who purposely informed an understanding of the research problem and illuminated the research question being investigated (Creswell, 2013; Patton, 2015). I also used convenience sampling as a recruitment strategy, relying on my existing contacts and networks I established within the school boards I had my practicums in.

3.3.3 Participant biographies. Each participant was given a pseudonym. Kim is a Grade 8 mathematics and literacy teacher. She has been teaching for over twenty-five years and has taught at her current school for twenty-one years. She has participated in The Annual Mathematics Conference of the Ontario Association for Mathematics Education and became involved with inquiry-based pedagogy after attending workshops and division meetings that pertained to this approach.

Leslie is a teaching and learning coach. She has been a teacher for fifteen years. She has been a teaching and learning coach for six years and most of her coaching experience pertains to mathematics. Leslie became involved with inquiry-based mathematics teaching and learning after observing her mentors use this approach in their classrooms. She attended professional development workshops that focused on experiential learning and using manipulatives in mathematics, which also informed her current teaching philosophies about inquiry-based learning.

Jackie is a mathematics instructional leader. She taught for five years in the classroom setting and has been working for the Ministry of Education as an instructional leader for seven years. She provides support for teachers, administrators, and superintendents who are involved with mathematics teaching and learning at the elementary level. In her current role, Jackie facilitates teachers in their own professional learning inquiries so they can feel prepared to support their students in inquiries.

3.4 Data Collection and Analysis

I collected my data through semi-structured interviews with three consenting participants, identified through the pseudonyms Jackie, Kim, and Leslie. These interviews lasted approximately 45-60 minutes and followed a predetermined list of open-ended questions that pertained to the research purpose. Once I completed the face-to-face interview process, I read the interviews over individually and then transcribed and coded the data, looking for emergent themes and divergences in relation to the research questions in order to learn more about the integration of inquiry-based practice in the mathematics classroom.

I coded data by highlighting themes and words relevant to how teachers incorporate inquiry-based pedagogy in the math classroom. I also looked for connections between interviews in order to see the similarities and differences between responses to specific questions. More specifically, I used in vivo coding to analyze the data, preserving participants' meanings of their views. I also used this method of coding to interpret my research findings, looking for phrases that revealed patterns and regularities (Miles & Huberman, 1994; Charmaz, 2006). I looked at null data to acknowledge what participating teachers did not speak to, as I believe it is important to highlight the gaps and major discrepancies that remain in relation to the research purpose. Four themes emerged that directly linked to the overarching research question: How does a sample of intermediate mathematics teachers enact inquiry-based pedagogy? These themes include: teachers' conceptualizations, instructional approaches, challenges, and benefits of inquiry-based teaching and learning.

3.5 Ethical Review Procedures

As I believe in the importance of selecting participants who are *willing* to share information, potential candidates were provided with a letter detailing the purpose of the study, the contact information of the research supervisor, and the voluntary consent form. I also verbally shared my background knowledge in relation to the research topic and explained that participants have the ability to withdraw at any time during or after the interview process. I ensured that all my participants were given the necessary information about my research, consent, and confidentiality and explained that there were no known risks to participation in this study. I assured that participants were given pseudonyms to remain anonymous, as my research will be available on the Masters of Teaching Research Paper TSpace. I also explained that any information related to their school or students will be excluded. Throughout the interview, I reassured my participants that they had the right to refrain from answering any question they did not feel comfortable with. At the end of my interview, I explained that participants had the opportunity to review the transcripts before I conduct my data analysis, editing any statements that they did not feel comfortable sharing. The only people who have access to my assignment work are my course instructors.

3.6 Methodological Limitations and Strengths

3.6.1 Limitations. There are a variety of potential limitations to this research study. According to Gergen and Gergen (1991), "With due caution, scientists can safely avoid disfiguring the picture of nature with their own fingerprints" (p. 76). As qualitative research does not claim to be objective, researchers acknowledge that they bring their subjective values to their studies, affecting the research process. As I have had experiences teaching inquiry-based math, I am aware that my thoughts and emotions can affect the research process. I understand the phenomenon of reflexivity in research and I believe it is important that the researcher is self-conscious about how their experiences shape the findings and conclusions drawn from the study (Creswell, 2013).

Due to the ethics approval limitations, I was unable to observe student responses to inquiry-based learning in the math classroom. I was also unable to interview students directly about inquiry-based learning and therefore, I was limited to accessing teachers' perspectives on how students experienced inquiry-based approaches to mathematics education.

3.6.2 Strengths. Despite the limitations of the study, there are strengths that will be valuable for the researcher. As mathematics education is shifting toward inquiry-based instruction, it is beneficial to interview teachers who use this approach, allowing them to share their experiences. The anecdotal nature of this study allowed participants to validate and make meaning of their own experiences. As data was acquired through interviews, participating teachers had the opportunity to provide information on different strategies and instructional methods that will inform my own practice.

3.7 Conclusion

In this chapter, I have reviewed some of the key methodological concepts and procedures in this study. I have outlined the instruments of data collection and how I analyzed my data. I have reviewed ethical considerations, as it is important to ensure all my participants feel comfortable participating in my research. Finally, I have identified a range of limitations and strengths that could affect my findings. The results of this study will be further explained in subsequent chapters.

Chapter 4: Findings

4.0 Introduction

In this chapter I report and discuss the findings based on an interpretation of data collected from three different face-to-face interviews with three intermediate teachers. The interviews explored how teachers enact inquiry-based pedagogy in the mathematics classroom and were conducted with the intent of gaining insight into the strategies teachers employ when engaging in this practice.

The findings resulting from the interviews are organized around the research questions and presented through themes that discuss intermediate teachers' beliefs, conceptualizations, and practices of inquiry-based teaching in the classroom. Through this discussion, these teachers elaborated on different strategies they used to introduce and implement inquiry-based teaching in the mathematics classroom and discussed ways to facilitate learning through this method of teaching. The findings discuss the role of the teacher and the student in relation to the practice and implementation of mathematics inquiry, as well as the implications for inquiry-based learning more generally. The analysis of the interview data presented four key themes:

4.1 Mathematics Teachers' Conceptualizations of Inquiry-Based Approaches

- Inquiry Positions the Teacher as the Facilitator
- Inquiry Focuses on Learning Process Rather than Product
- Inquiry is a Life Skill

4.2. Instructional Approaches That Support Inquiry-Based Teaching in the Mathematics Classroom

- Activating Prior Knowledge

- Collaborative Group Work
- Making Learning Meaningful

4.3. Challenges Associated with Implementing Inquiry-Based Approaches in the Mathematics Classroom

- Meeting the Needs of the Students
- Lack of Knowledge
- Assessment

4.4. Benefits of Inquiry-Based Approaches Include Positive Student Outcomes

- Student Engagement
- Understanding of Mathematical Concepts

4.1 Mathematics Teachers' Conceptualizations of Inquiry-Based Approaches

4.1.1 Inquiry positions the teacher as the facilitator. In response to how teachers conceptualize inquiry-based approaches, all participants mentioned that teachers act as facilitators during inquiry-based mathematics lessons. Their role is to provide students with opportunities to take ownership of their learning experiences, prompting them to discover new ideas and make connections. Leslie is currently a math teaching and learning coach with fifteen years of teaching experience in intermediate and junior classrooms. Leslie believed a teacher's role in an inquiry-based classroom is to support the students and learn *with* them, rather than delivering information to be memorized. Leslie described a shift from "teacher as the holder of knowledge" to "teacher as the facilitator of learning." She believed the teacher provides support to the students and states that teachers should not provide tests or assignments and let students "flop on their own." Leslie preferred to help students through the inquiry process through giving them direction: "here, let me help you, let me show you the way.'" She believed the teacher is there for support to guide the students through the learning process, prompting them to move in certain directions. Her idea of a teacher's role as a facilitator in the inquiry-based learning environment is consistent with Carl Roger's (1967) education theory where the teacher *supports* student learning rather than controlling it (Rogers, 1967).

In accordance with Leslie's beliefs, Kim explained that teachers facilitate learning through inquiry by providing students with the right tools to succeed. She further explained that teachers guide students in a facilitator role and stated that: "[Teachers] maybe rephrase the question for them [students] or show them where to go for other strategies." Kim clarified that teachers *guide* students in understanding a mathematical concept during an inquiry without providing the answers. Consistent with Kim's beliefs, Simon and Schifter (1991) believe it is the teacher's responsibility to create a learning environment that encourages inquiry by providing the right resources and tools to enhance students' conceptual understanding. Jackie is a professional development leader for inquiry-based teaching and emphasized that a facilitator needs to be aware of their students, further adding that:

> People often think a facilitator will relax while kids are at work but you have to know a lot more than a teacher-directed approach because you have to be aware of all the different strategies kids would potentially use, all of the different types of levels on a continuum they could be, and the kinds of questions they might ask, how to answer them, how to prompt them… all of these things you have to be aware of.

Therefore, the role of facilitator involves more than guiding the students. In order to guide the students, teachers must anticipate *what* students might say and *how* they will develop an answer during an inquiry. As Pelfrey (2005) emphasized, teachers should be responsive to student needs and provide the tools necessary to prompt them during the learning process.

4.1.2 Inquiry focuses on the learning process rather than product. Schön (1987) advocated that teachers should engage in practices that focus on the learning process rather than the product. Consistent with this view, all participants conceptualized inquiry-based learning as a process. They all mentioned that inquiry is process-based, where students communicate their thinking and apply their knowledge to enhance their conceptual understanding. Kim emphasized that the learning process comes from the students and mentioned that it is *how* students get there, their process:

> There's a better understanding of what they're doing and how to get there rather than just doing it by rote because if they forget a step, if they forget the *why*, it's not going to be ingrained in their mathematical knowledge. So they have to understand why they're doing it and how they get there.

Leslie had a similar perspective and explained that instead of viewing problems as something to solve, inquiry allows students to really explore different reasons why they arrived at a certain answer. Leslie further emphasized the importance of the learning process and mentioned that teachers' feedback is also around the process:

> The feedback you're going to give in all your assessments happens around the process. The product you make at the end is great but it could all fall apart at the end and the most important thing is that you've learned along the way.

Therefore, Leslie and Kim value the learning process and believe it is important for the students to understand *how* they get to the product.

Similar to Kim and Leslie, Jackie conceptualized inquiry as a process and stated that you need to know "orally what they [the students] are saying, physically what they are doing…" She mentioned that inquiry is about student efficacy, their ability to produce a result, *how* they get there. As Manouchehri (1997) stated, "Learning is not a stimuli-response phenomenon. It requires self-regulation and the building of conceptual structures through reflections and abstractions. Constructivists view learning as making sense, an adaptive, gradual process" (p. 202). Collectively, all of my participants viewed inquiry in terms of process – how students arrive at the answer and making sense of why they achieved a certain result.

4.1.3 Inquiry is a life skill. It is important to note that only one participant mentioned that inquiry is a life skill. This is a valid and notable conceptualization, demonstrating that inquiry has a purpose. Leslie explained that teachers should be using inquiry in mathematics to prepare students to become good thinkers and problem solvers in the real world. Jackie and Kim focused on inquiry in the classroom but did not mention the importance of this teaching approach beyond the classroom experience. When Leslie was asked about her beliefs associated with inquiry-based learning, she viewed inquiry as a lifelong skill:

> It is about showing students that it is a life long skill and lesson that you will have forever regardless of the job you're in. They can harness the skills and strategies and then explore on their own in a responsible way.

Checkley (2006) affirms Leslie's beliefs and emphasized that inquiry builds students' understanding and ability to connect concepts they learned in school with real-life situations in the working world. Inquiry allows students to think critically and use their judgment and reasoning skills to reach a solution or various solutions – skills that can be transferred to real world contexts.

4.2 Instructional Approaches That Support Inquiry-Based Teaching and Learning in the Mathematics Classroom

4.2.1 Activating prior knowledge. Consistent among all three participants is the idea of activating prior knowledge and using what students already know to help them solve a mathematics problem. Jackie believed it is important to generate appropriate questions that allow students to formulate their prior knowledge before they can integrate and assimilate new knowledge. Jackie further emphasized that teachers should carefully formulate appropriate questions related to the open-ended mathematics problems they provide in order to activate students' background knowledge, as the rest of the lesson progresses on the basis of what students already know. In accordance with Jackie's perspective, Steffe (1991) emphasized that teachers' plans must be informed by the mathematics of the students and relate to what the students already know. Jackie described that each lesson builds from where the students are in terms of their mathematical understanding. She explained that inquiry-based activities in mathematics incorporate concepts that the students are already familiar with.

Both Kim and Leslie really supported the idea of generating prior knowledge *first*, showing students how to answer complex questions using what they already know in order to understand *why* they arrived at a particular answer. According to Leslie, teachers need to generate background knowledge in order to change and refine their teaching approach – especially middle school teachers, whose major role is to prepare students for high school:

> …Because in a middle school, teachers do not know what students have done outside, before they come in to our school… then really changing your approach from year to year based on what the students know about inquiry and are able to handle [in mathematics].

Therefore, it is important for teachers to know their students' level of understanding in mathematics in order to implement the appropriate inquiry-based teaching strategies. Kim had a similar perspective and mentioned that it is important to generate prior knowledge first. Kim further emphasized that inquiry-based learning in mathematics involves posing a problem and having the students use what they already *know* to solve the problem. She mentioned that it is important for teachers to remind students about what they have taught them in the past, asking them questions like: "What do you know that you can apply? Have you done any problems similar to this?" Kim believed that students enhance their understanding of mathematical concepts if they can integrate what they already know with what they have discovered into the inquiry. She stated that, "It [inquiry] is not telling, it's more- some of it is discovery and some of it is working with what they have, using what they have in new ways or even in familiar ways to come up with a process." Therefore, teachers facilitate learning through questioning and students need to use what is familiar to them when they engage in inquiry-based learning. Kim and Leslie's approaches to activating background knowledge are supported by Brousseau (1987), who claimed that students must have freedom to use their background knowledge to respond to a mathematical situation in order to develop their mathematical understanding.

4.2.2 Collaborative group work. When asked to give an example of what inquiry looked like, all participants mentioned group work. Jackie mentioned that when students are working in groups, it is important for the teacher to circulate, noting what each student is doing in the group. It is important to note that Jackie did not mention whether group work contributed to greater conceptual understanding or student engagement and perhaps this is because she has not been in the classroom for eight years.

Kim and Leslie both emphasized collaborative group work in their discussions about inquiry-based classroom structure. Kim mentioned that students are grouped strategically, according to their level of math ability. She also mentioned that teachers mix up the groups so students have the opportunity to share their strategies with others and examine strategies that are different from their own. She explained that group work during mathematical inquiry allows students to reflect on, revise, and revisit their own work. Kim described what collaboration looks like in her classroom:

> We give them a problem and then they have to show me the steps in how they solved the problem, working in groups… Then the next time I give them another piece of paper, they can see what other people have done on that piece of paper and they might see a strategy that worked for them and say: 'let's see if we can use this

> method.' But, it's not like stand up and explain to me, because sometimes they don't know what they're doing.

Therefore, group work encourages students to problem solve and try new strategies, as they examine their peers' work. Students do not have that pressure of performing and instead they can reflect on and revise their solutions as they gain new insights from others in a non-competitive classroom environment. According to Steffe and Thompson (2000), student responses might be revised as they reflect on their thinking with their classmates during the consolidation process.

Leslie highlighted the importance of consolidation stating that students must consolidate at some point during mathematics inquiry in order to make sense of the information. She mentioned that students work together to construct knowledge and then consolidate their thinking. She believed that inquiry offers a lot of different opportunities to work with everyone in the class. Similar to Kim, Leslie mixed up groups not only to encourage students to share strategies but with the purpose of making students feel comfortable communicating and getting to know other students' abilities. Consistent with my participants' views, Cole and Wasburn-Moses (2010) emphasized that inquiry-based teaching is a student-centered approach that places heavy emphasis on collaborative learning. Participants approaches to group work were consistent with research that highlights how teachers see their students respond to the same problem in different ways, as they share their strategies with other classmates (Pirie & Kieren, 1992).

4.2.3 Making learning meaningful. All participants expressed the importance of making learning mathematics meaningful through inquiry. Meaningful learning is associated with student interest and the teachers' ability to make lessons relatable to the students. According to Manouchehri (1997), the focus in inquiry classrooms is on students making meaning. Consistent with this viewpoint, Kim insisted that for inquiry-based mathematics to be meaningful to students, the teacher has to "make it real" for them and not "just throw questions at them from a textbook." She also described that students can make meaning in mathematical inquiry if they are interested in what is being investigated.

Similar to Kim, Jackie described that inquiry-based mathematics is more meaningful and authentic when it correlates with students' interests:

> From my perspective, we generally deal with student need or student interest, or an area that is really going to support students. From the students often, hopefully it can be problem-based, something that they feel they need to act upon.

According to Jackie, inquiry is driven by student needs or interests. She further explained that the learning is meaningful if it connects to the students' interests. This finding is significant because it is important to understand that student interest is an important factor in sustaining the inquiry activity. When explaining inquiry more generally, Llewellyn (2012) emphasized that students are engaged in investigations that interest them and he described that teachers must make learning relevant by constructing lessons around students' interests.

Similar to Jackie's beliefs about the need for mathematical inquiry to align with students' interests, Leslie mentioned that when students are interested in the inquiry, they do not even realize they are doing math. She observed students doing their *own* math exploration based on a certain topic they were interested in and explained this as an effective learning experience. These findings are consistent with Hmelo-Silver, Duncan, and Chinn's (2006) belief that inquiry is meaningful if it is based on student interest and challenges students to solve 'authentic' problems.

4.3 Challenges Associated with Implementing Inquiry-Based Approaches in the Mathematics Classroom

4.3.1 Meeting the needs of the students. All participants discussed the challenges of meeting students' needs when asked about the barriers to inquiry-based mathematics teaching. Kim emphasized the difficulties of attending to students' learning paces: "If there is a gap in their learning, how do you take them back and still move the others forward… that's a challenge." This finding suggests a tension between ideas about inquiry-based learning and the challenge of including all students to engage in inquiry in the context of certain students lacking the requisite skills to move forward. Although this "gap" was not explicitly mentioned in the literature, some research has discussed the difficulties of attending to students' individual needs. In line with Kim's belief, Pirie and Kieren (1992) emphasize that teachers must be aware that not every student will be ready to move on at the same time. Teachers need to account for and manage the myriad of student needs in the classroom, especially during an inquiry-based math lesson. Kim further explained:

> Then there are kids that don't get it [the math concepts] and need manipulatives a lot longer – they're slower so you take them aside and you do that. They might need manipulatives for longer because they don't internalize it. They're not failing they're just doing it differently and doing it slower… [Students are] having difficulty getting there and need extra assistance.

Therefore, it is the teachers' job to do everything they can to ensure students internalize and understand the mathematical content they are inquiring about. Similar to Kim's perspective, Jackie stated:

> Ultimately, you want students to understand. If students are starting to build an anxiety and they're not getting it, you need to do whatever you can. We're moving away from that deficit model and now it's really about success for all. If a student is not doing well in your class, you need to figure out how to help them. There are so many different layers.

Jackie explained these layers: "You have your individual kids with individual needs. You have your language pieces, you have your social pieces, you have your special needs and differentiation for sure but also accommodations and modifications." She believed that it is the teacher's ultimate goal to help their students succeed. As Pirie and Kieren (1992) emphasize, teachers must be aware that different students are at different levels of mathematical understanding. Inquiry-based learning is more effective when the teacher develops suitable interventions to reach a diversity of student needs (Pirie & Kieren, 1992).

Leslie also believed it is essential for the teacher to be aware of student needs in the inquiry-based math classroom. According to Leslie, when teachers are aware of student needs, they can determine the "scaffolding or trajectory for each student." She further explained that differentiation is difficult at first, but it is important to be aware of student needs and provide guidance as needed. In support of this finding, Pirie and Kieran (1992) emphasized that understanding is an ongoing process, which is by nature unique to that student. Classrooms are comprised of various students at different learning levels who need extra assistance. It is the teachers' role to make the necessary accommodations and modifications to make difficult concepts more comprehensible for certain students.

4.3.2 Lack of knowledge. Jackie and Leslie both referred to teachers' lack of math background knowledge as a challenge to inquiry-based teaching. Leslie explained that the biggest challenge is not having the foundational math background:

> I think the biggest [challenge]…it's a lack of a deep understanding about the math concepts. It's really not having that foundational background from university like: "What really is the most important thing to know about fractions or about algebra?" How can things between fractions be more fluid in terms of representations?"…That knowledge, not just about the teaching strategy, but the actual really deep concepts and big ideas in mathematics is where I can see probably this year we're going to spend more time [coaching teachers] on.

According to Leslie, teachers need to have a deep understanding of math concepts in order to teach inquiry effectively. In a study by Chapman (2011), professional development programs were self-directed and parallel mathematical inquiry activities that teachers implement with their own students. More recent professional development programs provide teachers with agency and the necessary background knowledge and skills to facilitate inquiry lessons in mathematics effectively (Bruner, 1996; Chapman, 2011).

As Jackie is a professional development leader, she had a lot of insights and experience in relation to how much professional development prepares teachers to guide mathematical inquiries effectively. Jackie believed it depended on the teachers' comfort level with mathematics. She mentioned that she takes the teachers through the inquiry process, allowing them to experience what it is like before they implement it in their classroom. Although professional development programs in mathematics are becoming more attuned to teacher needs, Jackie mentioned it is still challenging for teachers to implement mathematical inquiry in their classroom because: “There’s just a lot of layers and often we [teachers] do not have full comprehension of those layers.” Therefore, teachers need to figure out how to answer their own questions during the inquiry process before they ask their students questions.

Kim did not mention anything about teachers’ lack of knowledge but instead emphasized that teachers should use their *own* background knowledge to provide the right tools to encourage student understanding of math concepts. According to Steffe (1990), teachers should be content specialists and recognize where students are struggling in order to prescribe appropriate interventions. Furthermore, teachers who do not possess enough skills and knowledge in mathematics to provide appropriate support, lack confidence when implementing inquiry-based approaches.

4.3.3 Assessment. Kim and Jackie mentioned the challenges of assessing students during inquiry. Jackie mentioned that assessment happens all the time during an inquiry. It is the teacher’s responsibility to assess the process and evaluate *how* students arrived at an answer. According to Jackie, teachers must understand the difference between assessment and evaluation. In order to assess, Jackie stressed the importance of knowing where your students are in order to appropriately assess their learning. Teachers need to acknowledge the different forms of assessment, understand the purpose of assessment, and make time to see what each student is doing. Jackie compared assessment in inquiry-based learning to assessment in rote learning and stated that teachers feel safer assessing in a rote-learning environment. Perhaps this is because teachers are only assessing one layer in rote learning – knowledge. According to Jackie, assessment in mathematical inquiry has many layers:

> Teachers have more layers they have to work with. In terms of thinking, application, and communication, which are a huge part of the curriculum, you actually don't have as good of an opportunity in the teacher-directed environment versus an inquiry.

Teachers are assessing more aspects of the learning process, checking in with students along the way. Jackie further highlighted that inquiry fits nicely within the curriculum and aligns with the assessment practices that teacher's use in today's schools. Kuhlthau, Maniotes, and Caspari (2007) mentioned that assessment can be challenging in inquiry-based learning as students are doing different things. Assessment becomes complex as it focuses on the *process.* The process encompasses many different layers (i.e. students' knowledge and understanding, their efficacy, how they problem solve) pertinent to student learning that teachers need to monitor. Teachers have to think about how students communicate their ideas, how they apply their thinking, and how they comprehend the material (Kuhlthau, Maniotes, & Caspari, 2007).

Kim explained the challenges of assessment in a different way and expressed concern about not being able to get the 'percents.' She believed that using percents as a way to assess students is very rigid, making it difficult to assess the learning *process* accurately. Similar to Jackie, Kim outlined the various layers of assessment stating that there is communication, application, and knowledge. She further explained that "there are some kids that just cannot get there, so that is why I absolutely hate percents on a report card." Within assessment, teachers must consider students' individual needs, thinking, communication, and application and report on all of these layers, which is challenging for teachers. In accordance with the governments' policies, teachers must give percents. However, these percents do not clearly demonstrate that a student understands a concept. As Kim states:

> I think, in the primary and junior grades when they give them just the letter grade, it gives you a range and I think if we weren't so pressured to give percent and we could give a range, there'd be a little more flexibility in using more inquiry-based strategies more often, and less of the paper-pencil.

Therefore, assessment is a challenge for Kim because she has difficulty getting the percent from a teaching approach that is very much based on the learning *process.* Assessment *of* learning in inquiry requires more research. Leslie did not mention assessment directly during her interview and perhaps this is because she was more focused on the inquiry process, guiding students along the way and adjusting teaching style when necessary. As assessment and evaluation are integral components of teaching and learning, it is important that teachers have students generate some kind of product or performance that demonstrates their learning and understanding. The literature acknowledged that assessment in inquiry is challenging, however there is no in-depth discussion about obtaining percents in inquiry. These findings suggest that assessment in inquiry-based math classrooms is very different from regular classroom assessment as it is based on process rather than product. Participants found assessment challenging in an inquiry-context, agreeing that teachers need to monitor *how* students generate conclusions and problem solve to reach an answer. It appears that although participants in this study acknowledge the importance of the learning *process,* they monitor and assess the process in different ways.

4.4 Benefits of Inquiry-Based Approaches Include Positive Student Outcomes

4.4.1 Student engagement. All three participants believed student engagement was essential to an effective inquiry-based math lesson. As earlier findings affirm, it is important to make inquiry-based mathematics lessons authentic and meaningful for students in order to engage them. The literature stated that the goal of this type of teaching and learning is to promote active engagement (National Council of Teachers of Mathematics, 2000). Leslie explained that student engagement helps minimize classroom management issues:

> Classroom management is so important and I find that engagement almost trumps anything else you're going to be doing for classroom management other than consistency. Consistency is number one and then when they're engaged you have less classroom management problems.

When students are engaged and focused on the learning, there is less opportunity to misbehave. Leslie also explained that students are engaged as they take ownership of their learning and formulate their own questions, predict their own strategies for problem solving, and consolidate their thinking with their classmates. In line with Leslie's view, Simon (1995) emphasized that although a teacher will pose a task, it is what the students make of it that determines their potential for learning.

Similar to Leslie's view, Jackie also believed student engagement in inquiry alleviates classroom management problems. Although inquiry is student-centered and gives the teacher less control over what the students are doing, if they are engaged, problem behaviours will emerge less frequently.

That being said, I asked Kim how her students responded to inquiry math lessons and she stated that her students really like it:

> They do like it. They find it fun, there's less pressure, and it's safe for them because what they don't know they know that their partner can help them with or somebody else can help them with in the classroom. It's not performance-based.

Students can collaborate and really engage in the learning process without the pressure to perform. Leslie also mentioned her students "absolutely loved" inquiry-based math activity, especially when it was done in a cross-curricular way. According to Leslie, students had choice and they were able to inquire about a topic that interested them, analyzing scatter plots. She mentioned that because her students were more interested in the material, they demonstrated higher levels of engagement and stated that: "[Students] started to do their own math exploration without even realized they were doing their own math exploration on their own, as their own homework." In line with Leslie's observations, Whitehead (2015) asserted that engagement creates an environment where learning is sustained because students are more interested in the material. In order to maintain student engagement, teachers need to create a challenge for the learner, providing them with opportunities to become active learners. All three participants agreed that inquiry-based learning in math required higher-order thinking. Whitehead (2015) stated that as students engage in the three components of higher-order thinking – organizing information, analyzing it, applying it – they are engaged.

4.4.2 Deeper understanding of mathematical concepts. Although inquiry-based teaching is an open-ended technique that embraces uncertainty, students can better understand the material because they are more *involved* in learning and the construction of their own knowledge. Kim stated: "The process is coming from the students and they are more likely to understand it [the content] if they are actively involved in the process." Kim further states that student involvement can mean sharing strategies, generating ideas, and collectively developing solutions. Dewey's (1963) "experiential education" matches Kim's beliefs as his theory suggests that learning is enhanced when students are personally involved in the learning experience. Cobb, Wood, and Yackel (1993) had similar beliefs, emphasizing that it is the teacher's responsibility to cultivate conceptual knowledge and facilitate learning through collaborative discussion during inquiries. Research has shown that students in inquiry-based classrooms have greater understanding of mathematics and experience more success because they are more actively involved in their learning (Cobb, Wood, Yackel, & Perlwitz, 1992; Cobb, Wood, and Yackel, 1993).

Leslie and Jackie also believed that inquiry-based teaching contributed to greater understanding of math concepts. Leslie mentioned that inquiry-based learning environments allow students to engage in higher-order thinking and hands-on learning, enhancing their understanding of the content. In her classroom, her students demonstrated understanding of the concepts and went beyond the expectations of the math lesson to explore multiple solutions and disaggregate the data. Leslie explained that this illustrates a really solid understanding of the content. In line with Leslie's views, Fosnot (1996) emphasized that teachers enhance student understanding by providing them with investigations that allow students to explore multiple solutions and justify their answers. Jackie's beliefs are similar as she mentioned that teachers are able to better observe student understanding in the inquiry-based math environment versus the teacher-directed environment. She believed that teachers are more likely to capture all of the skills that are important in mathematics in an inquiry-based environment – the thinking, application, and communication. In inquiry, the teacher has the opportunity to ask questions to check for understanding and consolidates student thinking in order to better support the student in an enriched learning environment. Similar to participant beliefs, Simon (1995) emphasized that it is the teacher's role to observe and encourage student understanding during inquiry and determine where and when to provide meaningful support.

4.5 Conclusion

As the results have suggested, there are many components of inquiry-based teaching that affect the teachers *and* students. The themes were developed as responses to the research questions and discussed intermediate mathematics teachers' conceptualizations and practices of inquiry-based approaches in the classroom. All participants regarded themselves as facilitators of student learning during inquiry, as supported in the literature. The findings suggest that teachers do more than guide students; they *understand* their needs and abilities in order to provide effective support during collaborative inquiry activities. As seen in the literature and as the findings of this study affirm, inquiry in math is a learning *process* that comes from the students –

obtaining a product to evaluate is not a top priority. It is important for teachers to attend to student needs, as they must scaffold the skills students can apply in real life situations.

The participants in this study also experienced challenges when enacting inquiry-based pedagogy in the mathematics classroom. Consistent with the literature, participants believed that teachers should possess enough background knowledge in order to effectively guide the inquiry. As inquiry is very open-ended, participants also discussed the difficulties in meeting students' needs. It is important for teachers to *know* their students and *understand* how they learn in order to provide effective support and engaging inquiry-based activities. However, this was found to be challenging in the middle-school years as students change schools.

As findings indicate, inquiry is also an interactive, collaborative style of teaching and learning that students seem to enjoy. Participants underscored the importance of student interest and believed that if the inquiry is interactive and relatable to students, they will be more inclined to participant and enjoy what they are exploring. As students are involved in the learning, participants suggest that they can better understand the material.

As Chapter Four identified the participants' beliefs in response to the research questions, Chapter Five will discuss limitations of the study, conclusions, recommendations for practice, and areas for further research.

Chapter 5: Discussion

5.0 Introduction

As outlined in Chapter One, the purpose of this study was to learn more about how intermediate teachers enact inquiry-based mathematics pedagogy in their classrooms. In addition, this study intended to provide insight on what teachers observe in terms of student outcomes. The findings serve to support the extant literature pertaining to inquiry-based mathematics and to specifically tell us more about how teachers implement this pedagogy in the classroom. This chapter summarizes the research findings, highlights the implications and recommendations that have resulted from the research done, and suggests directions for further research.

5.1 Discussion of Findings

All three participants shared many of the same ideas about inquiry-based mathematics pedagogy and believed it to be a student-centered approach that focuses on the learning process. They also believed that inquiry-based teaching increases student engagement and provides them with a more comprehensive understanding of difficult math concepts. Following the interviews with three educators, findings were organized within the following themes as responses to my research questions: (1) Teachers conceptualizations of inquiry-based teaching, (2) Instructional approaches associated with implementing inquiry-based teaching in the mathematics classroom, (3) Challenges Associated with implementing inquiry-based teaching in the mathematics classroom, (4) benefits of inquiry-based teaching include positive student outcomes. In the subsections below, I will be further discussing key findings within each of these themes.

5.1.1 Mathematics teachers' conceptualizations of inquiry-based approaches. Interview responses demonstrate that teachers conceptualize inquiry-based mathematics teaching and learning as student-centered, where the teacher is a facilitator and learns *with* the students, guiding and supporting them throughout the learning process. As facilitators of learning, teachers encourage collaborative discussion and sharing of ideas. This serves to remind us that a teacher's role involves more than transmission of knowledge. My findings suggest that during inquiry, teachers are co-learners who are actively involved in their students' learning process, providing them with the tools to succeed. They must critically engage and support their students, providing a classroom environment where students can take ownership of their learning experiences. Participants further explained that inquiry engages and inspires students to develop critical thinking and problem solving skills – skills important for life-long learning. These findings align with the research done by Checkley (2006) who stated that in inquiry-based environments, students develop understanding and ability to connect concepts they learned in school with real-life situations in the working world.

5.1.2 Instructional approaches that support inquiry-based teaching and learning in the mathematics classroom. The responses from the participants as well as the extant literature suggest that teachers implement similar instructional approaches during inquiry-based lessons. All three participants mentioned that they typically begin an inquiry-based mathematics lesson by activating prior knowledge. These findings relate to Steffe's (1990) belief that teachers' plans must derive from what the students already know. Therefore, it is important to activate prior knowledge before engaging in an inquiry-based math task in order to effectively support students during the learning process (Steffe, 1990).

In addition to activating students' prior knowledge, it is important to recognize the significance of collaborative group work during the learning process in an inquiry-based mathematics lesson. All participants discussed how inquiry-based mathematics involves grouping students together in order to encourage more mathematical discourse and exposure to different strategies. Kim discussed that she poses an open-ended math problem that is relatable to her students' lives and divides them into small groups, providing them with manipulatives and resources to guide their problem solving. She emphasized that she is the facilitator, circulating to support students and guide them in formulating questions to solve the problem. She emphasized that collaborative group work is beneficial for her students as they have more opportunity to share strategies, reflect on, revise, and revisit their work.

Participants reported that collaborative group work enhanced student understanding, as they were able to share strategies and reflect on their work. Cole and Wasburn-Moses's (2010) research on inquiry in mathematics affirmed that inquiry-based teaching places heavy emphasis on collaborative group work. Inquiry-based mathematics enables students to respond to the same problem in different ways, practicing a variety of strategies (Pirie & Kieren, 1992). Participants elaborated on the benefits of collaborative group work and stated that students can reflect on and revise their solutions as they construct their knowledge of various mathematical concepts.

Participants also discussed the importance for teachers to make learning meaningful through inquiry-based mathematics. The literature elaborates on this, stating the importance of constructing mathematical inquiries around student interest (Llewellyn, 2012; Hmelo-Silver, Duncan, & Chinn, 2006). These findings align with Hmelo-Silver, Duncan, and Chinn's (2006) assertion that meaningful mathematics inquiry is based on student interest and challenges them to solve 'authentic' problems. When discussing the importance of meaningful learning experiences, participants focused on aligning lessons with students' interests to make learning more authentic. This finding highlights the importance of making inquiry-based mathematics lessons relatable to students' real world experiences. Inquiry-based mathematics honours students' thinking and students' questions, providing teachers the opportunity to build on their interests in order to further engage them in the learning process.

5.1.3. Challenges associated with implementing inquiry-based approaches in the mathematics classroom. It is important to note that most of the challenges participants discussed were consistent with the literature. However, participants experienced additional challenges that were not emphasized in the literature as much. Participants' views on assessment reflected research done by Kuhlthau, Maniotes, and Caspari (2007) who mention that assessment can be challenging in inquiry-based learning as students are doing different things. Similarly, participants stated that assessment in inquiry-based mathematics is challenging, as "it has many layers." Jackie mentioned that it is important to know where your students are in the learning process in order to effectively assess their critical thinking and communication skills. As there are many forms of assessment, most participants agreed that teachers must understand these forms and their purpose of assessment in order to appropriately evaluate their students.

The three participants also discussed the difficulties of meeting the needs of their students during inquiry-based mathematics. This challenge aligns with *knowing* your students, as teachers must recognize and understand the myriad of different learners in their classrooms in order to effectively guide their students' inquiries. Research suggests inquiry-based learning is more effective when the teacher develops appropriate interventions to reach a diversity of student needs (Pirie & Kieren, 1992). This serves to remind us that recognizing and acknowledging the different student needs and learning styles is an important step toward an effective inquiry-based mathematics program.

5.1.4 Benefits of inquiry-based approaches include positive student outcomes. The present study found that participants believe there are two main benefits to inquiry-based mathematics. Kim expressed that because inquiry-based mathematics encourages collaboration and communication, students share their strategies with their peers and evaluate different ways to solve the problem. Cobb, Wood, and Yackel (1993) emphasized it is the teacher's responsibility to facilitate this learning and enhance conceptual knowledge during an inquiry-based math lesson. As inquiry is more open-ended, it is important that the teacher provides students with the tools to apply their problem-solving skills successfully. As participants perceived, collaborative discussion cultivates meaning of mathematical concepts and contributes to better understanding. As students have the opportunity to become more involved in their learning experiences during inquiry, students gain a more comprehensive understanding of math concepts. This is especially important for teachers who might have students in their classroom struggling with mathematics.

Overall, the literature review and findings of this study yielded similar results in the study of how teachers enact inquiry-based mathematics pedagogy.

5.2 Implications

5.2.1 Implications for the educational community. This research study can provide insight into how teachers enact inquiry-based pedagogy in mathematics teaching. While the focus of this study was on intermediate grades, the findings that emerged are applicable to younger students in Grades 4, 5, and 6 within the K-12 system. This research study also offers practical strategies with regard to enacting useful pedagogical approaches, which can impact the teaching practice of educators who implement inquiry-based mathematics in their classroom. However, it is also important to recognize that the challenges associated with inquiry-based mathematics might affect teachers' performance. Findings revealed that in order to *effectively* implement inquiry-based approaches in mathematics, teachers must be aware of their students' learning needs to provide appropriate support. This study should serve as a reminder that inquiry-based teaching and learning in mathematics is a process and student-centered endeavor. Consistent with the conclusions of Steffe (1990), the present study finds that teachers should recognize where students are struggling in order to confidently support them in their learning. In broad strokes, this study has two important implications for educational reform.

First, teachers' lack of knowledge about mathematics and how to use inquiry approaches contributes to their comfort level and ability to effectively support students. Teachers must know where they are struggling in math first before they can assist their students. When teachers lack background knowledge of math concepts, students may not be effectively supported in their learning about mathematics. Parents expect that teachers can help their children in understanding concepts, but this is not always the case. Teachers should do their research and enter the classroom with enough knowledge about the concepts to guide students through inquiry-based learning. Teachers may feel overwhelmed or unaware of how to teach using this approach in an effective way – this is the reason why professional development in this instructional approach is essential in order to ensure that teachers enter the math classroom as ‘specialists’ who facilitate their students’ inquiries. It is essential that professional development continue in inquiry-based mathematics, as it is an approach designed to challenge and engage students and a fundamental component of teacher education. Therefore, educational communities need to promote and continue professional development in inquiry-based mathematics in order to cultivate teachers’ knowledge about how to teach through an inquiry-based approach in an effective way.

Second, this study suggests that it is challenging to meet the needs of different learners during an inquiry-based mathematics lesson. My participants did not mention many specific ways to support students who are at different levels of learning during an inquiry. As participants mention, it is important to make modifications and accommodations being aware of every student’s learning style. However, it is difficult to move others forward while supporting those who are falling behind. As my participants stated that they must account for and manage a variety of individual needs in the inquiry-based mathematics classroom, administrators need to continue offering appropriate interventions that help teachers effectively support their students. Consistent with the conclusions of Pirie and Kieren (1992), teachers must be aware that not every student will be ready to move on at the same time. It is the teachers' responsibility to effectively guide and support students who fall behind, providing them with the necessary tools to succeed. This research study stands to contribute to our efforts in discovering more about how to effectively support students in their learning during inquiry-based mathematics lessons.

5.2.2 Implications for my future teaching practice. As a result of the research I conducted, I realized it is not enough to provide students with an inquiry-based task and have them solve it. Teachers must learn *with* the students during inquiry and be able to provide support to individual students. This means teachers must have a deep understanding of mathematical concepts in order to effectively support different learners during inquiry. I believe ongoing professional development is beneficial for teachers, as it provides them with opportunities to learn about up-to-date teaching strategies in a collaborative space. As a future educator, I recognize the importance of ongoing learning and exploration in order to become an exemplary teacher. I acknowledge the fact that as a teacher, I hold the knowledge and understanding that I will use to support my students in their learning. Acknowledging that I wish to attain a deeper understanding of math concepts as a teacher who may be called upon to teach mathematics, I embrace a position that values inquiry and learning for my students and myself. As an ongoing learner, I plan to be prepared and transparent about my desire to acquire deeper understanding of mathematics. In my own practice, I intend to employ inquiry-based approaches to encourage collaborative learning experiences that are both purposeful and enduring.

As a teacher, I need to reflect on how I can use inquiry-based mathematics to enhance students' understanding of mathematics concepts rather than hinder their knowledge. As Manouchehri (1997) emphasized, the focus in inquiry classrooms is on students making meaning. I will make my inquiry-based mathematics a concrete part of my approach as an educator, as I value student-centered learning and collaborative discussion. I will make my future classroom a place of active learning where students can engage in collaborative discussion to share ideas and strategies. I want to use inquiry-based mathematics in a purposeful way in order to provide students with meaningful learning experiences. Overall, I believe inquiry-based mathematics has the potential to help students enhance their problem solving skills and leads to deeper understanding of mathematical concepts.

5.3 Recommendations

The implications of the present study point specifically to several recommendations for ministries of education, school administrators, and teachers. Three recommendations will be outlined below.

5.3.1 Providing more resources for teachers. More books and better online resource should be provided for teachers and made available in schools regarding effective instructional strategies for implementing an inquiry-based approach in mathematics. I suggest that teachers examine more resources pertaining to different inquiry-based mathematics activities and how to implement them and they should also use these resources to enhance their understanding about mathematical concepts.

Therefore, teachers will be exposed to different inquiry-based tasks they can use to engage students and enhance their problem-solving skills.

5.3.2 More professional development. As the participants in this study emphasized teachers' lack of knowledge about math concepts as a challenge to implementing inquiry-based approaches, I recommend that there is ongoing professional development offered in the school board to provide more training for inquiry-based mathematics and mathematics concepts more generally. I believe there should be administrators and coaches available to provide valuable feedback and effective support in using an inquiry-based approach. This study reveals that there is much to be learned about inquiry-based mathematics. To build teachers' knowledge about this approach, I also suggest that there is more comprehensive training programs that focus on how to handle the challenges associated with inquiry-based teaching and learning in mathematics.

5.3.3 Provide opportunities to share ideas. As a result of my findings and own experiences with inquiry-based mathematics, I think it is beneficial to provide more opportunities for educators to meet and share insights about how they use inquiry in their math classroom. I suggest that teachers have grade meetings more frequently and use similar inquiry-based mathematics tasks in their classrooms and discuss how the students responded. They can also share what was successful and what was unsuccessful about how they used inquiry and discuss how to improve for next time. I think that these meetings would generate a variety of ideas and expose teachers to new strategies they could implement in their mathematics classrooms.

5.4 Areas for Further Research

Inasmuch as the present study has served to expand upon the extant literature, it has also highlighted the need for further study. There are three areas for further study that I would suggest. Firstly, in future research endeavors, it is recommended that a greater emphasis be placed upon how teachers can make specific modifications and accommodations during math inquiry for students with individual education plans. As I found that it is important to meet the needs of all students, further research should focus on *how* to make appropriate modifications and accommodations in order to support those who need additional help in mathematics.

I also suggest that more research be conducted on assessment in inquiry-based mathematics. As my findings revealed that assessment is challenging in inquiry-based mathematics, it is important for teachers to know about different ways they can assess student learning when using this approach to teaching. As inquiry focuses on the learning *process*, it is important for teachers to understand that assessment is ongoing. Further research should explore *how* to provide ongoing assessment, as teachers should know where their students are at before engaging them in further mathematical inquiries.

As inquiry-based approaches are student-centered I wonder about students' perspectives. I think it would be interesting to conduct more research about student understandings and experiences of inquiry-based mathematics.

5.5 Conclusion

This study made evident the many ways teachers enact inquiry-based mathematics pedagogy in their classrooms and the associated challenges. As mathematics teaching has shifted from traditional teacher-centered approaches to problem-solving investigations, it is important to gain an understanding of how to use inquiry to enhance students' conceptual understanding. This study suggests that teachers can use inquiry-based approaches to improve student understanding of mathematical concepts that can be applied in a diversity of contexts beyond the classroom environment. It is essential that professional development programs provide teachers with enough support and knowledge to effectively teach mathematics through an inquiry-based approach. It is also important for teachers to invest time in learning about how to effectively teach mathematics using this approach. As an educator, the findings from this research project allowed me to learn new ways to implement inquiry-based approaches in mathematics by bringing forward strategies that have been effectively used in experienced teachers' classrooms. As educators, we can use this knowledge to become better facilitators of learning in the mathematics classroom.

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Appendix A: Letter of Consent for Interview

UNIVERSITY OF TORONTO
OISE | ONTARIO INSTITUTE FOR STUDIES IN EDUCATION

Date: ___________________

Dear ___________________,

My name is Raquel Drabkin and I am a graduate student at OISE, University of Toronto, and am currently enrolled as a Master of Teaching candidate. My research will focus on how teachers are implementing inquiry-based pedagogy in their classrooms and what they observe in terms of student achievement and engagement. I am interested in interviewing teachers who confidently teach in an inquiry-based way in order to share best practices with the education community. I think that your knowledge and experience will provide insights into this topic.

I am writing a report on this study as a requirement of the Master of Teaching Program. My course instructor who is providing support for the process this year is Dr. Rodney Handlesman. The purpose of this requirement is to allow us to become familiar with a variety of ways to do research. My data collection consists of a 40-60 minute interview that will be audio-recorded. I would be grateful if you would allow me to interview you at a place and time convenient to you.

The contents of this interview will be used for my assignment, which will include a final paper, as well as informal presentations to my classmates and/or potentially at a conference or publication. I will not use your name or anything else that might identify you in my written work, oral presentations, or publications. This information remains confidential. The only people who will have access to my assignment work will be my course instructor, Rodney Handlesman. You are free to change your mind at any time, and to withdraw even after you have consented to participate. You may decline to answer any specific questions. I will destroy the audio recording after the paper has been presented and/or published which may take up to five years after the data has been collected. There are no known risks or benefits to you for assisting in the project, and I will share with you a copy of my notes to ensure accuracy.

Please sign the attached form, if you agree to be interviewed. The second copy is for your records. Thank you very much for your help.

Sincerely,

Researcher name: _________________________________

Phone number, email: ______________________________

Instructor's Name: ____
Phone number: ________________ Email: ______________________

Consent Form

I acknowledge that the topic of this interview has been explained to me and that any questions that I have asked have been answered to my satisfaction. I understand that I can withdraw at any time without penalty.

I have read the letter provided to me by ______________________(name of researcher) and agree to participate in an interview for the purposes described. I agree to have the interview audio-recorded.

Signature: _______________________________________

Name (printed): __________________________________

Date: ______________________

Appendix B: Interview Questions

Name of participant: ___________________________

Position of participant: ________________________

School board: ____________________________________

Name of school: _________________________________

Time of interview: ______________________________

Date: ____

Thank you for agreeing to participate in this study. This research aims to learn about how teachers are enacting inquiry-based pedagogy in their mathematics classrooms. The interview will last approximately 40 minutes and I will ask you a series of questions related to inquiry-based teaching and learning. I want to remind you of your right to choose to not answer any question. If you would like to stop the interview process at any moment during the study, please let me know. Do you have any questions before we begin?

Section 1: Background Information

1. Tell me about your current position – what grades and subjects do you teach?
2. How many years have you worked as a teacher?
3. How many years have you been teaching at this school?
    a. Can you tell me more about the school you are currently teaching in? (Size, demographics, program priorities…)

   b. What, if any, math resources do you have access to in your school? (e.g. labs, manipulatives, software, technology)

4. Do you fulfill any other roles in the school in addition to being a classroom teacher? (coach, advisor, councilor, leader)
5. What is your background in mathematics education? Did you study math in your undergraduate degree? Is math one of your teachable subjects? Do you have any other certifications or training related to math education (AQ courses)?
6. As you know, this study aims to learn more from participants about how they enact inquiry-based approaches to teaching math. Can you tell me more about what experiences have informed your interest and commitment to inquiry based learning (e.g. personal, professional, educational)?
   a. How did you become involved in inquiry-based teaching?
   b. What experiences prepared you for applying inquiry-based approaches to teaching math?
7. How long have you been using inquiry-based pedagogy in your teaching?

Section 3: Beliefs/Values (WHY?)

8. What does inquiry-based learning mean to you? In your view, what are some of the core approaches, practices, and underlying philosophies guiding an inquiry-based approach to teaching and learning?
9. What do you believe are the benefits of an inquiry-based approach to teaching and learning, generally speaking?

10. In your view, what are some of the core approaches, practices, and underlying philosophies guiding an inquiry-based approach to teaching and learning *math*?
    a. What does an inquiry-based approach to teaching and learning math look like?
    b. How does this approach differ from traditional approaches to teaching and learning math?
11. What do you believe are some of the benefits of an inquiry-based approach to teaching and learning *math*?
12. And what do you believe are some of the limitations of this approach to teaching math?
13. Can you tell me how your students have generally responded to inquiry-based learning in your math classroom?

Section 3: Teacher Practices (WHAT/HOW)

14. How do you introduce inquiry-based approaches to learning in your mathematics classroom?
15. What instructional strategies and approaches do you use to create opportunities for learning that are inquiry-based in your math classroom?
16. Can you give me an example of a math lesson that you have conducted that applied an inquiry-based approach?
    a. What grade and strand were you teaching?
    b. What were your learning goals?
    c. What opportunities for learning did you create and how?

   d. How did your students respond? What outcomes of learning did you observe?

17. What are some of the resources that you use when applying an inquiry-based approach to math instruction? (books, manipulatives, games, websites, tools)
18. What steps do you take when creating an inquiry-based math lesson or unit?
   a. What does planning typically involve for an inquiry-based math lesson?
   b. What approach do you use to structure your inquiry-based lessons?
   c. Typically, how do you assess and evaluate students when applying an inquiry-based approach to teaching and learning math?
19. What experiences have you had that have supported you to do this work?

Section 4: Influencing Factors (WHO?)

20. What challenges do you encounter when applying an inquiry-based approach to teaching math? How do you respond to these challenges? What would further support you in meeting these challenges?
21. What kind of feedback have you had from people outside the classroom regarding your practice of using an inquiry-based approach to teaching and learning math?

Section 5: Next Steps/Challenges (WHAT'S NEXT?)

22. What advice or recommendations would you give teachers who are interested in teaching mathematics through inquiry-based approaches to teaching math?

Thank you for your time and participation