

Does It Really Matter What I Ask?
How teacher questioning influences the learning of mathematics

by

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Bachelor of Education, University of Victoria, 1989

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Abstract

Questioning is an important teaching strategy used when engaging children in mathematics. Teacher questioning influences children's learning opportunities and thinking. Therefore, there is a need for educators to understand how they use questioning, and to be aware of what kinds of questions are leading to what kinds of results. In this project, I draw on current research and literature to examine how teacher questioning affects the learning of mathematics in early childhood settings. I provide suggestions that teachers may implement to develop their student questioning skills and create a learning environment that encourages deeper levels of thinking.

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Chapter One

Introduction

If one accepts the definition of mathematics to be an understanding of relationships, order, and structure, one would likely agree that the development of mathematical competencies in the early years of learning affects one's ability to navigate through demands in life (Linder, Powers-Costello, & Stegelin, 2011; Niklas & Schneider, 2014). According to Sarama and Clements (2006) the ability for children to learn mathematical understandings has been greatly underestimated. Research has shown that the achievement of mathematical concepts during the early years is a strong predictor of later academic success in most subject areas (Jacob-Vessels, Brown, Molfese, & Do, 2014; Niklas & Schneider, 2014). According to Clements and Sarama (2011), the mathematical learning potential for many children is limited by the structure of their educational programs hindering the interaction of the student's ability to interact with their environment. Currently, many early learning mathematical programs are limited in scope, offering simplistic snapshots of concepts, and progress at a quick pace, not allowing for reflection or deep understanding (Greenes, Ginsburg, & Balfanz, 2004). Effective early learning environments provide high quality mathematical experiences, but many classrooms are lacking in this area (Clements & Sarama, 2011). Due to my experiences as a kindergarten teacher, and drawing inspiration from my graduate studies, I am interested in providing opportunities for young children to participate and interact with mathematics in more personally relevant and meaningful ways.

Children are natural explorers who are curious about the world around them (Linder et al., 2011). As children move and interact with their natural environment, mathematical relationships are informally developing (p. 29). Children's natural curiosity leads them to

compare, problem-solve, navigate spatially and recognize patterns as they act upon their environment and engage with peers. Upon observation, researchers have discovered that young learners are capable of much greater levels of mathematical thinking than educators had previously expected of them (Greenes et al., 2004).

Through our traditional methods of classroom teaching, students have come to expect knowledge to be transmitted from the teacher to the student, placing the student in a passive role (Dixon, Egendoerfer, & Clements, 2009). These researchers suggest that educators examine current teaching methods and shift to a learning environment where the students take an active role in their learning (p. 1069). They recommend learning environments move towards an inquiry based learning method where the children are encouraged to be actively engaged through reasoning and analysis, instead of learning by rote in order to promote higher levels of mathematical thinking (Jacobi-Vessels et al., 2014).

As a primary teacher, I have invested time and energy in developing my teaching skills in the area of mathematics. Throughout my graduate studies, and the opportunities my studies have provided for deep self-reflection, I have given great consideration to my role in creating mathematical learning spaces for young children. Thom (2012) explained that the opportunities for students to learn mathematics are dependent upon the choices we make as teachers, but more importantly, the ways that children learn to interact with mathematics impacts the way they view their world (p. 10).

This project will consider the impact teacher questioning has on mathematical understanding. I will explore the role of teacher's active listening and the impact it has in responding to students during mathematical dialogue in the classroom. I will also reflect on my

teaching practices, examining how my role influences the opportunities for mathematical experiences.

Rationale

Reflecting upon my childhood experiences of learning mathematics, I recall classrooms where the desks were arranged in rows facing the front of the class. The teacher would present the information for the day's math lesson and then my classmates and I would quietly use pencil and paper to complete the assigned questions. I recall continually asking the teacher if my answers were correct as I completed the required operations with hesitation and little understanding. Mathematics was linear. It was learning the applicable rule and applying it to the problem to arrive at the only acceptable correct answer. These experiences shaped my view of mathematics and stifled my mathematical way of thinking.

Many years later, when I was assigned to teach in primary grades, I attended many math workshops determined to learn how to provide meaningful mathematical experiences for my students. The participation in these workshops inspired me to transform my thinking about mathematics and the importance of teaching mathematical concepts in developmentally appropriate and meaningful ways. With each passing year, through reflection and conversations with colleagues, I continually strove to develop my practices and methods in teaching mathematics. The importance of my relationship with mathematics and the world around me continued to shift and grow. During my graduate coursework I had a moment of self-actualization where I began to comprehend how limited and narrow my thinking continued to be, and the implications that this way of thinking had on all aspects of my life. A graduate course focused on curriculum and instruction in elementary mathematics ignited my desire to question and reflect upon my current mathematical teaching practices and to move in the direction of a

different theoretical framework. The process of shifting my thinking began shooting like the sparks from a fire. I wondered, along with Thom (2012), “What shifts in thinking are necessary to conceive classroom mathematics as something other than a line of hand-me-downs from teacher to student?” (p. 144). The desire to change was burning, but the lack of knowledge to implement these new concepts soon began to stifle the flame. Later in the elementary school year, I welcomed the opportunity for my class to participate in a research project with a professor from a local university. I observed the manner in which she engaged and interacted with the students. I witnessed kindergarteners’ mathematical ways of thinking that stretched way beyond anything I had previously thought possible. I continued to listen and question my own pedagogy. As a part of the research project, the professor, two research assistants and myself, worked with small groups of children and followed the professor’s lesson plan. During follow up discussions, I was continually amazed at the professor’s findings and became frustrated with the results collected from my group. The various groups of children working with the professor expressed in-depth understandings of mathematical concepts that reached far beyond learning expectations in kindergarten. As these students restructured their mathematical ways of knowing, their understandings were communicated by bodily gestures and verbally justifying their way of thinking. I was missing something, and what I was missing was substantial. Through continued self-reflection and dialogue with the professor, I discovered that the way I was engaging the students through questioning limited their responses and ways of mathematical thinking. I was reminded of van Manen’s (1986) words when he stated that many adults have projected the wrong message to an inquisitive child, that an answer is the end to a question (p. 41). Is this how I was affecting my students? I began to reflect by asking: i) Do different types of questioning by teachers impact the mathematical opportunities for learners?; and, ii) Does the level of teacher

engagement and awareness when listening to students' dialogue impact the type of questions a teacher asks? As I continued to consider these questions one of my students came to me and said, "I like it when Jennifer¹ comes. She makes me think. Then I hear other peoples' ideas and I get more ideas" (Charlie, personal communication, May 5, 2016).² I was awestruck by the deep insight of a five year old. He recognized the value of questioning, expressing and thinking within a mathematical community. It was at that pivotal moment I knew that if I desired to be an effective educator, a deeper exploration into these inquiries was necessary.

Theoretical Frameworks

This project will be guided by two theoretical frameworks: constructivism (Dewey, 1929; Piaget, 1952, 1969), and social constructivism (von Glasersfeld, 1983; Vygotsky, 1978).

Constructivist theory believes that knowledge and meaning is built upon previously constructed understandings (Ernest, 2006). Each interaction with the environment allows the learner to build upon previous ways of knowing. Learning is individualistic, and it is through personal reflection and interpretation of the experience, that the learner will utilize new meanings to build upon pre-existing knowledge. Therefore, teaching must begin with what the learner already knows so new constructs can actively be built upon the existing foundation.

Social constructivist theory recognizes that learning and understanding are constructed by social interactions (Ernest, 2006). This allows the learner to build upon previous constructs of understanding by reflecting on the experience, and through social interactions with others. Engaging others in dialogue significantly impacts one's ability to learn.

These theories and their influence on mathematical learning will be further explored in the literature review in the following chapter.

¹ Jennifer refers to the professor from the university.

² Charlie is the pseudonym given to the student to protect the child's identity.

Significance

Many elementary educators carry negatively rooted mathematical experiences from their past, which affect the range of strategies used by teachers to enhance their students' understanding of mathematical concepts (Cohrssen, Tayler & Cloney, 2015; Hodgen & Askew, 2007). Often kindergarten math programs are limited in scope, lack the inclusion of exploring concepts with any depth, and are presented in a linear sequential method, not revisiting concepts once they are taught. This makes it difficult for children to form meaningful relationships with mathematical concepts in an educational setting (Greenes, Ginsburg & Balfanz, 2004; Linder, Powers-Costello & Stegelin, 2011). While the engagement of suitable mathematical activities is of great importance, the quality of a teacher's instructional method is of equal significance (Jacobi-Vessels et al., 2016). The method of instruction affects the level of students' engagement, development of mathematical attitudes, and opportunities for concept development.

Linder et al., (2011) argued that learning mathematics is essential to successfully managing the skills of daily life. Young children are naturally keen observers of their environment and explore mathematical concepts as they develop relationships with the space around them. If these early learning experiences are positive and meaningful, children are more likely to form positive attitudes towards mathematics and continue to show an interest in the subject in later years. Teachers need to move away from the traditional method of teaching mathematics, where the focus is on the teacher presenting rules and procedures, to an inquiry approach to learning, where the teacher's role presents itself more like a facilitator (Linder et al., 2011, p. 30). This allows the teacher to help the children unfold their own connections of mathematical concepts through collaborative work, scaffolding and asking open-ended questions (Linder et al., 2011).

In many of today's elementary classrooms, mathematical instruction continues to be shaped by teacher-led instruction (Franke, Web, Chan, Ing, Freund, & Battey, 2009). One of the most common methods of classroom instruction is in the form of teacher questions (Kucuktepe, 2009). Unfortunately, the majority of these questions are considered to be low-level questions which require the recall of information or a single specific answer, neglecting the demand for critical thinking (Franke et al., 2009). These researchers have concluded that many teachers find it challenging to inquire about the student's way of thinking during exploration and meaning making of a concept. Asking high level questions during this process would require the student to synthesize and draw inferences from their trains of thought and to solidify their thinking through an explanation.

Frank et al. (2009) suggest that the ability of a teacher's questioning methods is reliant upon carefully listening to the students. The importance of actively listening to a student's explanation or reply to a question is often overlooked by educators (Gordon, 2011). To be truly responsive to the student's needs requires the teacher to be actively attentive to the learner's thoughts and words. It is through the act of listening that a teacher is able to understand a student's way of thinking and therefore to consider questions that will invite the learner to develop deeper mathematical understanding (Franke et al. 2009; Moyer & Milewicz, 2002).

Project Overview

In Chapter One I addressed the topic of this project and I presented the two guiding questions that will inform the literature review. I discussed the relevance of teacher questioning in mathematics and the value of teacher-student awareness, the impact these have on my desire to develop my professional teaching practice, and the journey that has led me to this place.

I also shared the three theoretical frameworks that guide the literature review. In Chapter Two, I explain the guiding theoretical understandings in greater detail. I also provide a literature review of the supporting research in the field. In Chapter Three, I address the findings from the literature review and incorporate them into a teacher workshop. The power point will present the impact of the relationship between teacher questioning and the role of teacher-student awareness, on the learning of mathematics. Chapter Four includes my reflections on how this journey has impacted my thinking about teaching mathematics in the kindergarten class, how my relationship with mathematics has shifted, and how my new understanding has reshaped our classroom learning experiences. I also include recommendations for future studies.

Chapter Two

Over the past few decades, constructivism has been one of the most impactful theories in mathematics education (Steffe & Wiegel, 1992). Globally, mathematic educators are viewing one's mathematical learning as an active, constructive process (Cobb, 2005; Cobb, Yackel, & Wood, 1992). As a result, this capstone will be guided by two complimentary theories that draw on this understanding and impact children's mathematical learning: i) constructivist theory (Davis & Sumara, 2003; Dewey, 1929; Ernst, 1991), which recognizes that one recursively constructs his or her own understanding of the experience; and, ii) social constructivism (Bruner, 1962; Davis & Sumara, 2003; Glaserfeld, 1989; Rogoff, 1984; Steffe & Kieren, 1994) where knowledge is constructed through social interactions.

Co-emergence with the Curriculum

The renewed British Columbia provincial curriculum seeks to educate students for the 21st century. The focus of the newly revised curriculum is on developing deeper conceptual understandings, while emphasizing flexible, student-centered environments that provide the best learning experiences for students (British Columbia Ministry of Education, 2016). It is suggested that these environments promote curiosity, and active student engagement, enabling students to take an increased responsibility for their learning. The outlined standards are presented at a level of high conceptual understanding which are listed as the "big ideas" (British Columbia Ministry of Education, 2016), and include: communication; thinking; and, personal and social responsibility. The Learning Standards for Kindergarten mathematics address some of the following curricular competencies:

- i) use reasoning to explore and make connections; ii) to develop, demonstrate, and apply mathematical understandings; iii) develop and use multiple strategies to engage in problem solving; iv) communicate mathematical thinking in many ways; v) use

mathematical vocabulary and language to contribute to mathematical discussions; vi) explain and justify mathematical ideas and decisions; vii) reflect on mathematical thinking; and, viii) connect mathematical concepts to each other (British Columbia Ministry of Education, 2016).

Several of the following research studies, while addressing the impact of teacher questioning on students' mathematical understanding, also support the Learning Standards outlined in the BC Ministry of Education Kindergarten mathematics curricular competencies.

Constructivism Theory

Constructivism focuses on individual learning where people recursively reorganize their current understandings of knowledge in an attempt to make sense of their worldly interactions (Davis & Sumara, 2003; Dewey, 1929; Ernst, 1991). Constructivists claim that knowledge cannot be passively transferred from one person to another, but rather that knowledge is actively constructed through individual experiences of authentic tasks and the reconfiguration of their understanding of reality. According to Dewey (1929), learning is a “process of living” (p.19). As one draws information through the use of his or her senses, knowledge is continually being shaped and reformed. Constructivists view learning as complex and non-linear since learning is actively constructed as one attempts to make sense of his or her interactions with the world. Because one's interactions and the reflection of those interactions are the driving force of forming new constructs, the mind and knowledge recursively loop and cannot be separated from each other. When reflecting on these cognitive transformations, accessible spaces are available to invite new ways of thinking, develop new cognitive constructs, and form new theories about the occurrence. Therefore, educators need to be cognizant of a child's knowledge and present opportunities to build on the learner's interests (Dewey, 1929).

When adopting a constructivist (Davis & Sumara, 2003; Dewey, 1929; Ernst, 1991) position, implications for the teaching and learning of mathematics must be considered. If learning is an active process, where the learner receives information through his or her senses, relevant, meaningful, mathematical activities need to be provided where learners are able to engage using their hands and minds (Dewey, 1929; Ernst, 2006). As the student interacts within his or her environment, sufficient time needs to be allotted for the learner to recursively process the new information and form connections and pathways to pre-existing mathematical ways of knowing. Therefore, it is vital that teachers are aware of students' previous mathematical knowledge so that new structures can be built upon existing understandings. Teachers need to be sensitive to a student's personal methods of learning and thinking and provide mathematical opportunities relevant to the student's ways of learning (Ernst, 2006).

Social Constructivist Theory

Social constructivism acknowledges that an individual constructs his or her own sense of meaning, but emphasizes that this active restructuring of concepts emerges through social interactions and dialogue with others (Steffe & Weigel, 1992). It is through the information gathered as an individual interacts with his or her environment, converses with peers, and observes others' movements that one abstracts knowledge and restructures his or her current ways of knowing. It is the individual's interweaving of the social activity and reworking of current cognitive structures where learning takes place. The development of understanding is fluid and responsive as multiple perspectives are shared and communicated through dialogue. A different level of understanding is achieved when members interact within a group when contrasted with individual understanding. While individuals engage in a group dialogue, ideas collectively proceed to build and be restructured. With this collaboration of ideas, greater

learning takes place through interactions within the group than what is possible on an individual basis (Cobb, Yackel, & Wood, 1992; Fosnot & Perry, 2005; Thom, 2012).

Social constructivist theory provides guidelines for the teaching of mathematics in the classroom (Bruner, 1962; Davis & Sumara, 2003; Glaserfeld, 1989; Rogoff, 1984; Steffe & Kieren, 1994). This theory focuses on an approach to mathematics that has shifted from working independently to developing mathematical ideas while working together, and communicating current understandings through dialogue. This theory lends itself to creating learning spaces where children interact and work together, using dialogue to question, clarify, and defend personal understandings. Mathematical understandings are reached as the individual considers meaning while the group members communicate alternate ideas, negotiate meanings, and achieve new goals (Bruner, 1962; Glaserfeld, 1989; Rogoff, 1984; Steffe & Kieren, 1994).

Importance of Mathematical Learning in the Early Years

Research shows that a student's level of mathematical understanding in kindergarten is strongly predictive of future academic achievement (Moss, Hawes, Naqvi, & Caswell, 2015). The following studies discuss the acquisition of foundational mathematical competencies during the early learning years.

Moss, Hawes, Naqvi, and Caswell (2015) reported on a five month study adapted from a Japanese Lesson Study, situated in an urban school in Ontario, where 90% of the student population was comprised of Syrian and Iraqi immigrants and refugees. The format of a Japanese Lesson Study has been used for nearly a century in Japan, and is now globally recognized as a successful method for professional development in mathematics (Chassels & Melvill, 2009; Doig & Groves, 2011; Groves, Doig, Widjaja, Garner & Palmer, 2013). This method enables educators to continually collaborate with colleagues to restructure their ways of mathematical

knowing, develop deep understandings of the concepts, understand underlying goals, and connect the students' understandings to those goals. Participant observation is a key feature of the lesson study process. All participants observe one teacher demonstrating the collaboratively designed math lesson to a couple of students while the other educators observe student learning, and document data which will be used to revise the lesson. With the new acquisition of practical knowledge, educators return to their own classes and teach the revised lesson (Doig & Groves, 2011).

This study investigated ways to improve the learning of geometry and spatial reasoning for young children. According to Bruce and Hawes (2015), spatial reasoning abilities are a strong predictor of future mathematical success as higher levels of mathematics are spatial in nature. The participants who formed the learning team included: four kindergarten teachers and one grade one teacher. Data were gathered through a combination of videos, audio recordings, completed field notes taken by research assistants, and focus group interviews. Prior to the beginning of the study, all of the teachers shared their lack of interest in the subject matter, anxiety about mathematics, and resistance to the Ministry's movement towards inquiry-based learning. The research assistants transcribed the data and categorized the findings into the "four lesson study adaptation categories" (Moss, et al. 2015, p. 383) applicable to: i) goal setting/investigation; ii) planning; iii) implementation and research lesson; and, iv) reflection of the teacher participants.

As the study progressed, researchers in an attempt to strengthen the lesson study process and provide maximum support for teacher development of content knowledge, included four more adaptations in the process: i) teachers engaging in mathematics; ii) teachers interviewing students regarding mathematical tasks; iii) collaborating and co-creating exploratory lessons;

and, iv) the creation of teacher resources. Two teachers taught the mini lesson that was collaboratively designed by the learning team to several children from their classes, enabling the remaining members of the learning team to observe and document their observations. All teacher participants reflected upon the observations and discussed ways to enhance the lesson.

Immediately upon revisions, the lesson was taught to a different small group of children. Upon completion, each teacher committed to teach the lesson in his or her own classroom and relay their students' responses to the learning team during the next professional development meeting. This method provided a process for teachers to gain an awareness of students' mathematical reasoning and how teaching methods influenced students' thinking.

The results indicated that all participants' perceptions of mathematical activities shifted as they engaged with the mathematical tasks. The activities designed for the participants were adapted for teachers to use with their own students. Activities included a series of transformational geometry and spatial reasoning tasks: i) 3D cube challenge; ii) 2D tangram puzzles; and, iii) 2D pattern block compositions. Teachers began to understand the value of mathematical competency and began to view geometry as visualizing, rotating, and transforming objects, not just naming shapes. A participant stated, "A key piece to [the] Professional Development is that the teachers actually engaged in the mathematics ... doing the math before we even consider[ed] bringing the math to our students" (p. 385). As teachers completed the activities with their students, through the teacher-child interview process, teachers developed their student observation skills which supported their abilities to ask questions and maximize their students' learning potential. All the research participants reported that as a result of this study, they gained a deeper understanding of the importance of geometry and spatial reasoning,

realized the importance of flexibility in teaching, appreciated the value of good questioning, and gained insight into the importance of responding to children's learning.

Mulligan (2015) provided a descriptive analysis of how 21 grade one boys in an independent school located in Sydney, Australia, developed graphs to understand and represent data modelling. These students were from an academically selected class, and were chosen as a result of their outstanding academic achievement, ranking from the 96th to 99th percentile when compared to other students of the same age. The researcher and the assistant employed a design-based research approach, where they created 16 sessions over a one year period to develop and build the students' interest and skills in representing and interpreting data, through the use of investigations that were provoked by students' questions about everyday events and represented by graphs. The students were divided into groups of 10 and 11 students to allow the researcher to scaffold discussions and implement tasks to challenge each student's understandings. An aim of the study was to provoke an interest in data modeling, as well as to develop data structuring skills and explore methods of representation. The researcher observed how the students represented and interpreted data. She sought to move the students beyond the mere construction of graphs to enable student questioning of the displayed data and understand why these interpretations were important.

A typical student group session began with a discussion on how representational data could answer a given question. Students were individually challenged to graphically represent the data in the most effective way. Students were asked to justify their method of representation and to document their thinking in written form. Students formed predictions from the data results and also included questions for the other students to answer during the group discussions. The groups discussed similarities and differences in their graphical representations and observed

strategies for improving their own graphs. With reflection upon their work and the new knowledge gained from the group discussions, students were challenged to find new or better ways of representing the data. Students' representations were collected for data, creating individual student portfolios, as well as the participant-observers' notes. The researcher and research assistant analyzed the data for "structural features, meta-representational competencies, and informal reasoning and generalization" (p. 656). The researcher and assistant then compared conclusions and resolved any noted differences.

The results demonstrated the acquisition of students' competency to represent data in graphical form. Through discussions, reflection, and refinement of the tasks, students increasingly developed sophisticated skills to label the variables in the graph and choose descriptive words for their categories. As a result of the students' varied roles in the group discussions, "explaining, inferring, predicting, and generalizing" (p. 662), the students developed the skills to use graphical representations to understand and make sense of their world. The data confirmed that young children were able to represent data, engage in discussion, learn from others' strategies and use critical thinking to explore the representations of the graphs far beyond the expectations of the traditional grade one curriculum. These selected, high achieving students, all progressed at varying rates throughout the study, as demonstrated by a comparison of their individually drawn graphs and written explanations.

Bruce and Hawes (2015) through the use of a Lesson Study, conducted an investigation to determine if in-class interventions impacted students' spatial thinking and mental rotation abilities in an urban school located in a mid-sized city in Ontario. A team of seven teachers (which formed the teacher-researcher team) and 42 underprivileged four to eight-year-old students participated in a four month study. The children came from low socio-economic homes,

required specialized support for a range of diverse learning challenges, and relied on supplemental food programs. Although all the students in the classes participated in the mathematics intervention activities, each teacher chose a sample of six students to be interviewed by an assistant researcher pre- and post- intervention. These students were chosen to reflect a sample which the teacher considered to be ranging from low to high level of mathematical performance. “In total, 17 low-, 14 mid-, and 11 high-performing students participated” (p. 335). In a quiet location of the school, each student completed “an identical battery of spatial reasoning and mathematic assessments” (p. 335). Each child was interviewed by an assistant researcher and the interviews were videotaped to ensure accuracy, were used for professional learning sessions to demonstrate the learning capabilities of students, and were kept for future analysis of bodily gestures. Qualitative data were also obtained through detailed field notes and audio-recorded interviews with a focus group. Data were transcribed and analyzed using two stages of coding. The first stage of coding determined key words from each spoken word. These codes were then divided into two categories: i) opportunities to learn; and, ii) teacher shifts in the projections of students’ abilities. The teacher-researchers collaboratively participated in mathematical activities, co-planned students’ activities, implemented tasks with students, then reviewed and redefined the activities. Students performed a series of tasks using interlocking cubes, blocks, tangrams, 2D and 3D shapes, and 3D pentominoes blocks. Teacher-researchers used a detailed observation guide to notice abilities in: orientation; symmetry; rotation of 2D shapes to compose larger shapes; decomposing 2D shapes; mentally rotating 2D shapes; and rotating 3D pentominoes blocks to create shapes shown in a drawing. The results showed a correlation between students’ low mathematical abilities and their spatial scores on mental rotation tasks. Data confirmed that interventions lead to significant gains in mental rotation skills and in

improving children's spatial thinking. As a result, teachers shifted their beliefs about teaching mathematics and realized that by providing more appropriate learning activities, students were able to make great gains, surpassing achievement expectations in spatial thinking and mental rotations.

Aunio and Niemivirta (2010) examined how children's specific aspects of numeracy skills in kindergarten can predict their mathematical abilities in grade one. This longitudinal study focused on data collected from 212 kindergarten students, with an average age of six, from northern and southern Finnish towns. Trained volunteer teachers administered the Early Numeracy Test to the kindergarten students, and the grade one classroom teachers administered the test to the grade one children. The Early Numeracy Test focused on forty skills: "concepts of comparison, classification, one-to-one correspondence, seriation, the use of number words, structured counting, resultative counting, and the general understanding of numbers" (p. 429). All test materials were sent from Helsinki University, and collected data were returned to the university researcher for analysis. The test was administered on an individual basis with the Kindergarten children. The grade one teachers administered a forty-five minute group test adapted from a standardized mathematical test used in this region. Researchers used "partial least squares path modeling"³ (p. 430) to analyze the data and establish the relationship between the variables. The results strongly indicated that a child's counting skills and understanding of relational skills before entering kindergarten predicted their application of arithmetic skills and general mathematical operations. The data confirmed the significance of the early understanding of counting, as well as of quantity and relation skills, to the future of a student's ability to apply mathematic skills.

³ The partial least **squares path modeling** (PLS-PM) is a form of analysis applied to data/ It is "a statistical approach to model complex multi-variable relationships among observed and latent variables" (Vinzi, Chin, & Henseler, 2010, p. 2). Researchers may use this model to analyze a study's findings.

Valuing Questioning

In her seminal work, *Learning to teach mathematics*, Nicol (1998) emphasized that mathematics teaching needs to focus on deep conceptual understandings, adding that “there is no single correct way to teach mathematics” (p.48). She asserted that best practices in teaching mathematics include: i) asking the students questions; ii) listening to the students express their thinking; and, iii) responding to students in a way that prompts deeper levels of thinking. Questioning and active listening opens opportunities for mathematical exploration and enables students to develop a relationship with mathematics. This foundational work continues to be the catalyst for further investigation into the significance of questioning in mathematics pedagogy. The following studies provide similar support for the value of questioning.

Frank, Webb, Chan, Ing, Freund, and Battey (2009) explored how teachers’ questioning strategies were used to further mathematical thinking with elementary students. Three teachers, two second grade and one third grade, were approached to take part in the study due to their participation in algebraic reasoning professional development for more than one year. These three elementary classrooms in Southern California shared similar demographical student populations, where 93% of the students received free or subsidized lunches and 52% were English Language Learners. The participating teachers taught with similar teaching styles - incorporating collaborative group work and whole-class discussions. Through the use of video and audio recordings, researchers collected data over a period of a one-week. The researchers used a coding scheme to specifically analyze teacher questioning practices that would further student mathematical thinking and discussion.

Recursive analysis identified four questioning categories: i) specific questions; ii) probing questions; iii) leading questions; and, iv) other questions. Researchers concluded that the

questioning practices of the teachers following a student's response significantly impacted the depth of all students' learning opportunities. Frank et al. (2009) revealed that when a teacher presented a student with probing questions, which have been formulated in response to actively listening to the student's verbalized thinking, teachers are able to gain insight into a student's mathematical way of knowing. These probing questions prompted further elaboration, thereby enabling students to consolidate their own understanding, as they justified their current lines of thinking.

Martin, Polly, McGee, Wang, Lambert and Pugalee (2015) also provided evidence on the impact of teacher questioning in mathematics. During this year-long study conducted at the beginning and the end of a school year. In two high-needs, low socio-economic school districts in the Southern United States, field notes were written observing specific teacher-student interactions and the types of questions teachers asked. Participating students, ranging from kindergarten to grade five, were from urban and suburban districts. Forty-eight teachers who were participating in professional development sessions focused on cognitively demanding mathematical tasks were randomly chosen and observed to determine what kinds of questions teachers asked to engage students in mathematical discourse. Teachers from District One, applied to their school district to be part of the study. The teachers from District Two were randomly selected by the district. The teachers and the researchers mutually agreed upon the days in which the observations were to occur. The three researchers conducted reliability checks and used thematic analysis to discover two major themes: i) the questions posed by the teachers greatly influenced the students' mathematical discourse; ii) and the teachers' choice of questioning influenced the development of mathematical tasks.

Researchers concluded that the depth of classroom discourse increased when teachers posed questions which invited opportunities for students to participate in open classroom discussions, justify their individual thinking, and develop new inquiring questions. This active participation resulted in a higher level of student mathematical thinking replacing the simply recalled one word answers. The types of questions teachers asked produced varying results. Asking high level questions in response to a student's comment encourages the student to justify his or her thinking. Questions such as, "Is this going to be the best strategy?" (p. 16) invited students to apply multiple strategies and encourages evaluative thinking as the group collaborates to make meaning. The teachers' use of a combination of low level fact based questions and high level questions probed the student to reason through their construction of a mathematical concept. Teacher posed questions using contrast and comparison inquiries, discouraged one word answers, and provided opportunities for productive class communication. When teachers replace paraphrasing students' responses with questions that build upon students' prior knowledge, students were prompted to rework their current understandings. This study was limited as there were just two observations, one at the beginning and the other at the end of a school year. Martin et al. (2015) claimed that the role of the teacher is to act as a facilitator; to ask prompting questions that invite students into a discussion, where they will use reasoning to explain and justify their understandings.

Mauigoa-Tekene (2006) offered similar accounts in a research study of 20 teachers in six Pacific Island Early Childhood Centres in New Zealand. This study addressed the importance of teacher questioning skills, the role of the teacher in regards to posing questions to students, and explored whether teacher questioning skills could be taught. This research included two stages- a pre-experimental design and participatory action research. Observational data were collected by

each participant before and after each stage and later compiled and analyzed by the researcher. Participants also took notes while observing each other, and reflected upon these observations. Drawing on observations by the researcher and other acting participants, five main themes emerged when the data were collected and analyzed: i) the majority of questioning was considered to be low level questioning which only allowed for recall answers; ii) allowing inadequate child response time (less than three seconds); iii) teacher prompting of responses; iv) asking children who were in clear line of vision; and, v) asking questions prompting a unison student response. These findings prompted the researcher to invite participants in reflective conversations and to conduct teacher workshops to develop their questioning skills. Post training, participants revealed the professional development to be beneficial in the understanding of how to formulate, present, and follow-up on responses to the posed questions. Before training, the participating teachers dominated the conversations and asked low level questions which limited the students' interactions with others, and stifled possibilities to further their thinking. Post training, teachers' structuring of questions improved, thereby increasing teacher-student interactions and allowing space for students to pose questions.

Aizikovitsh-Udi and Star (2011) explored the environments in which teachers implement and ask high level questions that encourage higher-order thinking, in their teaching practices. The research participants, two experienced teachers in the United States, participated in the year-long study. Researchers were interested in observing the questioning techniques of teachers as they taught math lessons guided by the curriculum, and the questioning techniques of teachers implementing a lesson created by the researchers developed to promote teacher questioning. Both teachers also participated in a week long professional development opportunity which focused on implementing the new teacher materials to promote question asking skills. One

teacher “the conserving teacher” (p. 1356) executed a traditional teaching methodology while the other participant “the leveraging teacher” (p.1356) focused on an innovative teaching style, taking on a facilitator role. Upon examination of the data, Aizikovitsh-Udi and Star (2011) concluded that their use of questioning practices were directly correlated to method of classroom discourse. The conserving teacher was the focal point of classroom discussions, providing her students with explicit information and posed questions to elicit an expected answer. The leveraging teacher encouraged classroom discussions where the students explored and questioned a variety of methods with some guidance to arrive at a solution.

Researchers also noted that each teacher applied different values to student listening. The conserving teacher listened to students to confirm the correct answer. The leveraging teacher listened to understand the student’s mathematical ways of thinking. In this form of “interpretive” listening, the teacher actively heard the student’s response and formulated questions to help the student conceptualize their understanding. The researchers concluded that simply providing teachers with in-service examples of questions to ask is not enough. This study revealed that teachers who encourage open classroom mathematical dialogue are more likely to shift towards asking high level questions which lead to in-depth mathematical thinking.

Moyer and Milewicz (2002) conducted a study with forty-eight preservice teachers and forty-eight children in grades kindergarten to grade six in the southern United States. Each teacher conducted an individual interview with a child to determine the categories of questions teachers use when working with children. Participants were told that the recorded interviews with the child would be used for a self-reflection process to examine their questioning techniques. Researchers used a combination of: i) teachers’ completed self-guided analysis; ii) teachers’ written personal self-reflections; iii) transcribed audiotapes; and, iv) descriptive data

provided on the children's non-verbal communication. This data was used to examine questioning strategies implemented by the pre-service teachers during individual mathematical interviews. Data collected from the videos was used to determine which questions were asked to promote children's mathematical thinking. Recorded questions were divided into several categories: i) questions that helped children to make sense of mathematics; ii) questions that helped children rely more on themselves to determine whether something was mathematically correct; iii) questions that helped children learn to reason mathematically; iv) questions that helped children to conjecture, invent and solve problems; and, v) questions that helped children to connect mathematics, its ideas, and its applications (Moyer & Milewicz, 2002, p. 299).

Through the opportunity to review the interview and completing the self-reflection process, teachers were able to evaluate their questioning strategies and techniques. Prior to the gathering of data, preservice teachers were provided with examples of interviews presenting a variety of questions to encourage deeper mathematical thinking, along with the opportunity collaborate with colleagues in discussion. Upon the collection of data, researchers used constant comparison to code emerging themes. The data showed that preservice teachers found the questioning practice and reflection to be beneficial for teaching classroom mathematics. Through the self-reflection process, teachers were able to observe the questioning patterns they used and explore different kinds of questions that had the potential to be more effective in promoting students' thinking. The results of the study emphasized the importance for teachers to reflect upon their own questioning skills in order to improve their effective questioning techniques for guiding mathematical instruction and deepening students' thinking.

Robitaille and Maldonado (2015) conducted a case study in Florida, to explore the use of teacher questioning and discussion techniques. The researchers gathered data from nine experienced, deemed exemplary teachers (by the district), ranging from elementary to high school. These teachers received their high standing as a result of their high marks on their teacher evaluations conducted by the district administration, for effective questioning and class discussion techniques. Through personal interviews examining: i) planning and preparation documents; ii) performance reviews; iii) reflective journals; and, iv) lesson plans, data were gathered, compared, and triangulated to provide credibility. Through the use of “code/recode, reflexivity, and verbatim quotes from the participants” (p. 11) data showed consistency and discovered patterns amongst the teachers. Results concluded that 50% of teachers insufficiently use effective questioning techniques. The researchers claimed that teachers often ask low level simple recall questions and are uncertain about the generated response that a question poses; is the question to assess or does the question assist with comprehension? This study concluded that there is a strong correlation between reflecting upon one’s teaching practices, and the effective use of questioning and discussion methods. Most participants reported that self-reflection significantly impacts one’s ability to develop their questioning and discussion methods by evaluating the word choice used in the question. All of the participating teachers emphasized the importance of collegial support during this process. Participants claimed that their own research along with collegial conversations was a very effective method of meaningful professional development which more teachers need to consider. The researchers and teachers in this study claimed that effective teaching is more than just asking high level, deep thinking questions. It must also include group classroom discussions where the students are able to formulate and

present provoking questions in which the group collaboratively explores the options to those questions.

Creating an Environment for Learning Mathematics

Researchers suggest that teachers strive to create a learning environment where children are able to construct their own mathematical understanding (Dixon, et al., 2009). Researchers suggest creating learning spaces where children are able to express their thinking, and in doing so, aid in the development of mathematical competencies (Greenes et al., 2004; Niklas & Schneider, 2014). By creating a motivating mathematical learning environment, children have the opportunity to develop complex mathematical understandings (Clements & Sarama, 2011). The following articles present the importance, complexities, and challenges of creating shifts in a mathematical learning environment.

Dixon, Egendoerfer, and Clements (2009) investigated the social norms of a grade two classroom in Florida. An accomplished veteran teacher completing graduate work was discontent with the information gathered from her studies and the textbook driven mathematics program she presented in her class. Data for this study were collected through multiple methods: student pre- and post- interviews; students' math journals; observations; video recording of the math lessons and work time; and, a teacher self-reflection journal. For the first three weeks of the study, data were collected as math lessons were conducted according to instructions in the teacher's manual. In an attempt to move towards a collaborative mathematical learning environment, the teacher introduced explicit social expectations for students working within a group. It was also explained that students would have to: i) justify their thinking; ii) ask questions for clarification; iii) justify their mathematical thinking to other members who posed questions; and, iv) accept mistakes as

part of the learning process. Data were collected for four weeks with the new method of mathematical instruction.

Upon examining the data based on this new approach, the researchers concluded that students actively participated in meaningful mathematical conversations and were able to justify personal ways of thinking. With the understanding that all group members would have an equal opportunity to contribute to the conversations, and given the freedom to directly talk with one another during the discussions, all group members participated in the conversations. Students proceeded to shift their ways of thinking to align their ways of knowing to the group's discoveries. Since the classroom environment encouraged open mathematical dialogue, students participated in in-depth conceptual understandings that were not permissible by direct teaching. Both the students and the teacher became aware of the emergence of knowledge as the group collaboratively negotiated mathematical meaning. For this class, mathematics evolved into an opportunity to explore and share ideas while developing mathematical concepts. Dixon et al. (2009) concluded that a mathematics classroom that invites open dialogue fosters children's natural curiosity and empowers them with knowledge.

Bruce, Flynn, and Bennett (2015) through the process of a Lesson Study, examined the importance of teacher professional development focused on math, in relation to increasing young children's understandings of mathematical concepts. Seven experienced teachers of four to seven-year-old children became co-researchers in an underprivileged socio-economic region of Ontario, and collected video data, student work samples, and "group-generated observation guides" (p. 544) to engage in debriefing discussions about their mathematics teaching over a six-month time span. Teachers observed their students participating in exploratory mathematical tasks and gathered anecdotal data on their learning. Three researchers also collected detailed

field notes and at the end of the study session cycle, interviewed teachers regarding the experience. All data were coded using a coding process that revealed dominant themes related to teacher learning. The dominating themes were then grouped into “increased quality of teacher observations and increased expectations of what you children can do in mathematics” (p. 544).

As teachers moved through the co-developed exploratory tasks and debriefed with each other and the researchers, strong implications for teaching mathematics emerged. Teachers reported that as their classroom observation skills improved during exploratory lessons, they were able to gain great insights into their students’ mathematical way of thinking, which they used as the trajectory for the lesson. Careful reflection of their observations provided the inspiration for planning the next consecutive lesson. This study emphasized the importance of exploratory group learning and how teachers’ careful observation impacted their questioning of the students, as well as the depth of classroom communication. Through this collaborative process, teachers also gained valuable insights into children’s continuum of mathematical learning, and the depth of professional development gained by working together and debriefing.

Bennett (2010) offered accounts of two new teachers in a public school system in Hawaii, observing how each teacher improved whole class mathematical discourse through the use of questioning. This case study included the following data collection methods: researcher field notes; semi-structured interviews; and, transcripts from a rural and urban school. The researcher/mentor met with the teachers to discuss the data after each observation, and offered opportunities for the teachers to clarify data interpretations. At the beginning of the four month case study, collected data demonstrated that both the teachers asked a limited amount of low level recall questions. Both teachers were disconcerted with the findings, as each teacher viewed themselves as competent in student questioning and class discussion methods. Upon reflection of

their lessons and discussions with the researcher-mentor, both teachers began to develop and form an understanding of their role in classroom discourse and the value of questioning. The researcher concluded that not all questions were equal and that the teachers needed to be aware of the kinds of questions being posed to the students, and to whom they were presenting the questions. Bennett (2010) stated that first year teachers often need support to reflect upon their practices and to develop an understanding of the significance of effective questioning and mathematical dialogue.

In a detailed study providing thick description, Jung and Reifel (2011) described how a kindergarten teacher with twenty years of experience used effective strategies in mathematical instruction to encourage children's mathematical communication and further their mathematical thinking. Over a twelve week period in a public elementary school in Texas, the lead researcher, acting as a participant observer, focused on the delivery of the teacher's mathematics instruction by recording detailed field notes, writing a reflective journal, and conducting semi-structured interviews. Researchers used a constant comparative method to code and categorize the data. Two main themes emerged from the data analysis: i) the influences of teacher's beliefs; and, ii) the restrictions of the curriculum. Triangulation was present throughout the entire study, and transcripts of the interviews were read by the participant. The data revealed the importance of establishing a classroom community where children learn together, value and share ideas, and negotiate mathematical meaning. The teacher focused on the students' learning processes through the use of discussions and negotiations, to gain insight into the child's way of thinking.

The research stressed the importance of providing reflective responses precisely at the teachable moment, using open ended "how" and "why" questions to invite students to verbalize their mathematical concepts and prompt deeper thinking. By presenting questions that "ask

children to express, rethink, and clarify their mathematical thoughts” (p. 201), students developed their reasoning skills. Jung and Reifel (2011) proceeded to stress the teacher’s crucial role in attentive listening to students’ responses. This active listening allowed the teacher to gain insights to children’s strengths and weaknesses, enabling the teacher to inform her teaching trajectories. The research concluded that the role of careful listening, questioning and responding to students are some key elements in developing an effective collaborative mathematical learning community. These understandings helped the teacher discover the important role of communication during mathematical learning.

While teaching a course on mathematical and pedagogical inquiry, Nicol (2006) conducted a collaborative inquiry project with fourteen prospective teachers, and fifty elementary school students in British Columbia. This project collected multiple sources of data at the university and school through journals, course work, audiotapes, videotapes, emails, and semi-structured interviews. Nicol (2006) explored three questions linked to pedagogy and inquiry: i) How do teachers respond to students when learning opportunities arise in an inquiry based setting? ii) What do elementary teachers view as problematic? and, iii) How can teacher educators support their students? Data were analyzed in three phases identifying themes and patterns which lead to the construction of a critical incident map. Nicol discussed the dynamics of an inquiry-based classroom as a space where ongoing action is provoked by events, inviting the group to work together and learn from each other. As the teachers attempted to interpret and apply this method of learning, the data revealed that teachers were challenged by their held mathematical beliefs and previous ways of teaching mathematics. Teachers were resistant to abandon the concept of following the math “rules.” Participants noted feelings of anxiety and frustration that the course lacked the structure they sought regarding how to teach mathematics.

Data revealed that teachers were challenged when attempting to understand students' thinking, redefining the role of a mathematics teacher, and in shifting their current understanding of mathematics to an unfamiliar teaching method. Overall, the results showed that teachers felt "vulnerable and uncertain" (p. 33), when they were unable to comprehend the students' line of thinking, respond to or question students' dialogue, which resulted in resistance to inquiry learning. This place of tension and uncertainty required the teachers to move into uncharted areas, where they were uncertain of the benefits, importance and methods of inquiry based learning. Nicol suggested that to overcome resistance teachers needed to develop active listening in dialogue "in which one listens and is listened to" (p.35). This study brings to the forefront some of the challenges for teachers and preservice teachers as attempts are made to shift their pedagogical thinking in teaching mathematics.

Summary

In this literature review, three interconnected areas were explored: i) the importance of mathematical learning in the early years; ii) valuing questioning; and, iii) creating an environment for learning mathematics.

The articles in the literature review bring attention to the importance of teacher questioning in students' development of mathematical understanding. Many articles highlighted the need for teachers to develop their own personal mathematical understandings and recognize their level of significance on providing rich occasions for young children to extend their mathematical ways of thinking (Bruce & Hawes, 2015; Moss et al., 2015). Research has shown that as teachers collaboratively participate in mathematical activities, their mathematical ways of understanding are transformed. Using this new understanding, teachers are able to mathematically engage with students using their observational skills to form probing questions,

encouraging students to deepen their conceptual understandings (Bruce et al., 2015). Through professional development and discussion with colleagues, teachers are able to develop a reflective teaching process which enables them to create a collaborative classroom environment (Bennett, 2010). Research has shown this environment to deepen students' mathematical understandings that exceed teachers' expectations.

In chapter three, based on the findings of the literature, I connect the implications of effective teacher questioning in mathematics for students, teachers, administrators and policy makers. Suggestions will be provided to help teachers develop their questioning practices and strategies to create a mathematical learning environment. I will also include a description of a professional development workshop for early childhood learning of mathematics. In chapter four, I reflect upon my continuing journey of developing a mathematical relationship and my transformation of questioning skills. I conclude with recommendations for further research in the field.

Chapter Three: Connections to Practice

In this chapter, I draw on information presented in the literature review to explore implications for teacher pedagogy, including how the literature informs: i) the role of teacher questioning on students levels of mathematical understanding; ii) the teacher's role in listening to students ways of thinking; iii) the teacher's response to students' ways of thinking; and, iv) how these interconnected roles influence the opportunities for students mathematical learning. Based on the guiding theories and the literature review in the previous chapter, connections will be made between; i) the teacher's understanding and personal relationship with mathematics, and how it impacts teacher pedagogy; ii) the teacher's role in posing questions to students, and how it impacts student learning; and, iii) how the classroom environment influences mathematical opportunities.

Informed by the literature, strategies and suggestions will be made for teachers and administrators with the purpose of supporting educators in developing positive attitudes towards mathematics, as well as understanding and valuing the skill of teacher questioning, and creating an environment that promotes the optimal learning of mathematics. This chapter also includes a description of a Power Point presentation (Appendix A) for primary educators who are interested in developing their teacher questioning skills in the area of mathematics. The teacher workshop aims to help educators develop an awareness of their own relationship with mathematics, reflect on their own methods of student questioning during class discussions, and develop an understanding of a classroom environment that promotes optimal mathematics learning.

The Importance of Mathematics in the Early Years

The literature reviewed in Chapter Two, provided insight on the mathematical capabilities young learners can potentially achieve when presented with appropriate learning opportunities (Moss et al., 2015; Mulligan, 2015). The literature suggested that children's early mathematical skills are strong predictors of future mathematical abilities (Aunio & Niemivirta, 2010). This implies that mathematics education in the early years needs to be valued by educators, with efforts being made to understand how to provide optimum learning opportunities reflected by the needs and understandings of the students. Based on the review of the literature, students exceeded learning expectations when they were challenged to develop their own means of representation and were able to show their understanding in a variety of ways. Throughout the process, students were provided with opportunities to discuss their understandings with other students, which enabled participants to learn from their peers' strategies (Mulligan, 2015). These findings also link to the learning standards in the new BC Kindergarten Mathematics curriculum. One of the goals is for children to communicate their mathematical understanding and justify their decisions. The teacher, acting as a facilitator, can incorporate class discussions to provide opportunities for students to explain, defend, infer, predict, and adjust their ways of knowing mathematical concepts. Teachers can also encourage students to represent their understandings in a variety of different ways to support their development of critical thinking skills.

For educators to value the role of mathematics in their students' lives, it is important that educators first develop positive relationships with mathematics. In the study by Moss et al. (2015), teachers claimed that through their personal engagement in mathematical activities shifts occurred in their own perceptions about mathematics. During active engagement in the activities, teachers began to understand the importance and relevance of the tasks before sharing the

activities with their students. Bruce and Hawes (2015), supported the aim of improving teachers' mathematical understandings, and noted that teachers found it to be of great benefit to collaborate with each other about the mathematical activities. One teacher was quoted as saying, that in addition to developing her understanding of math, she discovered the possibility of creating a curriculum with "no-ceiling" (p. 341). If she created learning opportunities that would expose, challenge, and enable spaces for students to solve problems, the learning capabilities were endless.

Drawing on the ideas from approaches taken in these studies (Bruce & Hawes, 2015; Moss, et al., 2015), teachers could form small groups with colleagues who are interested in developing their mathematical pedagogy, and regularly engage in mathematical activities suitable for their grade level. Through active engagement in mathematical activities, teachers have the opportunity to examine how the activities help to further their own, as well as their students' understanding of mathematical concepts. These studies suggested that collaborative discussions are of importance to develop a teacher's personal relationship and understanding of mathematical tasks. Therefore, teachers can draw from the studies and benefit from engaging in collaborative discussions about the task and its relevance to develop student understandings. The participating teachers in both of these studies commented on how the students' mathematical abilities exceeded their expectations when presented with appropriate learning opportunities. The literature suggests that teachers shift their currently held beliefs about mathematics curriculum to an open mindset, and as the teacher in the research by Bruce and Hawes (2015) observed, it is important to provide learning opportunities without imposing limits on students learning.

The research by Moss et al. (2015) stated that to provide optimal learning occurrences in math, it is crucial for teachers to be responsive to the students' mathematical reasoning. The

literature continued to express that this is a challenging task for teachers to develop. Moss et al. (2015) reported that as the teachers developed their observational skills through the lesson study process, their awareness of how to ask probing questions and scaffold student discussions also developed.

Based on the research, I suggest that practicing teachers and administrators draw from the experiences illustrated in the study and implement similar approaches. For example, administrators could allow release time for teachers to collaborate, provide the necessary technology for teachers, and become members of the collaborative team. After meeting with other colleagues and co-designing lessons, one teacher could work with a couple of students while the remaining teachers video-taped and observed the teacher-student interactions, documenting their observations. As a group, teachers could then review the data and collaboratively revise the lesson according to the needs in their own classrooms. The individual teachers could then record the session they conducted with their own class. Teachers could then review and review the recordings to reflect upon their interactions with their students, taking care to observe individual student's thinking and examining their responses to students' expressions of mathematical understanding.

The Use of Teacher Questioning to Support Student Learning

Research has identified that teachers' use of questioning skills and their responses to students' talk affects the opportunities for mathematical learning (Franke et al., 2009; Martin et al., 2015; Mauigoa-Tekene, 2006). Through engaging in collaborative mathematical dialogue, students are able to check their comprehension, build deeper mathematical understandings as they listen to peers explain their thinking, realign their own conceptual understandings, and develop future inquiries (Franke et al., 2009; Martin et al., 2015). The types of questions that

teachers use to interact with their students shape the classroom environment and enable varied levels of learning opportunities.

Drawing from the findings in the previous studies, teachers could ask questions for the purposes of the recall of information and to check facts, or to invite students to engage in meaningful conversations that require students to synthesize ideas (Franke et al., 2009). Questions that require students to respond with facts, rules or one word answers place the focus on the teacher doing most of the work. Questions which encourage students to build upon their explanations and ways of thinking place the focus upon the students' understandings, and are not directed by a predetermined teacher outcome. Moyer and Milewicz (2002) stated that teacher questioning is the most widely used instructional strategy. Therefore, I believe it is imperative to understand the effect that teacher questioning has on the students' learning opportunities. The key is to understand the effects of questioning, find a balance between the types of questions asked, and recognize the pivotal moment of when to ask them. This method of mathematical teaching may be challenging for teachers and students. The reviewed literature provides suggestions for teachers who are seeking to improve their questioning skills.

It is important that teachers develop an awareness of their own questioning strategies. In the study by Robitaille & Maldonado (2015), the literature suggests that teachers are frequently asking questions of their students. However, teachers are often unaware of the kinds of questions they present to their students and how their responses to the student's thinking affect the student's learning opportunities. This study discovered that teachers were asking a majority of low level questions and only allowing students two seconds to respond. At the beginning of the study, teachers were unaware that they were not asking questions that would promote critical thinking, problem solving, and establish a classroom environment that would promote optimal

student achievement. I can identify with the teachers in this study. Before beginning my graduate studies, I was also unaware of the impact of my questioning strategies on my students. I had participated in many math workshops attempting to effectively use the information provided. I attempted to use the questions provided in our district's recommended math program. I believed that since most of my students were able to recall or explain the correct answer, that I was providing a successful mathematics program. It wasn't until Jennifer⁴ and I co-taught math lessons as part of her research project that I changed my thinking. As I listened to her questioning techniques and the students' responses, I became very intrigued with the high level of student understanding. As I compared the student responses from our small group work, I began to develop an awareness of my own questioning techniques, and how my questioning skills limited the level of learning of the students in my group. So too in this study, teachers began to understand their questioning skills as they reviewed and reflected upon transcribed lessons and video footage. Participants stressed the importance of the self-reflection process on their questioning techniques. It was through this reflection that teachers became aware of the questions they asked, and the choice of words they used to lead the discussions and deepen student understandings. Observing colleagues and discussing questioning strategies was of great importance to the development of individual questioning skills. "The professional development needed to be on-going, allowing time for teachers to apply, reflect on the outcome, adjust, practice, and apply asking with collegial support for constructive feedback" (Robitaille & Maldonado, 2015, p. 13).

The literature suggested to teachers and administrators that if professional development is to occur, time and support needs to be given to the participants. An idea to consider is for teachers to find another colleague or form a small group of colleagues who would like to

⁴ Jennifer refers to the mathematics professor conducting research in my classroom.

improve their questioning skills. They could take turns video recording and documenting observations while watching another teacher's math lesson. Teachers could review the documentation together or only review their own lessons. Teachers could then discuss how they perceived their questioning skills and collaboratively adjust the techniques to promote student learning. Administrators could allow release time for teachers to work together, or if unable to provide release time, be part of the observation and discussion process.

Once teachers have developed an awareness of their questioning skills, Moyer & Milewicz (2002) stated that the next logical step is to explore how to develop effective questioning techniques and to become aware of what kind of mathematical questions to ask which are suitable to the current situation. Aizikovitsh-Udi & Star (2011) explained that it is more complicated than merely providing teachers with a list of quality questions. Powerful questioning is affected by the way the question is asked, and by the timing of the question. Asking a student a question following their initial justification often helps the student to elaborate upon their ideas. However, to truly understand the student's way of thinking requires a series of explicit questions focused on the student's explanation. This not only demands effective questioning skills, but as the literature in the studies of Franke et al. (2009), Aizikovitsh-Udi & Star (2001), and Moyer & Milewicz (2002), emphasized, it requires actively listening to the students' explanations, giving time to consider and integrate students' solutions which could be developed through the use of one-on-one interviews. The development of teacher questioning and student observation skills acquired during one-on-one interviews can be transferred to the classroom setting.

Using a similar format to those in the study, teachers could consider documenting their work with one or two students on mathematical activities, in order to practice asking questions

and responding to students' demonstrations of understanding. By recording and transcribing the sessions, or reviewing video recordings, teachers are given the opportunity for self-reflection of their techniques, and developing an understanding of students' ways of thinking. When reviewing the teacher - student sessions, it is important to notice the interactions that take place. One must carefully listen to the words used during the interaction, taking note of the initial question asked. It is very important to observe how the question was followed up. Teachers could write down the questions that were asked and observe when the student's way of thinking was the focus. Teachers could also identify when other follow-up questions could have been asked to deepen the student's understanding. Teachers are then able to consider questions that would have been more effective in helping the student reach a deeper level of understanding. The teacher could then write down a list of possible questions that could have been asked in that particular instance to focus on the student's thinking. During a follow up session, the teacher could review the past lesson with the child and ask some of the newly generated questions. Upon examination of the new video footage, the teacher could reflect upon the interactions and evaluate if the student was moved to a deeper level of understanding. Moyer and Milewicz (2002) provided a sample of the categories of questions that the teachers used when examining their own interviews. Teacher may use these examples as a guide or starting place from which to reflect upon their own questioning practices, as is mentioned in my workshop.

Questions that probed children's thinking in several categories: 1) questions that helped children to make sense of mathematics (i.e., Can you explain to me why that makes sense?), 2) questions that helped children rely more on themselves to determine whether something was mathematically correct (i.e., How did you reach that conclusion?), 3) questions that helped children to learn to reason mathematically (i.e., How could you

prove that to me?), 4) questions that helped children to conjecture, invent and solve problems (i.e., What would happen if...?), and 5) questions that helped children to connect mathematics, its ideas, and its applications (i.e., Have we solved any problems like this before?) (p. 289-299).

The literature in the study reviewed by Robitalle & Maldonado (2015) claimed that it is insufficient simply to teach teachers how to ask questions that will lead to deeper levels of thinking, or to provide cooperative learning opportunities. In order to implement effective teacher questioning and productive classroom discussions, the proper learning conditions must be created.

An Environment for Learning Mathematics

From the literature review, one is able to draw a common thread woven amongst the articles. Each makes reference to the importance of communication between the teacher and students in an inquiry based context (Bennett, 2010; Bruce et al., 2015; Dixon et al., 2009; Jung & Reifel, 2011). By creating a safe learning environment and purposefully listening to students responses as the class engages in mathematical activities, teachers can use questioning to further students' thinking.

Teachers may use the study conducted by Jung and Reifel (2011) as a guide when planning their mathematics lessons. Initially teachers could consider how to create a safe and comfortable environment, where students are able to freely express their thoughts and ideas. This space for students invites active participation and allows for the development of children's self-confidence. Next, the teacher could intentionally plan mathematical tasks that would challenge students' thinking and prompt children to discuss and debate possible solutions. During the discussions, the teacher could focus on the mathematical process and aid the negotiation of

meaning making, not the solution. The teacher could use proficient communication skills to ask open-ended questions to prompt students to express their ideas, rethink current understandings, and clarify their thoughts. The teacher could use reflective responses to validate their students' thinking and encourage deeper levels of thought. By purposefully listening to the students' responses, the teacher could gain insight to their mathematical understandings and revise and develop subsequent math lessons accordingly.

It can be difficult for teachers to shift their teaching practices from traditional lessons implemented from the provided mathematics curriculum to a classroom that focusses on learning through an inquiry based approach. The teacher who participated in the study with Dixon et al. (2009) experienced great tension in making the shifts in teaching styles. The study reported that students actively participated once they understood the skills necessary to work within a group. This teacher explicitly stated the social expectations during group discussions and made clear the expectations for expressing their mathematical understanding. Similar to the approach taken in this study, teachers could discuss and develop with their class the expectations for participating in group discussions. As with this participant, teachers would also benefit from recording the class lessons and reviewing the class interactions to reflect upon the classroom dynamics and the strategies used by the teacher and the students.

The study by Bruce et al. (2015), reiterated the need for teachers to provide adequate time for students to discuss and explore mathematical concepts. They also emphasized the importance of teachers discussing their classroom environment with other colleagues. Using this information, teachers might consider team teaching to gain another's perspective, using photos to reflect upon their lessons, or having another teacher observe the lessons, and discuss techniques to improve the learning experience.

Professional Development Workshop

The purpose of this capstone project is to raise awareness of the significant role that teacher questioning skills play in influencing students' opportunities for learning mathematical concepts. Thus, I have developed a workshop (Appendix A) for early childhood educators which presents theories and current research, and provides suggestions for administrators and teachers seeking to develop their questioning skills. I have also created a handout (Appendix B) that summarizes information from the workshop and acts as a reference and a guide for teachers to use when reflecting on their own questioning practices. The first goal of the workshop is to help teachers reflect upon their perception of mathematics and understand their own personal relationship with mathematics. The second goal is to bring awareness to the role of teacher questioning in mathematics, and to begin a process of self-reflection regarding one's own current questioning techniques. Lastly, the goal is to provide suggestions for a classroom environment which lends itself to effective teacher questioning.

In part one of the workshop, I present the goals of the workshop, briefly explain the guiding theories, ask teachers to reflect upon questions they currently ask when teaching geometry, and share my experiences that have lead me along this journey. In part two of the workshop, I begin with teachers reflecting on the value they place on the importance of mathematics. Then, I present current research on how mathematical understandings held by teachers and students effects mathematical learning opportunities. Similar to the participants in the studies, teachers will participate in mathematical tasks which conclude with a group discussion. Part three of the workshop begins with presenting information from the literature that discusses the effects of teacher questioning on the learning of mathematics. I draw on the research to explore how the participating teachers were able to reflect upon and improve their

questioning techniques. Following the methods employed in the research, workshop participants will work in small groups to apply the same techniques and discuss the results. In part four of the workshop, I draw on the literature and discuss the necessary elements and strategies educators used to create a learning environment which enabled effective questioning techniques. At the end of the workshop, I will provide an opportunity for discussion and reflection.

Summary

In this chapter, I drew connections between the reviewed literature and approaches that educators could implement to begin the process of developing effective questioning techniques when teaching mathematics. I provided specific examples for teachers to use as a guide when reflecting upon their own teaching practices. This chapter also described a professional development workshop for early childhood educators seeking to develop their questioning skills in mathematics. In the following chapter, I reflect upon my learning journey throughout this project and include suggestions for further research.

Chapter Four: Reflection and Conclusion

Current literature on the importance of mathematics, teacher questioning, and supportive learning environments has provided the field with valuable insights that have added to our understanding of how teacher questioning skills affect the opportunities for young children to engage with mathematics. The literature also addressed methods educators may draw on as a guide to support their development of student questioning (Aizikovitsh-Udi & Star, 2011; Franke et al., 2009; Martin et al., 2015; Mauigo-Tekene, 2006; Moyer & Milewicz, 2002). Moreover, the literature underscored the importance of a teacher's perception of his or her own questioning techniques and how it directly correlates to the depth of students' mathematical understanding. Teachers' questioning skills shape the classroom environment and enable various types of mathematical learning opportunities for students. Therefore, the literature supported that importance be placed on developing teachers' questioning skills as we move forward to implement the revised British Columbia mathematics curriculum. The reviewed literature in this project has challenged me to provide suggestions and practical methods for primary teachers to create a learning environment which enables them to ask a series of reflective, probing questions while engaging students in meaningful mathematical tasks.

In this chapter, I reflect on my personal learning throughout this capstone project. I revisit the initial considerations presented in chapter one: i) the impact teacher questioning has on mathematical understanding; and, ii) the role of teachers' active listening in responding to students during mathematical dialogue. I conclude with recommendations for teachers and administrators and suggest opportunities for further research.

Personal Experiences

At the beginning of this Masters journey, I held a completely different view of mathematics. Drawing on my own mathematical experiences throughout school, I believed math to be static; a series of algorithms and rules. This belief shaped the learning activities I presented to my class. As most of my students were able to give the correct response to the questions I posed, I concluded that I was successfully teaching mathematics. Within the first couple of days of our mathematics course, my ways of thinking were challenged. The professor asked probing questions that led me to deeper levels of thinking. I began to realize that much of my thinking was shallow and linear, which limited my possibilities of understanding and confined my teaching spaces. As shifts in my understanding emerged I began to view mathematics as a series of relationships. As my conceptual understanding shifted, it prompted me to reflect on how I interacted with my environment, and the opportunities I presented for my students to interact within our classroom environment. My thinking was pushed further when I had the opportunity to participate in Jennifer's research project. I was overwhelmed when watching the impact of her questioning skills on my young students. Never in my many years of teaching had I witnessed young children formulate and express the level of conceptual thinking that was taking place. I had a deep desire to become a teacher who was able to move students toward such in-depth levels of understandings. As I continue to develop my questioning skills, I am sensitive to include all students during class discussions. While I persevere to actively listen to students' responses, my student awareness skills continue to develop. Every time I pose a question to my students, I have become consciously aware if it is a low or high level question, and ask myself what the purpose was of the question I asked; was it to recall information, or was the purpose to lead the student to a deeper level of understanding, and did my question serve the intended

purpose? Having reviewed the literature, I have developed a deeper understanding of the importance of my relationship with mathematics, and how to improve my questioning skills to create optimal learning opportunities for my students. Thus, I am highly motivated to share my conclusions from the literature review with colleagues, in order to help them understand the importance and effects of their own questioning methods.

Educating Educators

I believe this research comes at a pivotal time in British Columbia as educators begin to implement the revised curriculum. I believe that there are many teachers, similar to myself, who carry mathematical beliefs derived from previous educational experiences- that mathematics focuses on applied rules to reach one correct outcome. The revised curriculum for kindergarten focusses on developing and applying mathematical understandings, while encouraging students to express their mathematical understandings in multiple ways. The curriculum acknowledges the importance of students explaining and justifying their ways of thinking. To be able to implement the revised curriculum, shifts in teaching methods need to occur. However, educators are being asked to make these changes in their teaching practices without receiving adequate support. Therefore, it is imperative that primary teachers be given the time to attend professional development workshops, and time to collaborate and reflect on their current teaching practices in order to acquire successful strategies to move forward.

Throughout the review of the literature, it became apparent that teachers need to collaborate with others to help make shifts in their mathematical teaching. The teachers involved in the studies by Bruce and Hawes (2015) and Moss et al. (2015), actively participated in mathematical tasks and discussed the tasks with others which enabled them to develop their personal relationships with the mathematical concepts before attempting to share the tasks with

their students. This appears to be the starting point for creating the kind of learning environment that enables endless mathematical possibilities. My hope is that this project will inspire teachers and administrators to create opportunities for colleagues to gather and begin to engage and discuss mathematical concepts relevant to their grades. Once suitable lessons have been collaboratively created, I propose that teachers watch and record each other working with one or two students as they engage in the lesson. The reviewed literature strongly implied that it was while the teachers reviewed and reflected upon video data, that their student observation skills developed as well as their awareness of asking probing questions (Moss et al., 2015). It is through the reflection and discussion process that teachers will open the door to enabling the possibilities for asking students a series of deep thinking questions.

As evidenced through the review of the literature, it is apparent that educators need to become more conscientious of their own student questioning skills. As I engage colleagues in conversation, I have realized that many educators are unaware of the value of their questioning practices. The workshop I have created can serve as a starting place for teachers to gather necessary information and begin the process of self-reflection into their use of questioning skills in mathematics. The reviewed literature emphasized that a teacher's questioning skills strongly influenced the method of classroom discourse, opportunities for mathematical exploration, and the depth of students' learning (Aizikovitish-Udi & Star, 2011; Frank et al., 2009; Nicol, 1998). Through this project, I have come to view teacher questioning as the foundation of a teacher's practice. Each question drives the momentum, encourages the direction, and shapes the tone of the classroom. The questions teachers pose influence and encourage the style of learning, and affect the conditions that shape the nature of the classroom community.

Based on the literature, I propose that teachers and administrators invest the time to review and reflect on their teaching practices. The teachers participating in the studies emphasized the importance of on-going self-reflection (Moyer & Milewicz, 2002; Robitaille & Maldonado, 2015). This can occur by teachers working with a supportive colleague to record, view, discuss, and retry math lessons, all the while taking care to observe the questions asked of the students, and noting the effects of each question. While reviewing, teachers must also carefully note how they are listening to the student's responses and if the follow-up questions are reflective of the student's way of thinking, moving the student to a deeper level of understanding.

The types of questions teachers ask are tightly woven with the type of classroom learning environment. It is a reciprocal relationship, where the questions posed and the classroom environment are dependent upon the other. For example, if a teacher is the holder of knowledge and poses recall questions to students, the exchange of information between teacher and student is brief and acknowledged with a right or wrong. If the teacher adheres to inquiry-based learning where the conceptual understanding is created by the group, the teacher acts as a facilitator and asks critical questions to prompt the students to deeper levels of thinking. As Nicol (2006) commented, this shift can be difficult for teachers who currently engage in traditional teaching practices. Therefore, I urge teachers to begin slowly, to begin by implementing the ideas for creating an inquiry-based classroom by drawing on the studies included in chapter two and the suggestions provided in chapter three (Jung & Reifel, 2011; Moyer & Milewicz, 2002). I also encourage educators to begin an open dialogue with fellow co-workers and slowly introduce new methods and ideas that work for their teaching situation. My hope is that this project and teacher

workshop will inspire educators to develop an awareness of the impact of their questioning skills on students, and begin the process of self-reflection of their own questioning practices.

Areas for further research

Although the literature has provided the field with an understanding of how teacher questioning affects young children's learning of mathematics, there is still a lack of current mathematical research in early childhood education. According to Aunio and Niemivirta (2010), children's mathematical understanding in the early years predicts the future of a student's ability to apply mathematical skills. Thus, there is a need for additional research on how educators can support young children in acquiring a firm mathematical foundation.

The reviewed literature provided strong implications for children's mathematical learning opportunities in relation to teachers' questioning skills. Further investigation on how to support teachers to examine their follow-up questions would be beneficial. Studies on what kinds of words and actions teachers use while interacting with the students during math lessons would also provide valuable insight to mathematics educators. The clarity of wording and word choice and their effect on children of diverse ethnic backgrounds and minorities while participating in mathematics learning would also be of interest to primary educators.

The reviewed literature provided insight on the importance of a teacher's ability to actively listen to a student's response in order to follow up with a probing, reflective question. This suggests a need for further research on developing teacher listening skills. How do teachers focus on a student's language? How do teachers interpret a student's body language and gestures? How do they interact with and observe their students as they engage with mathematical tasks? Further studies are needed to provide teachers with strategies to develop their observation skills to notice students' learning in that moment. Nicol (2006) provided evidence of the

difficulties teachers face when attempting to make shifts in their teaching practice, and recognized that many are reluctant to do so. With the understanding of the significance of teacher questioning, and the direction of the revised British Columbia curriculum, it is a critical time for further research in this field.

Conclusion

Teacher questioning is a powerful tool which affects students' mathematical learning opportunities. To develop effective questioning techniques requires time and on-going self-reflection. It is a career long process. Researching and reflecting upon my teaching experiences, it became evident to me that I needed to develop an awareness of my questioning skills, and needed to place a greater value on how my questioning techniques affected my students' mathematical learning opportunities.

Through this capstone project, I became aware of the necessary strategies to develop teacher questioning skills in mathematics and I discovered the importance of developing one's own relationship with mathematics. I also gained insight into the importance of teacher questioning and discovered practical methods to further one's questioning skills and acquiring the methods necessary to establish a classroom environment which enables effective teacher questioning. Therefore, I encourage educators to take the steps to develop their questioning skills to provide optimal mathematical learning opportunities for their students. It is my hope that this capstone project may serve as the starting point of an empowering journey towards transforming early childhood mathematics learning and the creation of effective mathematics learning environments.

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Appendix A

Slide 1

DOES IT REALLY MATTER WHAT I ASK?
How teacher questioning influences the learning of mathematics

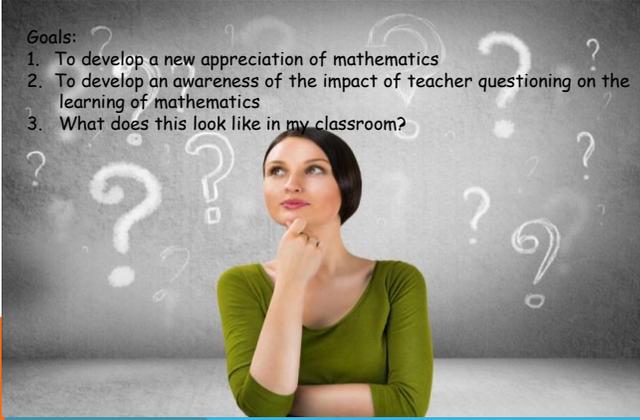
A photograph of a young woman with dark hair, looking intently at a green chalkboard. She is holding a piece of white chalk in her right hand, ready to write. The chalkboard has some faint mathematical equations written on it, including what appears to be a long division problem with the number 35 and a downward arrow. The image is framed by a blue border with an orange triangle in the bottom-left corner.

Slide 2

WELCOME

Goals:

1. To develop a new appreciation of mathematics
2. To develop an awareness of the impact of teacher questioning on the learning of mathematics
3. What does this look like in my classroom?



The image shows a woman with dark hair, wearing a green long-sleeved top, sitting with her hand to her chin in a thoughtful pose. She is positioned in front of a chalkboard that is covered with several white question marks of various sizes. The entire scene is framed within a white border, with a blue and orange decorative element at the bottom left corner.

Thank you for coming

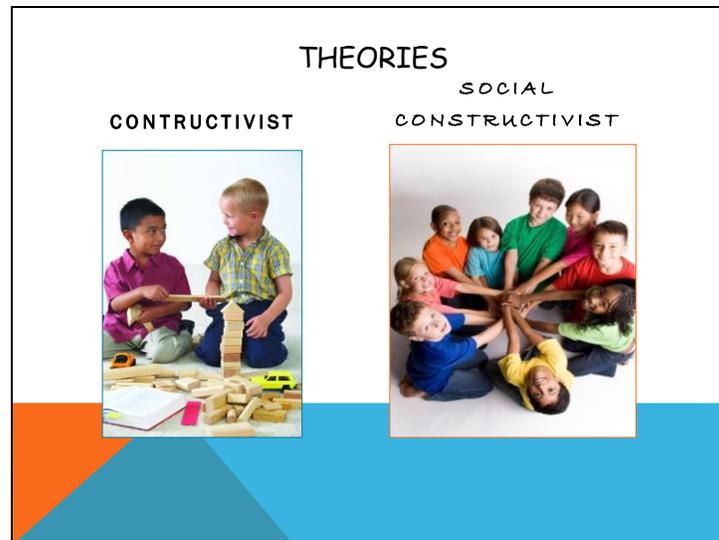
Today we are going to:

- Reflect upon your own questioning skills
- Give you some strategies to take away that will help you to move along your professional learning, and help you to continue to develop your teaching skills

Goals:

- To develop a new appreciation for mathematics
- To bring awareness to the impact that teacher questioning has on students' learning opportunities
- Examine how this can fit in your classroom
- How this merges with the revised B.C. math curriculum

Slide 3



Guiding theories

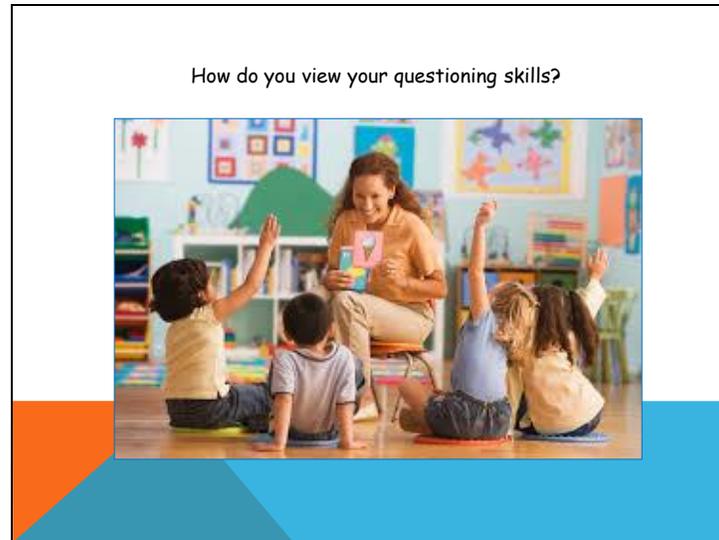
Constructivism:

- knowledge and meaning are built upon previously constructed understandings
- each interaction with environment builds upon previous ways of knowing
- learning is individualistic and through personal interpretation of the experience

Social Constructivism:

- understanding is constructed through social interactions
- understanding is built upon previous constructs of understanding as one interacts with others and negotiates meaning making

Slide 4

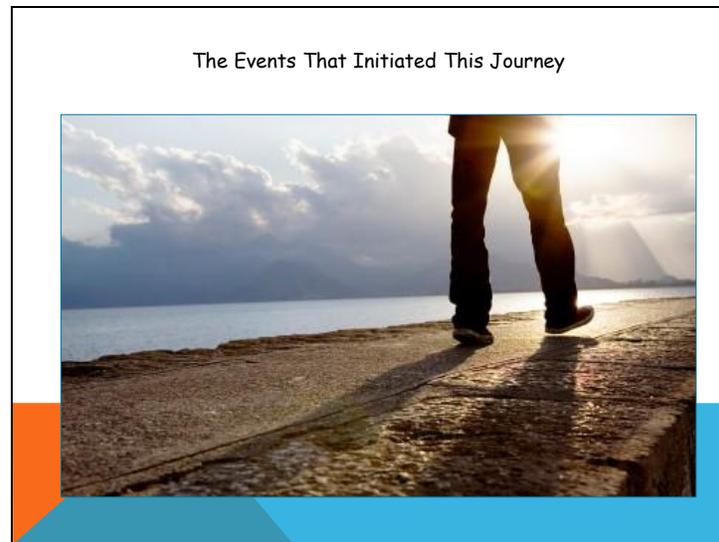


For the purposes of this workshop, let's use geometry for our examples.
What types of questions would you ask your students?

***Activity**

Take a few moments to jot down some of the questions that you have asked your students.

Slide 5

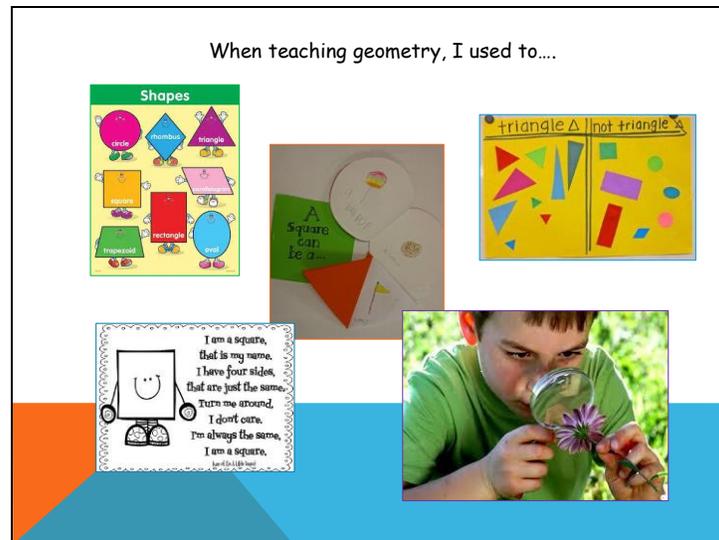


I thought that I was effective at teaching mathematics.

I thought that I was doing a good job.

Most of my students were able to give the correct answer when asked a question.

Slide 6



I would use a chart and look at the 2D shapes.

We would make a class chart.

We would sing songs.

We would use pretend cameras or magnifying glasses and go on a shape hunt in the classroom and outside to find the shape of the day.

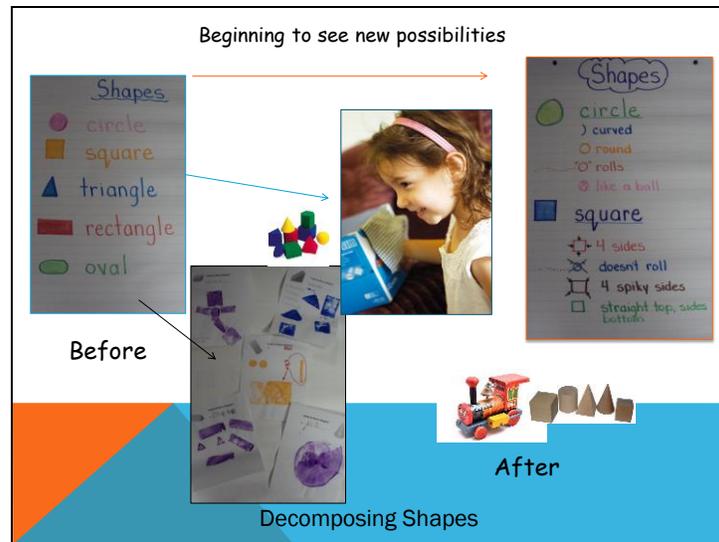
We would make little books,....A square can be a....

We would sort.

I thought that my students knew their basic shapes

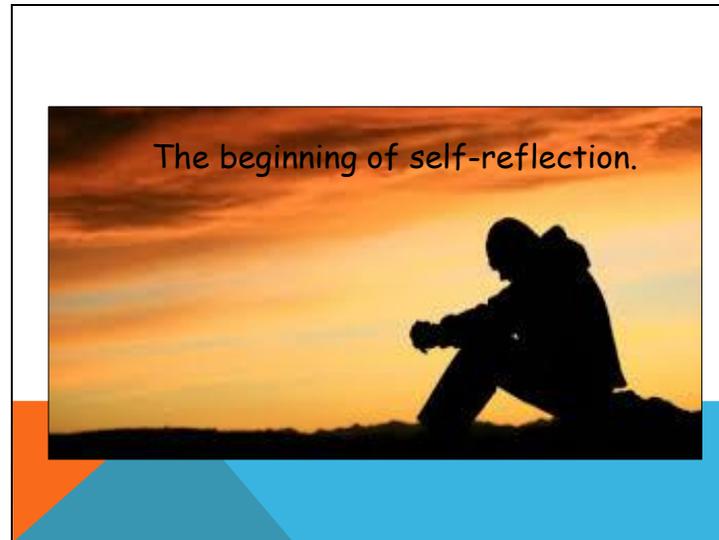
UNTIL.....

Slide 7



I took part in a research project with Dr. Thom
 There was something different about her teaching geometry
 It was like nothing I had experienced before.
 The results that she drew from the children left me spell bound
 What was she doing that I wasn't?
 I was following her lessons during small group time

Slide 8



That was the starting point of my self-reflection

Through discussions with the professor, I came to the realization that it was the way in which she asked the students questions that led to these deep understandings.

I was asking the students questions that left the learning opportunities stifled and shallow

So I thought to myself,.... All I need is a list of good questions and I too will be able to draw these great responses from my students

Instead she told me to begin reading articles on the importance of math in the early years.

Why?

What did that have to do with it?

Slide 9

Geometry, how important is it really?

A photograph of three young children playing on a grassy field. They are surrounded by colorful geometric toys made of plastic tubes, including triangles, squares, and circles. One child is crawling through a blue triangle, another is sitting next to a yellow circle, and a third is near a red square. The background shows trees and a clear sky.

Ask yourself, what emphasis do you place on geometry in your mathematics instruction?

Take a moment to ask yourself, "What emphasis do you place on geometry?"
I am embarrassed to say that I used to save it until the end of the year.
It was kind of the fun unit after the important skills had been taught.
Then I began to read the research...

Slide 10

Study by Aunio & Niemivirta (2010), showed that children's early relational skills predicted mathematical abilities.



Bruce and Hawes (2015), showed a correlation between low academics and spatial reasoning abilities.

In 2010, Aunio & Niemivirta studied 212 kindergarten students. The researchers tested 40 mathematical skills. The children in grade one were tested by their teachers. The results showed that the children's relational skills predicted their mathematical abilities.

Bruce and Hawes (2015), conducted a study to see if interventions would impact students' spatial reasoning and mental rotation abilities. The study concluded that there is a direct correlation between low academic abilities and spatial reasoning and mental rotation tasks. With intervention, students improved in their abilities and surpassed teacher expectations.

Slide 11

By trying the activities first, and discussing the activities with colleagues, teachers began to make shifts in their thinking about the significance of the activity, and began to form their own mathematical relationship.



Another part to this study was how the teachers went about their learning process. Not only did the teachers work with the students, but, they tried the activities, discussed the activities, and developed their own understanding of the significance of the activity **FIRST**.

GROUP ACTIVITY: In small groups, complete the following activities. Follow-up with a discussion.

1. **Shape train-** provide train engine and bag of 3D shapes. Make a train of shapes, but, the shape you place must have at least one difference that the previous shape. Explain to your group how your shape is different than the previous shape.
2. **Painting all sides** of the 3D shape - provide stamp pad, sheet paper, and 3D shapes. Ink and stamp each face of the shape. What shapes did you notice within your 3D shape? What surprised you? How do they fit together?

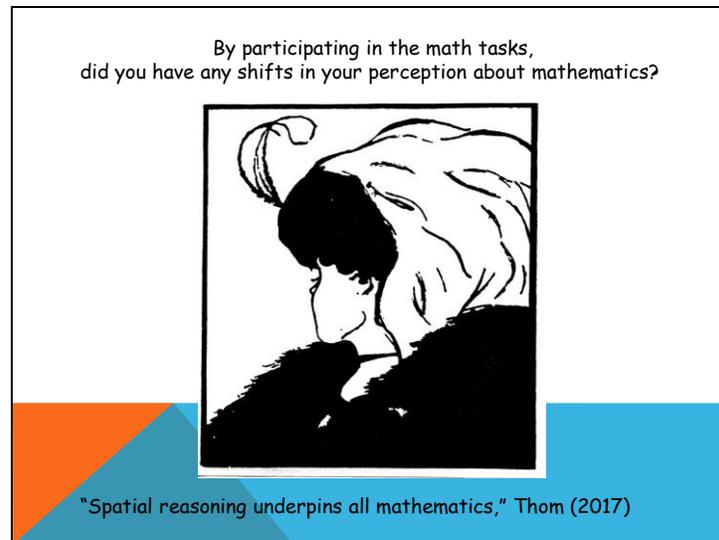
After taking part in interacting with the activity and discussing the activity with colleagues, teachers' perceptions of math began to shift.

They began to see the significance of the activity and began to develop their own mathematical relationship.

Did you notice any shifts in your thinking during the activity or as you discussed?

After watching how my class responded to the various activities in the study, I began to develop an understanding of how important geometry was in their ability to navigate and develop a relationship with their environment. I began to understand how much I was holding my students back from learning, how five year olds are capable of much more than I had ever expected, and the endless possibilities we as a class could achieve, if I created the opportunities.

Slide 12



Ask:

Did you notice any shifts in your thinking as you participated in the math tasks and discussed the tasks with others?

Dr. Thom - "Spatial reasoning underpins all mathematics." (personal conversation, Jan. 12, 2017)

In two of the four studies I reviewed, teachers used a lesson study approach to mathematics.

1. teachers engage in the mathematical tasks and discuss
2. teachers collaboratively design a lesson
3. one teacher tries the lesson with one or two students while the others observe
4. teachers discuss the lesson, make adjustments and try the lesson again

Teachers found this method very beneficial in gaining an understanding of the importance of the task and developing an awareness of how students think while engaging in the activity.

Slide 13

Best Practices in Teaching Mathematics
Nicol (1998)



1. Ask students questions
2. Listen to students express their ideas
3. Respond in ways that lead students to deeper levels of thinking

My understanding about geometry continued to shift as I read and observed the research lessons in my classroom.

I decided that I needed to spend more time on geometry.

Now it is the first topic that I begin the year with and incorporate it into other tasks all year long.

Now that I have developed an understanding of the importance of mathematical skills, I needed to look at how to improve my questioning skills.

If I could just memorize great questions like the ones Jane asked, I too could expand on student's thinking and draw out results that far exceed any previously held expectations.

Then I read *Learning to Teach Mathematics* by Nicol (1998)

The best practices in teaching mathematics include:

1. Ask students questions
2. Listen to students express their ideas
3. Respond in ways that leads students to deeper levels of thinking

Okay, maybe this wasn't going to be so simple...

Slide 14

Developing questioning skills is more complex than it appears.



The majority of questions asked are "short answer, low-level questions that require students to recall facts, rules and procedures"

Franke, Webb, Chan, Ing, Freund, & Battey (2009, p. 381)

"Teachers find it more difficult, ... to follow up on students' explanations and pursue students thinking in ways that support students as they try to detail their strategies or connect with their students strategies." (Franke et al., p. 380)

The skill of effective student questioning is more complex than one would expect.

Ask: Would you agree that you ask your students many questions throughout the day?

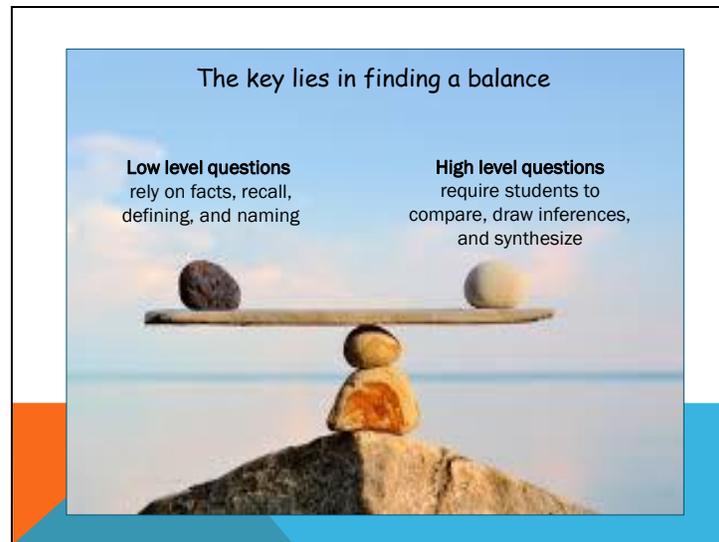
Research shows that most teachers ask their students a lot of questions.

Ask someone to read first quote: the study by Franke, Webb, Chan, Ing, Freund & Battey (2009)

Ask someone to read second quote: Franke et al.

Would you agree?

Slide 15



The key lies in finding a balance between asking low level, fact based recall questions and high level questions which require students to compare, draw inferences, and synthesize information.

Questions that engage learners:

- What do you notice?
- Can you show and tell me.....
- What is the same and different about
- If then.....
- You told me what if
- I wonder what if

The types of questions teachers ask create spaces for the type of student engagement with the task.

The types of questions will shape the nature of the classroom environment.

By asking the right kind of questions, teachers can create opportunities for high-level learning.

Slide 16



When teachers attentively listen and ask students probing questions they are able to uncover details in the students strategies.

Students are moved to deeper levels of thought When teachers build upon an element of their explanation

In the study by Franke et al., researchers video and audio taped three elementary classrooms.

They were specifically looking at the questions teachers asked to follow up on students' initial explanations, and to see if the questions built upon the students ideas.

Data discovered that teachers often asked questions and asked another follow up question.

However, these questions were usually asked to invite the student to clarify their explanation.

Seldom, did teachers ask a series of specific questions focused on an element of the student's explanation.

By asking a series of probing questions, teachers are able to uncover details in students strategies.

When teachers focus on what students say in relation to mathematical thinking, students are moved to deeper levels of thought.

According to this study, there are several benefits to asking a series of probing questions:

1. It helps the teacher understand students' thinking
2. It can help inform the teacher's practices to know how to plan the subsequent lesson

3. It helps the student clarify, solidify and correct their thinking
4. It provides opportunities for other students to connect to their own thinking
5. It is VERY important to listen to what the student says and build upon the student's thinking

Slide 17

Teacher questioning is the key to providing opportunities of higher level discourse.



Good questions open the door and make way to engage in thoughtful communication.

It requires **multiple** specific questions that build upon and element of the student's explanation.

Teacher questioning has the potential to further students' thinking, encourage problem solving, and invite multiple strategies.

A study by Martin, Polly, McGee, Wang, Lambert & Pugalee (2015), continues to build upon the previous study.

They claim that questioning has the potential to generate responses of students thinking, encourage problem solving, and help to develop mathematical strategies.

Good questions open the door and make way to engage in active and thoughtful communication.

It requires **MULITPLE** specific questions that build on an element of the student's explanation.

Questions that compare and contrast help students move to deeper levels of thinking

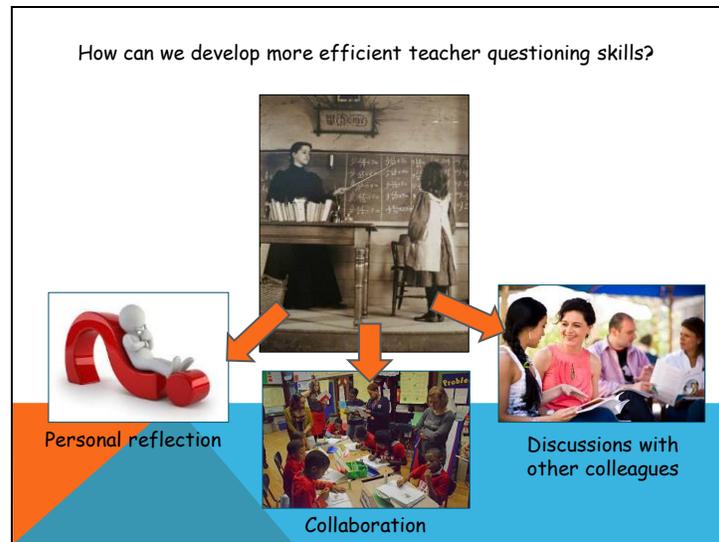
Questions that encourage multiple strategies and collaboration.

"Is this the best strategy?" (p.16)

Questions that focus on justifying strategies and making connections rather than just summarizing.

Teacher questioning is the key to providing opportunities of higher levels of discourse.

Slide 18



How do we move forward to developing more efficient teacher questioning skills? Studies by Aizikovitish-Udi & Star, 2011; Mauigoa-Tekene, 2006; Moyer & Milewicz, 2002; Robitaille & Maldonado, 2015, all have a common thread linking them together.

Teacher reflection, collaboration with colleagues, and collegial discussions.

This was achieved by several methods:

- lesson studies
- video taping, reviewing and reflecting upon the interactions and types of questions used, and discussing the findings with colleagues
- one on one interviews with a teacher and a student

Slide 19



What kinds of questions are leading to what kinds of results?

How were the student's questions followed up?

What kind of question would have been better at prompting the student to deeper levels of thinking?

As teachers participated in self-reflection, discussions and one on one interviews several important strategies emerged.

The importance of:

1. carefully listening to the students' explanations
2. when reviewing and reflecting, take note of what kinds of questions are leading to what kinds of results
3. carefully observe, how was the child's response followed up
4. consider what kind of question would have been more effective
5. try again

Slide 20

Questions that probed children's thinking in several categories:

- 1) Questions that helped children to make sense of mathematics (i.e., Can you explain to me why that makes sense?)
- 2) Questions that helped children rely more on themselves to determine whether something was mathematically correct (i.e., How did you reach that conclusion?)
- 3) Questions that helped children to learn to reason mathematically (i.e., How could you prove that to me?)
- 4) Questions that helped children to conjecture, invent and solve problems (i.e., What would happen if...?)
- 5) Questions that helped children to connect mathematics, its ideas, and its applications (i.e., Have we solved any problems like this before?)

Moyer and Millewicz, 2002, p. 289-299.

Moyer and Millewicz (2002) provided a great example of the questions teachers used when reviewing their questioning skills.

Ask volunteer to read slide.

These questions will be provided in a handout.

This study stressed the importance of teachers talking to other colleagues and the importance of self-reflection.

The process of improving one's questioning skills takes time,

TRY TASK:

- we are going to engage in a similar process to the participants in the study
- break into groups of 3 or 4
- 1 person will be the student, 1 teacher, and 1-2 observers
- hand out photos of 3D shapes
- teacher will show the student the photos one at a time
- teacher will ask student what they notice about the shape, observers will document questions and responses
- teacher will ask, "What do you think is on the other side of the shape?"

Discuss the interactions, what kinds of questions, what kinds of thinking were prompted, could more effective questions been asked?

- try again with the revised questions

Discuss with whole group

- what did you notice about the process?
- did you become more aware of your questioning skills?
- can you see how this process could be beneficial?

Slide 21



Effective mathematics teaching is more than just asking deep thinking questions.

One must also invite group discussions where students are able to collaboratively explore options to the questions.

How does this transfer into the classroom?

According to the research by Robitaille & Maldonado (2015), effective mathematics teaching is more than just asking deep thinking questions.

One must also invite group discussions where students are able to collaboratively explore options to the questions.

How does one go about creating such an environment?

Slide 22

Goals of the B.C. curricular competencies in Kindergarten



- i. use reasoning to explore and make connections
- ii. develop, demonstrate, and apply mathematical understandings
- iii. develop and use multiple strategies
- iv. communicate mathematical thinking in a variety of ways
- v. explain and justify ideas
- vi. connect mathematical concepts

Let's think about what this looks like keeping in mind the revised B.C. curricular competencies:

Invite someone to read the competencies

Research suggests creating an environment where children are able to construct their own understanding as opposed to the traditional method of teaching where the teacher is the keeper of knowledge and imparts his/her wisdom to his/her students.

Slide 23

Making the shift to a collaborative classroom model.



The teacher explained to students that they would have to:

1. Justify their thinking
2. Ask questions for clarification
3. Justify their thinking to others
4. Accept mistakes as part of the learning process

The teacher in the study introduced explicit social expectations for working in a group.



In a study by Dixon, Egendoerfer & Clements (2009), the teacher in the study was attempting to make the shift from traditional teaching to a collaborative classroom model.

The teacher in the study introduced explicit social expectations for working in a group - you could make a class agreement.

READ bottom of slide

The teacher discovered that with these new guidelines, dialogue was encouraged and the level of student participation increased.

Over time, her classroom evolved to an environment where there were opportunities to explore and share ideas while students developed mathematical concepts.

Slide 24

A kindergarten teacher's use of effective communication skills while teaching mathematics

Jung & Reifel, 2011

1. Created a safe environment for students to express their ideas.
2. Planned activities that would challenge students thinking and prompt class discussions to explore possible solutions.
3. The discussions focused on mathematical meaning making, not on finding the correct solution.
4. The teacher asked open ended questions to prompt ideas, encourage students to rethink understandings, and clarify thoughts.
5. The teacher used reflective responses to validate and encourage deeper thinking.



In another study, Jung and Reifel (2011) observed a kindergarten teacher's use of communication with her class.

They concluded that she: have a volunteer read the slide

In this study, it was also stressed that a teacher's active listening skills are crucial to gain insights into student's ways of thinking and understanding.

Slide 25

Self-reflection is a powerful tool to move towards the collaborative classroom community that you are striving for




Reflection is most effective when discussing and working with another colleague with similar interests. It is important to support and encourage one another.

As noted in several of the previous studies, Bruce, Flynn & Bennett (2015), explained the importance of self-reflection upon one's teaching practice. Not only is it important to step back and review the classroom dynamics, but it is also important to discuss with colleagues.

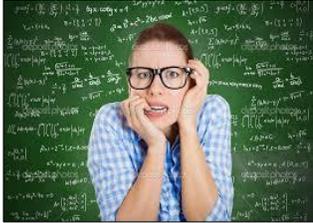
One can gain tremendous insight into one's practice when working with other members.

Some suggestions could be: team teaching, having someone observe some of your lessons, recording your lessons and viewing the tapes together (be certain to obtain parental permission)

It was through this process that teachers were able to make the necessary advancements in their teaching practices.

Slide 26

It is difficult for some teachers to make the shifts to a collaborative method of teaching



Some teachers feel vulnerable and insecure when unable to respond to students' ideas



Nicol, 2006, suggests to develop an active listening dialogue "in which one listens and is listened to." (p. 30)

Nicol, working with teachers in 2006, discovered that for some teachers to change from traditional, familiar and comfortable teaching methods to methods that were uncharted territories was a difficult transition to make.

Some teachers felt vulnerable and insecure when unable to respond to students' ideas.

For these teachers it created a place of tension and resistance to move forward.

Nicol suggests to develop active listen dialogue "in which one listens and is listened to" (p.30)

This is an ongoing process that takes time to reflect, revise, retry and reflect again.

It is most helpful to discuss and collaborate with others while attempting to make shifts in one's teaching practice.

Nicol stated, "Learning to teach is a career-long experience." (2006, p. 26)

Slide 27

The way I used to ask my students questions left the learning opportunities confined and stifled.



Now my questions are leading to opportunities for discovery.

I am still moving along my journey of developing my questioning skills.

I have realized that the way in which I used to ask my students questions left them stifled and confined with little room for growth.

I now am continuing to develop my mathematical relationships, and teaching methods that allow my students to explore possibilities and build upon their own understandings.

I hope that this workshop has inspired you to explore the endless mathematical opportunities that are out there by learning to ask effective questions.

Any questions? Discussion.

Slide 28

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Citations for photos

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Appendix B



Does It Really Matter What I Ask?

Children's early
relational
skills predicted
mathematical abilities

Aunio & Niemivirta,
(2010)

How teacher questioning influences the
learning of mathematics.

Teachers used a lesson study approach to learn about mathematics.

1. Teachers engage in the mathematical tasks and discuss their relevance.
2. Teachers collaboratively design a lesson.
3. One teacher tries the lesson with one or two students while the others observe.
4. Teachers discuss the lesson, make adjustments and try the lesson again.

Teachers found this method very beneficial in gaining an understanding of the importance of the task and developing an awareness of how students think while engaging in the activity.

Learning to Teach Mathematics
By Nicol (1998)

1. Ask students questions
2. Listen to students express their ideas
3. Respond in ways that lead students to deeper levels of thinking

Questions that probed student thinking in several categories:

1. Questions that helped children make sense of math. (Can you explain to me why that makes sense?)
2. Questions that help children rely on themselves. (How did you reach that conclusion?)
3. Questions that help children to reason. (How could you prove that to me?)
4. Questions that help children to invent and solve problems. (What would happen if)
5. Questions that help children to connect math, ideas, and applications. (Have we solved any problems like this before?)

Moyer and Milewicz, 2002, p. 289-299

Questions that Engage Learners:

- What do you notice?
- Can you show and tell me....
- What is the same and different about.....
- If..... then....
- You told me.....what if.....
- I wonder what if.....

The key lies in finding a balance between asking low level questions and high level questions.

Benefits to asking a series of probing questions

1. It helps the teacher understand student thinking
2. It can help inform the teacher's practices to know how to plan subsequent lessons
3. It helps the student clarify, solidify and correct thinking
4. It provides opportunities for other students to connect to their own thinking
5. It is very important to listen to what the student says and build upon their thinking

The types of questions teachers ask, create spaces for the type of student engagement with the task.
The types of questions will shape the classroom environment.

Important strategies emerged as teacher participated in self-reflection, discussions, and one-on-one interviews.

The importance of:

1. Actively listening to the student's explanations
2. Noting which questions were leading to which results
3. Carefully observing how the child's response was followed up
4. Considering what kind of question would have been **more** effective
5. Try discussing the concept again

The key lies in finding a balance between asking low level, fact based, recall questions and high level questions that require students to compare, draw inferences, and synthesize information.

Low level questions – rely on facts, recall, defining and naming

High level questions – require students to compare draw inferences, and synthesize

A Kindergarten Teacher's Use of Effective Communication Skills While Teaching Math

1. Created a safe environment for students to express their ideas.
2. Planned activities that would challenge students' thinking and prompt class discussions to explore possible solutions.
3. The discussions focused on meaning making, not finding the correct solution.
4. The teacher asked open ended questions to prompt ideas, encourage students to rethink understandings, and clarify their thoughts.
5. The teacher used reflective responses to validate and encourage deeper thinking.

Jung and Reiffel, 2011

By asking the right kinds of questions, teachers can create opportunities for high-level learning.

Which questions are leading to which kinds of results?

How were the student's questions followed up?

What kind of question would have been better at prompting the student to deeper levels of thinking?

"Learning to teach is a career-long experience."

Nicol, 2006, p.26