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**TEACHER LISTENING AND REFLECTION AS A WAY TO BROADEN TEACHER
PEDAGOGICAL AND CONCEPTUAL UNDERSTANDING OF MATHEMATICS AT
THE ELEMENTARY LEVEL**

By

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A DISSERTATION

Submitted in Partial Fulfillment of the

Requirements for the Degree of

Doctor of Education

(in Educational Leadership)

The Graduate School

University of Maine

May 2021

Advisory Committee:

Catharine Biddle, Associate Professor of Educational Leadership, advisor

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Advisor: Dr. Catharine Biddle

An Abstract of the Dissertation Presented
in Partial Fulfillment of the Requirements for the
Degree of Doctor of Education
May 2022

The purpose of this study is to examine how teachers can employ listening practices to gain a heightened understanding of not only what their students understand and how they are thinking about mathematics, but also as a way for teachers to build their own conceptual understanding of mathematics by reflecting on the different approaches their students are using. This study seeks to understand to what extent conscious listening, followed by reflective journaling through a systematic professional development process, enhances teacher understanding of both pedagogy and of mathematics. Math anxiety has been identified as a limiting factor in the effectiveness of math instruction and professional development; this study seeks to use individual and small group reflection through lab-based professional development to enhance teacher understanding of both math pedagogy, and mathematical concepts, in a way that minimizes math anxiety. The study will be done qualitatively with teachers using journals to reflect on what they are learning about how their students see and think about mathematics, and how these listening and reflective practices influence the teacher's own understanding of math.

These journal entries will be supplemented by field notes taken during both the professional development process and interviews of some of the teachers who participated in the process.

DEDICATION

I dedicate this work to my family and the staff and students in my school. My wife and two sons were supportive of my endeavors, while also being willing to provide relief by going on a ski with me or challenging me to a game of chess when it was time for me to take a break.

ACKNOWLEDGEMENTS

The students and staff at my school provided me with good feedback and with the insights which inform this work. I cannot say enough about the hard work my staff has gone through in the past year, the time during which this study took place. There were a few people who sparked my curiosity about how math works, or who blew on the spark when they recognized the presence of the spark. Larry Reese was my eighth-grade math teacher. He was always open to new ideas and entertained many of the underdeveloped ideas I had, encouraging me to search for unifying themes. His example is one that has influenced me for over forty years now. Nancy Austin is another mentor who had a profound impact on how I view mathematics, and the teaching of mathematics. She was the faculty director of the Masters program I took at The University of Southern Maine, where I earned my Master's Degree in Teaching and Learning. Aside from her influence on my math thinking, I also learned from Nancy the power of humor in overcoming challenges.

I am greatly indebted to Cheryl Tobey and Becky Tapley and the Maine Math and Science Association. Working with Cheryl and Becky was always energizing and enjoyable. They both have an abundance of ideas balanced with calm demeanors, something I appreciated as we worked to plan the professional development for a group of teachers reeling from the impacts of the COVID pandemic.

I would like to express my gratitude to all the teachers who participated in the professional development, whose journals and comments were integral to the research I did. These teachers maintained professional attitudes throughout the trainings despite the incessant

need to pivot due to changes in policy and changes in health measures related to the pandemic. Through it all, teachers continued to fully dedicate themselves to their work with their students. I would also like to recognize the support of my graduate cohort, in particular Laura Miller and Rad Mayfield, who provided feedback on a regular basis, and shared in a few laughs here and there along the way. I am also indebted to Cat Biddle and Ian Mette who ushered us through this work. Functioning both as pacesetters and taskmasters, their encouragement balanced with suggestions for improvement supported us in the process of learning, researching, and writing.

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CHAPTER I - INTRODUCTION

The real satisfaction from mathematics is in learning from others and sharing with others.

-William Paul Thurston

Children's experiences with math in elementary school set the stage for their math performance as they progress through their school career (NCTM, 2000). Elementary school is when essential concepts, such as number sense, are developed (Schifter et al, 1999). It is a time of great potential in students' development, when they are open to new experiences (Pollan, 2019) and can readily grasp concepts as long as instruction is clear and sequential (NCTM, 2000.). However, instruction that is not systematic and delivered by a teacher who is unsure of math concepts and current math pedagogy can easily obfuscate students' understanding of mathematics, frustrating them and creating an unsavory association with the subject matter which often persists through further school experiences, including high school and college, and often into adulthood (Lloyd, 2014). Most importantly, elementary school is the time that students begin to form their concept of who they are as math learners (NCTM, 2000). A confident learner who feels well-qualified and excited to explore mathematics will have the potential to travel much further than someone who feels uncomfortable with and intimidated by the subject matter. Therefore, the quality of the instruction, and the aptitude of the instructor, are of profound importance (Smith & Stein, 2011).

Slowly, math instruction has changed, with a movement in the past few decades away from a procedural approach, where discrete procedures were taught with little

discussion as to why the procedures work, to a more conceptual approach, where math concepts are explored, creating an overall framework of understanding to which the procedures are attached. This current movement fosters a fuller understanding of how math works. (Boaler, 2015)

Teachers need to be exposed to this shift in practice, especially since many elementary school teachers learned math with a focus on discrete procedures when they were in school and are uncomfortable, if not unaware, of the changes in pedagogy over the past few decades. Since many elementary school teachers are anxious about their math knowledge to begin with, helping them understand and see the value in a new approach must be done with sensitivity and tact.

This project will look at how teachers gain knowledge about mathematics through professional development experiences. The study will explore the potential of deep listening and reflection on what students say about math as a way for teachers to begin to explore and learn more about math, expanding their ways of looking at and thinking about math. By encouraging students to explain how they understand math, listening closely to what the students say, and then reflecting on what they have heard and learned from their students, teachers will not only improve their pedagogy, but will be able to improve their overall understanding of math as well.

Context

My interest in how mathematical thinking and understanding evolves in elementary school, and how teachers influence and impact this knowledge, changed dramatically one day when I was visiting a fourth grade classroom. Ironically, it was a standardized test

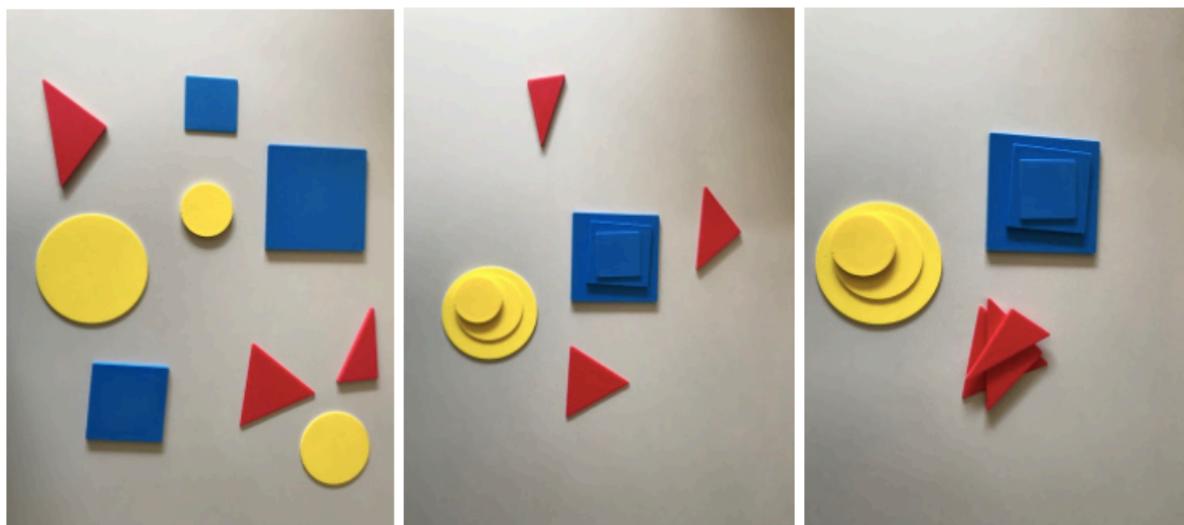
problem which prompted my evolution in thinking. I was looking over the shoulder of a student as he worked on a reading problem. The piece he was reading was about dogs and their innate number sense. The paragraph-long informational piece talked about an experiment with dogs where they were shown a number of treats. Then they were given the treats one by one. The dogs knew when all the treats had been given to them and stopped expecting another treat when the last treat had been given. The piece posited that dogs could “count”. Although I question whether the dogs could actually count, it was clear that dogs had an innate understanding of quantity. This started me thinking about humans’ innate understanding of mathematical concepts. If dogs have an innate sense of quantity, how would innate concepts manifest in humans? What are humans primed, by nature, to do and understand? I wondered how elementary math education stimulated these innate senses, as well as how elementary math education stymied these senses. How can we preserve and build upon what is innate as opposed to presenting math as a narrow, one-way path, which has been a more common way of presenting mathematics in my experiences as a student, teacher, and principal?

Not long after this experience I was observing a first grade teacher administering a one-on-one assessment with a student. She presented the student with a set of nine manipulatives: three yellow circles of different radii, three blue squares with different side lengths, and three red triangles which appeared to have similar areas, but were different in that one was equilateral, one was isosceles, and one was scalene. The teacher asked the student to group the nine figures *by shape*. The student proceeded to group the three circles in a pile, the three squares in a second pile, and separated the three triangles into three

additional groups of one triangle each. At this point, the teacher corrected the student, putting the triangles all together and explaining that they were all triangles (Figure 1)

Figure 1

Representation of Student Sorting Challenge



(a)

(b)

(c)

Images show shapes as originally presented to student (a), student's sorting of shapes (b), and teacher's "correction"

The teacher did not ask any probing questions, nor did she appear to think about the possibility that the student had separated the triangles because, indeed, they were all triangles but they were not similar shapes. The circles could all be enlarged or decreased by a scale factor to make the other ones in the group, as could the squares, but this did not apply to the triangles. If indeed this was what the student was thinking, she was showing an understanding of a concept that is typically not taught until much later in elementary school. This one incident made me think about the impact of a teacher, the authority in a subject area, telling a student that their thinking

was not complete when, in actuality, it seemed to be much deeper than the understanding the teacher expected. Had the teacher probed and asked questions, not only might she have realized something important about the student's understanding, but she may have both broadened her own conceptual understanding of mathematics, as well as realized a need to extend her pedagogical knowledge and techniques. Although this is a very clear example of a teacher failing to probe to figure out what a student knows and understands, and then informing the student that her thinking was wrong when her thinking was possibly much more advanced, it is not the only time that I have witnessed such interactions.

What happens to the average child during elementary school? Is innate math ability encouraged to grow, or does it become numbed, or even undone, by contradictory experiences, incomplete explanations, and incongruous learning? The State of Maine's EmPower ME standardized test results between 2014 - 2017 show a declining proficiency statewide for each class, every year, as the students traveled from third to fourth to fifth grades. The best performance was in third grade, the worst in fifth, consistently. Could school be making these students worse at understanding math? What were teachers doing, and not doing, to contribute to this? How did teachers' experiences around math earlier in their own lives impact their practice? What was the goal of professional development in undoing harmful practices and teaching productive practices? Was there a better way to plan and present professional development so that teachers would be less anxious about math and more open to possibilities? How did listening to one's students, and really hearing what they had to say, help unveil possibilities?

Before I began my doctoral work I led a book study of the National Council of Teachers of Mathematics *Principles to Actions: Ensuring Mathematical Success for All* (NCTM,

2014). This book study followed a very traditional approach to professional development. We met as a whole school in our cafeteria once a month after school. Each time we met we explored a couple of the eight principles of an effective math classroom, with the discussion focusing more on what the book said than what it might look like in our individual classrooms. The study continued until we had covered the eight principles. There were few opportunities for teachers to connect the learning to what they were doing in their classrooms. There were few opportunities for teachers to take what they learned, apply it to their practice, and then reflect on the experience, either individually or as a group. Teacher engagement was limited and the changes in practice and, consequently student achievement, were low. How might this experience have been better?

This year we entered into another exploration of math learning that was completely different in almost every way. Although we still focused on some of the principles of effective math instruction outlined in *Principles to Action*, our focus was both more concise and deeper. Instead of doing an overview of the eight principles, we focused on just three: Facilitating Meaningful Mathematical Discourse, Posing Purposeful Questions, and Eliciting and Using Evidence of Student Learning. Instead of looking at each of the principles as discrete, we examined how the principles intersected and worked together to make learning meaningful. Our learning this time around wasn't in a big arena with the whole school in attendance, but rather with small groups of teachers who were teaching like grade spans and who were using the same curriculum. Both application and reflection were consistently intertwined into the experience; teachers would reflect on practices and ideas we had collectively explored, apply the learning from these sessions in their classroom in the following weeks, and then reflect on how it went.

Formal meetings took place once a month, with teachers discussing their insights from the readings, their own experiences, and watching videos of one another applying the learning. In between formal meetings, teachers not only applied the concepts we had studied together, but also were given choices of articles to read and podcasts to listen to. Each month, teachers were invited to reflect on their learning through prompts in their individual journals related to the readings and podcasts, what they had tried in their classrooms, and how their thinking about mathematics and the teaching of mathematics was changing as a result.

Problem of Practice Statement

Early math understanding is predictive of a student's success later in school, not only in math, but in other areas. The National Mathematics Advisory Panel (2019) states in their report *Foundations for Success* that a student's math performance in preschool is a better predictor of later reading achievement than their early reading skills. Math skills are important, but are they being cultivated in a way that optimizes results later on, in math performance as well as their performance in other areas?

Because early success in math is predictive of success later in life in math and in other areas (National Mathematics Advisory Panel, 2019) it is imperative that all students are getting high quality math instruction during their elementary years (NCTM, 2000; NCTM, 2014; NMAP, 2019). Is this happening now? How do we ensure that it does happen? The key is to make sure that all elementary math teachers have a sense of how math works. An understanding of math is important, but equally important is a sense of how to effectively *teach* math so that students can flourish and build upon their natural abilities. The National Council of Teachers of Mathematics has outlined eight practices that teachers can use to facilitate effective math

learning in their classrooms; teachers need to learn about these practices and then have opportunities to employ the practices in their own classrooms (NCTM, 2014).

Teachers need professional development that allows them to build their understanding of math and explore their understanding of math in ways that they feel comfortable (Mewborn & Huberty, 2004). Teachers also need to have the time to learn about the best practices for teaching, not just math, but in general. How do students learn from each other? How do students take an idea and build upon it by asking questions and experimenting with theories?

Young children have a curiosity that is important to preserve and stimulate. How can teachers best nurture this curiosity so that an increase of math knowledge is a natural outcome, an ancillary benefit, to a child's natural desire to explore and make sense of the world around them? Beyond learning about math and developing a more thorough understanding of math concepts, beyond learning how to better facilitate general learning, I believe that teachers need to increase their abilities to help students uncover their own innate abilities around math. This is best done through asking the right questions, encouraging students to explore, and withholding judgment. The biggest breakthroughs in human knowledge have not been an outgrowth of students being told the ways things are, but rather by allowing curiosity to flourish and thrive while students are encouraged to build their own meaning and understanding.

Purpose Statement

This study will examine how to best influence and encourage teachers, who may have avoided the study of mathematics in college and post-college, and who may have anxiety around both learning and teaching mathematics, to learn more about the subject area. Many elementary school teachers avoided math courses in college, and report that they did not enjoy or understand

the study of mathematics when they were students. They feel anxious about learning mathematics, which extends to a nervousness related to teaching mathematics. What is the best way to help these teachers both overcome negative feelings about math, as well as learn to improve their instruction? The hypothesized outcome would be an improvement in both their pedagogy and their understanding of math concepts, as well as an improved sense of efficacy. It will look at the role of reflection in professional development as a way to reduce anxiety. A major focus of the reflection will be on what the teachers have gleaned from closely listening to what their students have to say and then analyzing the student thinking about mathematics in relation to their own thinking about mathematics. I have a good sense that teachers would see the value in this endeavor based on a study I did last year for the Maine Department of Education's *Numeracy 4 ME* program (2019). Part of the study allowed me to survey teachers about their math learning and understanding. The statement that received the highest positive response was "I feel like I can learn a lot from my students, not just about how they learn math, but about math itself, as students who are learning math see it much differently than adults." Ninety percent of the participants chose either "agree" or "strongly agree" with this statement.

Research Questions

1. How does professional development with a focused integration of reflective and expressive journal writing with small groups of elementary teachers impact, a) Teachers' ability to carefully listen to what students say to explain their thinking; b) Teachers' understanding of mathematical concepts; and, c) Teacher anxiety?

CHAPTER II - REVIEW OF LITERATURE

My review of literature will be broken into five sections. The first section will look at a recent history of how math has been taught in the United States over the past fifty years and the changes that have taken place over that time. The second section will examine the qualities of the typical elementary school teacher. The third section will define the attributes of quality math instruction, specifically “purposeful questioning”, “meaningful discourse” and “eliciting and using evidence of student thinking”, with an emphasis on what a listening teacher does. The fourth section will discuss what effective mathematics professional development looks like in an elementary school. The fifth section will look at the value of reflective practices and how they can be incorporated into professional development, with an emphasis on expressive writing as a reflective practice that has proven effective at reducing anxiety, freeing working memory, and improving performance.

Math Education in the United States Over the Past Fifty Years

The Soviet launch of the Sputnik satellite was a defining moment in the evolution of education in the United States. The Cold War called for a population of U.S. citizens who could problem solve and apply mathematics and science to create defense technology to keep up, and ideally bypass, the Soviet Union. The need was critical. With both countries increasing their nuclear armaments, advancement of math and science education became necessary to face an existential threat to not only the United States, but our whole world.

This led to a national curriculum created under the auspices of the National Science Foundation in the 1960s that incorporated social studies, math, and science, but that was met

with great backlash by the political right, who questioned inclusion of topics such as evolution. A more open approach to math, which allowed for and encouraged varied approaches to solving problems was misinterpreted and misrepresented by the political right, which fought to return to a more traditional approach grounded in rote procedures and memorization of formulas and theorems. This led to the “back to the basics” movement of the 1970s (Schoenfeld, 2014) with an emphasis on memorizing procedures and a de-emphasis on understanding the conceptual underpinnings of these procedures. It also led to a hierarchy in the learning of mathematics: Math was not for everyone, but for the elite who could withstand the discipline needed to keep up with a punishing pace, and who could keep going despite possibly not fully understanding *why* the procedures worked or when to apply them in a given situation.

In the 1980s, the National Council of Teachers of Mathematics released their *Agenda for Action*, with an emphasis on problem solving, a reflection of the cognitive revolution which recognized math procedures in itself as incomplete. A conceptual understanding of how and why the procedures worked was a necessary component of full understanding. Being able to apply the knowledge was recognized as a necessary skill for a student to be fully competent. (NCTM, 2012). The National Commission for Excellence in Education issued its report *A Nation at Risk: The Imperative for Educational Reform* in 1983 (NCEE, 1983) which evaluated education in the United States in relation to other nations and found that the United States came up short. This led to discussions around a national curriculum, a move that politicians were wary of given past experiences which led to other alternatives. The National Council of Teachers of Mathematics took on the challenge of how to best meet the needs of the nation’s educational system and developed standards to guide the teaching of mathematics. (NCTM, 2016). This work, grounded

in the belief that learning be an active process rather than memorization and practice of procedures (Schoenfeld, 2014) began in 1986 and continued for three years before Curriculum and Evaluation Standards for School Mathematics was finally released near the end of 1989 (NCTM, 2016). Work continued into the 1990s as NCTM, in conjunction with a number of other organizations, refined definitions, coming up with *Professional Standards for Teaching Mathematics* in 1991 and *Assessment Standards for School Mathematics* in 1995 (NCTM, 2016).

The beauty and the problem with these standards is that they were visionary rather than prescriptive. This was both elevating, in that it gave practitioners the opportunity to apply it according to their beliefs, but, being open to interpretation, led to a variety of interpretations and related curricula with a wide range of effectiveness (Schoenfeld, 2014).

During the Bush administration, there was great attention paid to education, as George HW Bush made education one the cornerstones of his agenda. The No Child Left Behind Act represents Bush's hope that all children, regardless of race, socio-economic standing, or disability would have access to an education equal to that of everyone else. National assessments were adopted by states to help them measure their progress. The Bush administration set learning growth goals and then came up with supports for school that did not make annual yearly progress (AYP) toward achieving these goals.

Ten years following the adoption of No Child Left Behind, 48% of schools were failing to make AYP nationwide, but this should be seen through the lense of moving a big ship takes time. Also, assessments were becoming refined, getting closer to matching the standards they were designed to assess. Schools, and teachers, using data to inform instruction took a while

to promote, to train teachers how to do it well, and then even more time to learn how to change their instruction accordingly.

Eventually, forty five states would adopt the national standards in math. This has since dropped by four, with Oklahoma, Indiana, Arizona, and South Carolina all withdrawing from their adoptions of national curriculum in recent years. Interestingly, according to the 2019 national data, three of these four states are performing significantly lower than the national standard.

It has been a long struggle, and the battle is probably far from over, but there is a general acceptance in the world of math education that problem solving skills and conceptual understanding of math are essential to a student's enjoyment of math and their ability to effectively employ math in their everyday lives (NCTM, 2016).

Qualities of the Typical Elementary Teacher

College students enrolled in elementary education as their major have the highest math anxiety level of any college major (Beilock et al, 2010; Hembree, 1990). Furthermore, there is little in the way of math requirements for elementary school education students when they are in college (Beilock et al, 2010; Malzahn, 2013). With little required of them in terms of math knowledge in college, coupled with high levels of anxiety around the subject area, the majority of elementary school teachers enter their teaching career with an imbalance of understanding of the subjects they are expected to teach, with mathematics being the subject that receives the least attention (Malzahn, 2013). This avoidance of math is a remnant of a philosophy common in the past that "love of children, not knowledge of subject matter, is the basis of elementary school teaching" (Ball, 1988, p. 41). Most elementary school teachers enter their teaching career with

only a smattering of math experiences and training on how to best teach math (Malzahn, 2013). In addition, anxiety reduces elementary teachers' feelings of self-efficacy in relation to the math instruction they provide their students (Park et al, 2014).

Challenges with teaching mathematics are compounded with time. Although teachers do improve their abilities to instruct as they develop their practice, math is a subject area that has traditionally received little attention when it comes to improvement in teacher competencies (Malzahn, 2013). Mathematical pedagogy changes with time so unless teachers keep track of current trends, their instruction will not incorporate these advances (Mewborn & Huberty, 2004). The majority of elementary school teachers are over forty, with over twenty-five percent of them over fifty (Malzahn, 2013); they are far removed from their preservice instruction in mathematics, both in the subject matter and in the pedagogy of teaching that subject matter. Furthermore, few teachers get much in the way of professional development training around math in general, and specifically about changes in math instruction and changes in the ways of understanding mathematics (Malzahn, 2013). If teachers do not fully understand a new curriculum, or how to effectively teach the curriculum, there is a tendency to avoid its teaching or to teach it in an improvised way that doesn't align with its intent (Schoenfeld, 2014), a practice that can be worse than not teaching it at all.

Attributes of Quality Math Instruction

The National Council of Teachers of Mathematics (NCTM) defines eight essential practices that comprise effective mathematics instruction. These are: Establish mathematical goals to focus learning, implement tasks that promote reasoning and problem solving, facilitate meaningful mathematical discourse, pose purposeful questions, build procedural fluency through

conceptual understanding, support productive struggle in learning mathematics, and elicit and use evidence of student thinking (NCTM, 2000). All eight practices work together to optimize instruction. More recently, the Rights of the Learner in mathematics are gaining attention as a way to ensure equitable access to quality learning (Kalinec-Craig & Robles, 2020; Hintz et al, 2019). These rights are the right to be confused, the right to claim a mistake, the right to speak, listen, and be heard (e.g.engage in conversation, ask questions, share ideas, and listen to the thinking of others), and the right to write, do, and represent only what makes sense to you. These rights build on the “funds of knowledge” concept (Moll, 1992) established nearly thirty years ago, identifying that students come to the classroom with a fund of knowledge created from their own experiences and personal understanding of math. If these funds are accessed and connected to the math instruction the student will have a much more complete understanding of mathematics (Kalinec-Craig & Robles, 2020).

These funds of knowledge are best accessed through the three practices of posing purposeful questions, promoting meaningful discourse and, especially, eliciting and using examples of student thinking (NCTM, 2000). Integral to these three practices being effective is the role of the teacher as listener; the teacher must listen to the discourse taking place to understand what the students are saying about their learning, and then use this knowledge of student thinking to build future learning experiences (Di Teodoro et al, 2011). Jacobs, Lamp, and Philipp (2010) examined this further, conceptualizing the term *professional noticing of children’s mathematical thinking*, based on three steps a) attending to what strategies students are using; b) interpreting their understanding; and c) deciding how to respond.

Quality professional development enables teachers to progress in both their understanding of mathematics, as well as their understanding of the pedagogy of math (Mewborn & Huberty, 2004). In a survey of elementary school teachers nationwide, only about one in ten teachers reported having taken more than 35 hours of math professional development in the past three years (Malzahn, 2013). A major reason that teachers avoid training in mathematics is because they are anxious about it; it is not a strength for many elementary school teachers, so they shy away from math (Widmer, 2019).

Effective Professional Development for Elementary Math Teachers

Professional development is the key to helping teachers improve their math skills, both in relation to math concepts and pedagogy (Mewborn & Huberty, 2004). However, if the professional development is done in a way that triggers teachers' math anxiety, it may be counter-productive. Site-based professional development which is done in small groups of teachers of similar grade levels, using the classroom as a lab and the district curriculum as the subject matter, has proven to be an effective way to provide effective learning opportunities for teachers (Neumann, 2014; Mewborn & Huberty, 2004). This approach allows teachers to converse with others who are sharing similar experiences around shared curriculum with teachers who have similar teaching assignments. Although the studies by both Mewborn and Huberty (2004) and Neumann (2014) identify the need for teachers to be able to apply what they are learning over a sustained amount of time and with a cohort of teachers in similar situations, less than half of elementary teachers in the United States apply their professional development learning in their classroom and then discuss how it went (Malzahn, 2013).

The Value of Reflection

Reflection and journaling has gained attention in the past few decades as a way to cement student understanding (Veine et al, 2019). It is now beginning to garner similar attention as a way for teachers to explore their own learning. It is a way for teachers who may be intimidated by sharing their thoughts aloud to write about what their thoughts are while exploring their understanding of math concepts and pedagogy (Park et al, 2011; Turner, 2013). Teachers writing in journals were more likely to fully explore their thinking and emotions through journaling (Meth, 2003). Furthermore, a study done in 2011 found that expressive writing helped students in a Midwestern university not only overcome their feelings of anxiety, but actually express themselves more clearly mathematically (Park et al, 2011), as the process of writing about their experience freed up working memory which was being hijacked by worry and was now available in the building of conceptual understanding. A recent article in National Geographic quoted a study where a psychologist found that people who used expressive writing to explore their feelings about climate change were more likely to increase not only their awareness, but also reduce behaviors that contributed to climate change, when compared to a control group (Kunzig, 2020).

In a survey of elementary school teachers in Maine, respondents spoke about their anxieties around learning and teaching mathematics, with 71% disagreeing with the statement “I took a variety of math classes in college beyond what was required” (Widmer, 2019). What the survey did show was a high positive response to the prompt, “I feel like I can learn a lot from my students, not just about how they learn math, but about math itself, as students who are learning math see it much differently than adults.” Of all the questions asked in the survey, this question

had the highest percentage of positive agreement, with ninety percent of the respondents choosing either “agree or strongly agree”.

Although studies have looked at reflection and expressive writing as a way for students in primary, secondary, and post-secondary schools to improve their math performance as well as reduce their math anxiety (Meth, 2003; Park et al, 2011; Veine et al, 2019), there is a dearth of information about teachers using this approach as a way to improve their own math knowledge and understanding, and to reduce anxiety. Although there is much literature on listening as an integral part of teaching (Hintz, 2019; Kalinec-Craig & Robles, 2020; NCTM, 2000; NCTM 2014), the listening is usually tied to formative assessment to determine what students are understanding. What is missing is the practice of listening closely to what students have to say about their thinking as a seed to grow teacher understanding about math concepts; as teachers listen to the numerous student approaches to thinking about math, and reflect on how these different approaches are related, I believe the teacher will be able to grow his or her understanding of mathematical concepts.

Conceptual Framework

This conceptual framework shows the way that professional development, teacher understanding of math and pedagogy, and student understanding of mathematics have all been inter-related in the past, represented in red (Figure 2), and the way that I imagine my work re-representing that relationship, represented in blue (Figure 3).

Figure 2

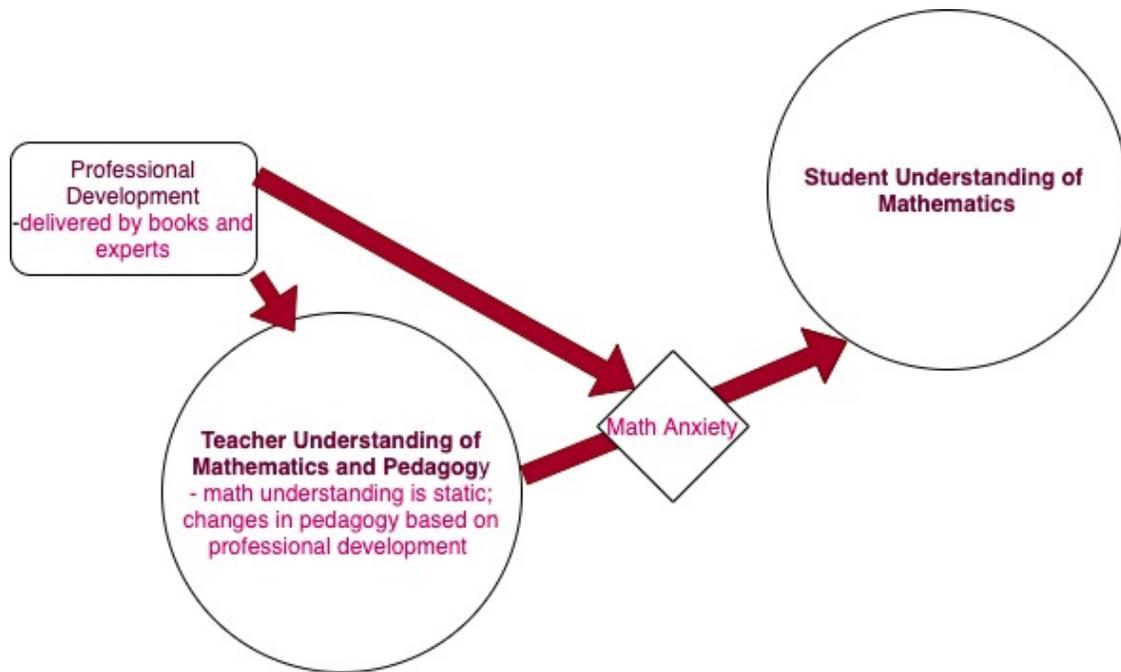
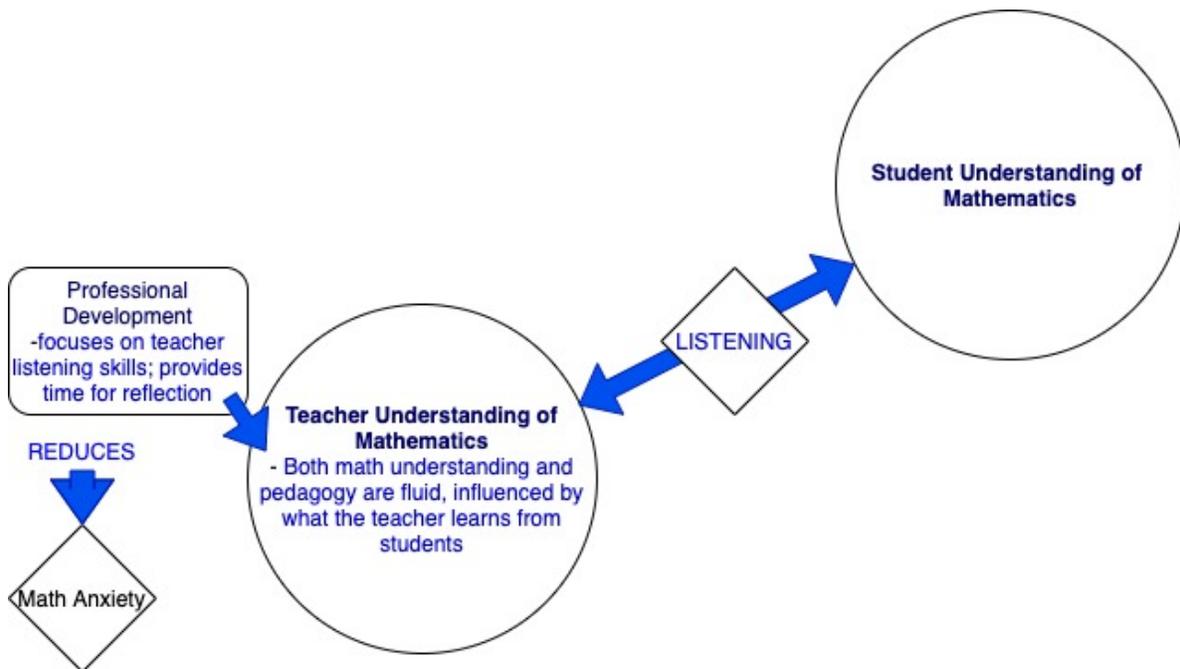


Figure 3



In the past, the dissemination of knowledge was viewed as one-way, from the teacher to the students. My model would make this transfer of knowledge a two-way path, hypothesizing that teachers can boost both their pedagogical knowledge *and* their mathematical knowledge by listening closely to what their students are saying. By reflecting on their students' thoughts and words during their professional development, and growing their understanding of relationships within mathematics through journaling, reflecting, and sharing with colleagues, teachers will not only improve their math knowledge, but also their sense of efficacy related to both teaching math and understanding of math (Park et al, 2011). Whereas math anxiety has impeded math instruction in the past, professional development done in small groups, based on teachers' actual instructional practices, and utilizing journaling and reflection would all serve to reduce teacher anxiety.

Listening to what students have to say is central to my model. Professional development would focus on effective classroom discourse and how to ask questions that lead to divergent thinking about mathematics on the part of the student. The professional development would also focus on how to get students to effectively demonstrate their understanding of, and thinking about, mathematics when they write and speak about their experiences. Although I will not be looking at the growth in student math understanding as an outcome, if teachers are reflective, learning more about mathematics, and reducing their levels of anxiety, it should be followed by an increase in student understanding. One reason I will not be looking at student performance is that I am concerned that it could cause an increase in teacher anxiety; if they knew that student improvement was a measure of the effectiveness of their teaching than anxiety

levels could rise and undo the impact of the professional development and the growth in listening abilities among the teachers being studied.

Justification for study

Anxiety impedes one's ability to learn, or to even recall concepts which have already been learned (Ramirez, Gunderson, Levine, & Beilock, 2013). Elementary school teachers have a much higher than average rate of anxiety when it comes to their feelings around understanding and teaching math (Hembree, 1990; Beilock et al, 2011). Creating a safe learning environment is a key to helping teachers overcome their anxiety (Drago-Severson, 2009; Heifeitz, 1994). Furthermore, much of what makes for a safe learning environment for teachers has also been identified as needed for effective professional development (Drago-Severson, 2009). In a study of what teachers needed most to make professional math development effective, three themes emerged. First, K-5 grouping of teachers didn't work well as the differences between concepts and subject matter were too great; it was better for teachers to meet in grade specific, or smaller grade span, groups. Two, sustained development over the course of the year linked to classroom practice allowed a continuity of learning and gave time for ideas to be absorbed. Third, site-based professional development where teachers and the professional developers were all working with the same curriculum, students, and school environment helped the developers see the specific needs of the school and its teachers (Mewborn and Huberty, 2004).

My hypothesis is that if quality professional development is structured around teachers reflecting on the statements that students make about math, paying close attention to how their students learn and think about mathematics, teachers will not only learn much about their students, but will also learn much about themselves. Teachers who listen carefully to what their

students are saying can begin to expand their own understanding of the many ways to approach math concepts and learning. This will benefit the teachers through not only their own increased understanding of mathematics, but also an increased understanding of how to best teach mathematics to a wide variety of students with myriad needs and ways of approaching mathematics.

CHAPTER III - METHODOLOGY

My examination of reflective, small-group mathematics professional development with an emphasis on listening to what students say, reflecting in journals, and sharing in small groups was conducted as a case study. This case study examines a discrete experience, that being a half-year of professional development that incorporated a focus on listening skills and which utilized the combination of reflection and expressive writing as a way to render the learning deep and impactful (Krathwohl, 2009) as a solution to the problem of partially or ineffective professional development experiences.

Setting and Context

I used the professional development groups at my school as my test site. Throughout the process, I worked with Cheryl Tobey and Becky Tapley, Maine Math and Science Association math consultants, to design professional development that included journaling, focusing on listening to what students are saying about their math thinking, and reflecting on the teacher's own personal growth as a mathematician. The training emphasized ways our understanding of math and math instruction has changed in the past twenty years, as many of the teachers at my school have been largely removed from the changes that have taken place so far this century. I met with Cheryl and Becky regularly in the fall of 2020, before the professional development training took place, to plan an overall approach to the professional development. We were in agreement that using three of the NCTM's Eight Principles that constitute effective math teaching as our focus: Facilitating Meaningful Mathematical Discourse, Posing Purposeful Questions, and Eliciting and Using Evidence of Student Learning. In the past, I had led a

professional development book study of this book, but we covered it quickly, with each hour-long monthly session looking at two of the principles. The goal for the professional development for this project was to *reduce* the scope and *increase* the focus, with the knowledge that studying a discrete area in depth would yield better results (Loucks-Horsley et al, 2010) than a comprehensive, yet shallow, overview, which many of the teachers had already had. (A little over half of the teachers who participated in this case study also participated in the overview training of the NCTM principles in 2018.)

The training sessions that we planned took place once a month for the winter, spring, and summer of 2020. We divided the teachers by grade level, with a K-1 group, a 2-3 group, and a 4-5 group. Each group had six to eight members, made up of the classroom teachers at those grade levels as well as support teachers (special education and Title I). The training sessions were designed to be an hour in length, followed by asynchronous learning that we anticipated could be done in a half-hour, but which allowed teachers to spend more time if they wished.

Cheryl, Becky, and I met before and after each session to reflect upon the experience and plan for the next experience. The sessions certainly evolved with time as we grew our understanding of what worked best. We also improved our sense of what fit best in that hour span of time as we progressed.

The training sessions all took place during the height of the COVID 19 pandemic, starting around the very worst days of the pandemic in Maine (mid-January, 2021). Therefore, we decided that all sessions, with the exception of the final three sessions in June, would be conducted remotely. The first session, with the K-1 teachers, was where we discovered the need to move slowly, especially in regards to technology, as teachers learned to navigate an online

learning environment. As we continued the professional development, teachers became more adept at navigating and technology became more of a boon than a burden.

We also realized early on that we had too much material. Rather than cram a lot of material into our time, moving on before the learning had been fully digested, we decided to slow down and really match the pace to the aptitude of each individual group we were working with. For our reflective process to be truly effective, we knew that teachers needed time to think and express themselves, as well as time to respond to others. Further, we realized that, especially during the pandemic, teachers needed some time and space to breathe.

Each professional development session consisted of short whole group explorations of the theme we were studying, eg. active listening, then shifted to smaller breakout room discussions, usually in pairs or groups of three. We varied how we did the grouping. Sometimes, for example, if we were working in groups of three we would attempt to have one teacher from each of the two grade levels represented during the session working with a Title I or special education teacher, while other times we had people working with teachers on the same grade-level team. We had a focus question or two for the group. Initially, we all joined one of the breakout rooms, but after the first session realized that if our goal was teachers having truly candid discussions it was more likely to happen without an authority on the subject in the room with them. This would cause an issue with data collection because one of my data sources was to be field notes from these discussions. Our way around this was to have the teachers document what they were discussing using Jamboard stickies and text boxes. Another workaround was that we would come back together after each session and discuss what the major discoveries of their sessions were, which is where I would take notes.

Overall, attendance was good at the sessions. The regular education teachers were the most regular attendees. Special education teachers ran into the challenge of having to balance special education professional development requirements with regular education. One of the 16 teachers doing the training missed two sessions, while two more missed one session each. The rest of the teachers were in attendance for all sessions.

We ran three sessions a month, one K-1, one 2-3, and one 4-5, over the course of six months so at the end we had conducted eighteen professional development sessions, with each teacher having attended six sessions which were designed to meet the age needs of the students they taught.

Each teacher was asked to videotape a short vignette demonstrating their practice in relation to the techniques we were studying twice during six months. For example, the first video session was to illustrate questioning that was open-ended and required students to speak about the process they were using and explaining why they were using it. These videos became the subjects of discussion in the subsequent meeting. They were also sources of data for me to use, substituting for the field notes I had planned to take in the classrooms.

The final sessions were the only “live” sessions. The live session at the end was the perfect way to draw our learning to a close, although the final 4-5 session happened on the final day of school and reflected the turbulence created by the final day with students impacting the effectiveness of the professional development on that day.

Research Design

My first source of data came from the journals the teachers kept. Cheryl, Becky, and I set up a Google Classroom, with each teacher having their own journal. Each teacher was given

time to write in their journal both during our professional development sessions, as well as during the asynchronous learning sessions in between the virtual sessions. Each journaling session was guided by a prompt or series of questions to prime the writing, but teachers were given a lot of space for exploration. Much of the reflection focused on questions of what they had tried in their classroom and what they had learned in the professional development sessions, as well as a reflection on how it had gone and what they might do differently next time.

My second set of data came from field notes taken during the professional development experiences. Since Cheryl Tobey and Becky Tapley facilitated the professional development sessions, I had the opportunity to listen and take notes related to teacher conversations and insights, of which, by design, were frequent and indicative of deep learning.

My third source of data is from the “field” observations in the classrooms. Video was the main method for doing “observations” for a number of reasons. The first reason has to do with the complications of having outsiders in the classroom during the pandemic. Since having a number of other teachers observing a lesson increases COVID exposure both for the teachers and for the students in the classrooms, we instead relied on video of classroom lessons. These videos were sometimes produced by me, if that was what the teacher requested, although more often were vignettes that the teachers collected and chose to share. The latter option gave the teachers more control over what they choose to share, which ultimately seemed to reduce the anxieties associated with a classroom observation.

My goal in looking at teachers’ lessons was to catalog changes in questioning techniques, looking for more open-ended, divergent questioning techniques and less convergent questioning, a practice often referred to as “funneling”. I looked for a change in the questioning techniques

and teacher language. There is a group of second and third grade teachers at my school who began, organically, talking about observing each other and how videoing lessons may be a way to overcome problems with scheduling observations, as a lesson that is preserved on video can be viewed anytime. Furthermore, a video can be viewed multiple times and by multiple people, another bonus. The fact that there was a group of teachers already talking about videoing their teaching helped to make the idea of lessons being videotaped more acceptable, and possibly even desirable.

Ultimately, though, I wanted to remain very open to what I found. I definitely headed in an inductive, or “data-driven” (Kuckartz, 2019) direction, as I didn’t want to look for any specific findings; rather, I hoped for the findings to emerge and shine some light on something that has yet to be discovered. In this sense, I hoped to mirror what I would expect of the study’s participants’ interactions with their students: questioning is structured in such a way that unique approaches and new insights surface as a result and those results prompt the questioner to re-examine his assumptions.

Research Question

How does professional development with a focused integration of reflective and expressive journal writing with small groups of elementary teachers impact, a) Teachers’ ability to carefully listen to what students say to explain their thinking; b) Teachers’ understanding of mathematical concepts; and, c) Teacher anxiety?

Sampling

Given the small number of participants at my school I used data and insights from all of the teachers who were willing to work with me. Since all teachers at my school are elementary teachers, all teachers fit the parameters of the study group. All said, this was a group of approximately twenty teachers, with the sixteen regular education teachers being the constant participants. The small number of participants was further justification for the case study approach to my research (Saldano, 2013.)

Data Collection

I assessed three things in this study:

1. Responses to the professional development model as a way to learn math in a way that minimizes anxiety;
2. Changes in teacher actions in the facilitation of classroom discussions; and
3. Changes in both teacher's pedagogy as well as their understanding of math as reflected in their journal writing in reaction to what students say and show in the classroom.

An integral part of my study is the *value of reflection and the learning that proceeds from the process of reflection*, therefore my plan included participants using journals to record their thoughts about what they are gleaned from listening closely to the students they worked with. What insights did they gain into the way their students approach mathematics? What changes did they make in their teaching strategies? And what I wanted to really focus on is the question of what they learned about their own understanding of mathematics through this process. Journaling worked well because it allowed teachers to record their thoughts as they came; furthermore our plan for our professional development incorporated journaling into what the students were doing

in the classroom so that there was a connection between how the students were learning math and how the teachers were learning about it as well. Having participants keeping journals enabled me to assess their thoughts on learning over a period of time, something that would have been much more difficult to do if I were to have used interviews as my main approach to gathering data. Furthermore, journaling allows participants more autonomy to share what they want to share when they want to share it (Meth, 2003). However, as the study progressed I came to realize the value of the interview, and ultimately updated my plan to include interviews as well.

Data Analysis

I looked for evidence of common themes in teacher's journal entries, changes in the way teachers delivered their math instruction, asked questions, and how their students reacted. I didn't want to enter into this study with a set determination of what I was looking for, so I used an inductive approach to my coding. Since I asked my teachers to approach their classrooms inductively, I felt I should model the same approach in my study.

The triangulation of field notes from classroom observations and the professional development sessions, entries from the teacher's journals, and the interviews with teachers who agreed to be part of the interview process, as well as my reflections on those discussions, was integral to my formulating a broad perspective on what is going on; reviewing multiple sources and methods helped me parse out what elements are consistently effective and impactful (Saldano, 2013; Kaiser, 2019). I choose to follow a fairly loose, or soft, prestructure of my study (Saldano, 2013) with the reasoning that my goal was to examine how teachers furthered their practice, both their knowledge of pedagogy and math concepts, by keeping an open mind and

listening closely to what their students said about their learning and thinking processes. As my hypothesis is that this careful listening and open-mindedness is a key to growing their practice, I recognized both the importance and impact of mirroring the same approach in my research.

Instruments/Protocols

I created interactive math journals for the teachers to use with prompts related to the work of the month, which I would update at the start of each new session. The journal was an electronic journal, aligning well with the professional development, as the trainings were all taught via Zoom. Teachers accessed the training using their computers, so having the journals electronically-based worked well. We used Google Classroom as the platform for our work, which was beneficial on a number of levels. First, it was familiar to teachers, as teachers started using Google Classroom regularly when we first switched to remote learning in March of 2020. Even though we returned to in-person instruction with a few minor exceptions, teachers continued to use Google Classroom. Another benefit was that we modeled how to use Google Classroom. Some teachers proficiency with Google Classroom was beyond ours, but for others, seeing how we manipulated Google Classroom to facilitate learning was advantageous. Beyond familiarity and modeling was the ancillary benefit that teachers learned what it was like to be on the learning end of the process by being the recipients of the professional development training. Ideally this allowed them to better understand the process their students were having.

Classroom observations were made possible via video. As mentioned earlier, the pandemic prohibited groups of teachers from gathering in one another's classrooms to do observations, but like many things during the pandemic, this led to a practice that, in the end, was more beneficial; *allowing and encouraging teachers to video themselves, and then choose*

only what they felt comfortable sharing, worked to both reduce anxiety and increase the return on the participation.

Teachers had options around the video production. Some teachers filmed themselves working with an individual student, while other teachers videoed a whole-class lesson. Other teachers asked for me to come in and do the video work. Although the option was there to edit the video, most teachers chose not to and showed the unedited version.

The video process allowed teachers to “get inside” one another’s classrooms without physically doing so, a necessary precaution during the height of the early days of the pandemic, when no one was vaccinated and understanding of how the virus spread was still in its nascent stages. Furthermore, it allowed teachers to see themselves. And not only once; they could review the video numerous times, allowing teachers to look at the practice of others, and their own practice, more than once.

Validity/Trustworthiness

One threat to validity was the potentially negative impact of videoing the teachers while teaching. Having another person in the classroom recording the lesson, or sharing the video, both had the potential to cause anxiety equal or greater to the anxiety I hoped to quell during the professional development experience. One way this was addressed was by only videoing the classrooms of teachers who volunteered, and by being explicit about what the video process would be like and how the videos would be viewed as evidence. In the end, most teachers did the recording of classroom practices on their own; I did help in some classrooms, but the fact that most teachers did this on their own counterbalanced this concern.

One of the largest concerns I have about this study is the fact that it happened under circumstances that are so unusual. It took place in the midst of a pandemic which had neither a defined end date nor a remedy in the way of a vaccine at the time of the study. The direct threat to people's health was an immediate stressor, but in addition to that stressor were the added stressors of increased unemployment, which may have an impact on the families of the individual teachers I worked with, and heightened political tensions related to the pandemic (as well as to a very unusual election year following an unusual presidency). The first night of our professional development was the afternoon of the January Sixth assault on the United States Capitol.

Teachers felt overworked and unsure about shifts in educational programming. Our school employed remote learning as our delivery method spring of 2020, as well as during a brief period the following fall. We started the school year of 2020 with full weeks of in-person instruction (however, with a remote option for families if they chose), but had to switch into the aforementioned remote learning for a half week, which then shifted into two weeks of hybrid learning, with half the school attending for two days a week and then learning at home for the other three, with the other half of the school employing the same approach on opposite days. These constant shifts in how things are done, along with all the unknowns surrounding the "new" approach, took increased mental effort and time. Teachers requested a reduction in their professional learning, so trying a new method of teaching on top of all the other new methods certainly played a factor in this study. This exceptionally angst-filled time ensured that teachers were most likely experiencing some sort of anxiety, even if it is not math anxiety per se. Looking for a reduction in anxiety, I did not have to worry about the absence of anxiety in our

environment at the start of the study as anxiety permeated every facet of our collective experience in the winter and spring of 2021, the time of this study, as well as the year preceding the study.

Another threat, of course, is my own biases. I am lucky in that I worked with two members of the Maine Math and Science Alliance, with whom I was able to discuss my findings. These discussions helped me examine my own biases through peer review. Furthermore, I worked closely with Laura Miller, our assistant superintendent. She also served as a foil to my biases by reviewing my work.

I also plan to use participation validation as a way to validate my study (Maxell, 2005). I will invite participants at the end to review the findings and provide feedback. I feel like having the participants weigh in at the end will be helpful to me in gaining an understanding of the effectiveness of the study, will recognize the participants' insights as valuable, and will help me plan next steps.

Limitations

Concerns I have around validity are that the sample size may be too small to yield significant findings. I have presented my findings as a case study. Case studies offer a unique snapshot of an experience, but the experience is one that is usually limited because of the particularities of the many factors which can't be replicated in other environments. A further factor playing into this study is the unusual circumstances of the 2020-2021 school year; these circumstances had impacts on everyone that will take time to measure and understand.

Ethical Considerations

I have worked to protect the anonymity of the participants. Using journals as a source of information, I have striven to be cognizant of the fact that people are usually very open when writing in journals and, as a precaution, have tried to be especially careful of how I managed the reporting of the data provided through the journal entries. Also, I have done this research in conjunction with Cheryl Tobey and Becky Tapley of the Maine Math and Science Alliance. I will have to ensure that I give credit to the work they are doing and to be clear on who did what. Furthermore, I have attempted to make explicit the divide between this study and the district's evaluation process. We have a culture in our school of risk-taking. Teachers are encouraged to take risks; in fact, that is something I look for when I do evaluations. I would much rather have teachers trying something new that has shown potential in research and literature and being unsuccessful than replicating past practices with only limited or no growth in student and teacher learning. I believe that this culture is of a benefit to my study, but am also aware that teachers who have participated have taken risks beyond the ordinary.

CHAPTER IV - FINDINGS

This chapter is organized thematically. The data collected, which came from journal entries, field notes taken during professional development discussions, notes shared in Jamboard breakout rooms, field notes taken on teachers' videotapes of their classrooms, and from interviews with six teachers, helped identify these themes, which were connected to the research question I set out to investigate:

How does professional development with a focused integration of reflective and expressive journal writing with small groups of elementary teachers impact, a) Teachers' ability to carefully listen to what students say to explain their thinking; b) Teachers' understanding of mathematical concepts; and, c) Teacher anxiety?

The main themes to emerge were related to the research question. The process utilized small-group professional development and reflective journaling to help teachers 1) ask meaningful, probing questions and then carefully listen to what their students were saying; 2) increase their own understanding of mathematical concepts; and 3) reduce their anxiety around math (and given that the study took place during one of the COVID spikes while in the midst of the Coronavirus pandemic, their anxieties in general). This section will review *the three main themes of the research question*, while also showing evidence of *the effectiveness of the design of the professional development*, specifically the use of reflective journals, small discussion groups consisting of teachers from similar grade spans, and *teachers using their classrooms as learning labs*. The professional development sessions were developed specifically to help teachers learn to listen better to what their students were saying, build their own understanding of mathematics

based on how their students were approaching math, and, through the process, reduce their own anxieties around math, and in general. Finally, this chapter will look at an improvement of the student learning experience, followed by closing remarks.

I've outlined my findings into sections. First, I'll discuss the role of quality questioning in improving the classroom experience. Next, I'll explore the relationship between asking good questions and listening carefully to the responses. Careful listening to what students were saying was a key concept of our professional development, as I hypothesized that teachers could learn not only much about what their students knew by listening, but also learn about math itself from their students, who all would have their own way of thinking about and approaching mathematics. In the section about questioning and listening, I also explore how the listening built a classroom environment of respect, which was something that emerged when I was reading journal entries and interviewing teachers. I found this noteworthy; students appreciated being listened to, leading to an improvement in the class culture. Another goal of my research was to explore how the design of professional learning could work to reduce teacher anxiety. Initially, I was considering anxieties around math, but we entered into the pandemic as my research plan was developing, so I broadened my definition of anxieties to include anxieties related to the pandemic.

In the next section of my findings, I will write about how the design of the professional development worked to promote teacher learning. This section is divided into subsections that look at the power of reflection, working in small grade-specific groups, using the classroom as a learning lab, and partnering with a professional organization with an expertise in teacher learning

and the subject matter being taught. Finally, I'll look at how the student learning experience improved by the changes being made in the classrooms at my school.

The Role of Quality Questioning in Increasing Student

Understanding of Mathematical Concepts

Through guided exploration, small-group discussion, classroom implementation, and individual reflection on these processes, teachers continually refined their definition of quality questioning. As they refined their definition, they also refined their practice by changing the way they were posing questions in their classrooms and then reflecting on the impact of these changes in practice. Through ongoing reflection on these classroom changes, they began to notice and define benefits to their students, including better understanding of the subject matter, higher level of engagement, students feeling empowered, and more examples of students learning from one another.

Themes began to emerge. First, as illustrated in the following quotes, teachers began to realize that the questions they asked in the classroom made a difference in how deep their students went in their attempts to understand the concept and how interested the students were in the subject matter. Teachers went from defining quality questioning as “Leading them into the direction you want them to go” to

“A good question ...

- could take a long time to figure out.
- does not have only one answer.
- could consider differing viewpoints.
- allows someone to give examples or connections to another experience/problem

Unless it is a factual question, you [the teacher] shouldn't have a completely predetermined answer in your mind for what you expect the answer to be.”

We revisited questioning during each professional development session and during the asynchronous learning experiences, constantly updating our definitions of quality questioning based on readings, discussions, and classroom practice. Teachers changed their definitions as the process deepened. Not only did definitions evolve, but practice did as well. One teacher clearly illustrated the changes in her practice, stating:

Reading about questioning in mathematics has caused me to be more vigilant with students when asking them about their understanding. I probe them more consciously and keep asking questions until they can fully explain their reasoning. I am also taking care to check in more with my students who are not as involved in class discussions and ask them the same questions one-on-one to ensure that every student can vocalize or write about their learning.

One area of focus was on divergent questioning versus convergent questioning.

Convergent questioning looks for answers that “converge” with expected responses, whereas divergent questions, also referred to as “open-ended”, are much more open to interpretation and innovation. The exploration of the value of divergent questions led some teachers to embrace this approach for the first time, as well as all teachers examining how this type of questioning enhanced the learning in their classrooms. As one teacher explained in an interview:

Those two-part lessons with the open ended responses, I've seen some really interesting responses come out of that. And it's taken time and they've really had to show grit with it, where students will look at it and immediately shut down. And then, when given the time, and knowing that they are going to work on it, they're able to kind of pick themselves up and think creatively about how to solve the problem, and sometimes they need a little more prompting than others but I try to step back as much as possible, because I want to see what they can do on their own and, and there's been some very different responses.

Although this teacher discovered that students struggled with open-ended questions, she set the expectation that they would explore, and gave them the space to do so. The result was the

“different responses”; students did not all see the same thing, but rather exercised their creativity and made their own sense of what they were learning.

The level of comfort with convergent questioning techniques grew for all, but there was certainly a continuum of comfort and success. Not all teachers were consistently successful in asking effective open-ended questions, and many indicated that it was something they were still learning how to do. One teacher reflected on her own experience as an undergraduate student with a professor who asked open ended questions regularly, and how it related to her as a learner:

I [recall] a Professor for Sociology that always used to ask Open Ended questions all class every class and from how I understood it never gave concrete answers but let the students talk it out and never really shared an exact black or white / yes or no answer at the time. It used to drive me absolutely bananas but...it was for a reason and I did not know that. I wish I had known! I likely would have been less frustrated perhaps if I had known that the end goal was there will not ever be any concrete black or white or yes no answers. I may have learned more had I not been so stuck in my own way OCD/ rigid wise.

This teacher has begun to employ open ended questions, now that she sees the value and the practice becomes more widespread in our school. She outlined her approach in her journal:

This year through all of our Math Professional Development (as well as even a little bit of Restorative Practice) asking Open-Ended Questions allows for students to share their thinking and hopefully expand further on why [when responding in their EveryDay Math journals]. Vocabulary that we have used a lot thus far this year has been: predict, notice, wonder, compare/contrast (similarities and differences) and explain. Sometimes I even add, “How could you explain how you did _____ as if someone was just walking into our classroom during Math and you wanted to be the expert teacher to catch them up to speed?”

Some teachers came around to understanding and seeing the value in divergent questioning, while others understood the value from the start, with this teacher stating in the first journal entry:

A good question should be open-ended, with different possible entry-points. A good question should not hint at the answer so much as guide students in the right direction. The focus of the question should be to encourage students to think for themselves.

Although my thoughts about the root of this difference is speculative, I would say the difference between those who quickly embraced, or already were already using, the practices we studied, was based on a number of factors, with the combinations of these factors all being different and having different outcomes. For instance, in some cases a veteran teacher would have had the time to try out different methods and hone her practice to the point of deciding to use open-ended questions, while another teacher may be just out of a pre-service program, using them because they have come from an educational institution which encouraged the use of such practices. For the veteran teacher, it would be a change in practice, which could, depending on the teacher, either be cumbersome and difficult or energizing and appropriately challenging. For the veteran, it would build upon previous experiences, while the less-experienced teacher wouldn't have those prior experiences to help make the process more whole.

Even with the teachers who embraced both the concept and practice of divergent questioning, there were moments they lapsed into less effective practices. For example, this teacher realized that she had a perfect opportunity to ask probing questions, but fell into old habits:

I had a great moment the other day with Jimmy - the class was solving a problem about the volume of Willis Tower in Chicago, where they had the heights of the 9 different towers, all having the same base. Everyday Math had the goal of getting students to see that they could save steps because some of the towers had the same height. Jimmy started adding the heights of the towers together, and I almost stopped him... Then realized that would be a fantastic shortcut to finding the volume of the towers, akin to stacking the pieces of the tower on top of each other. I'm not 100% sure this was where he was going with the idea, because unfortunately I got so excited

about the idea that I didn't ask good questions and said out loud how it would work... live and learn!

Although this teacher may have failed to proceed the way she could envision as being the best way, she was very aware that she could have done better. This awareness, enhanced through the reflective process, is a necessary step in the improvement of one's practice. As we progressed through the process, teachers had multiple opportunities to reflect on their application of our learning through writing in their journals and through the small-group discussion. Most often, change was not immediate, but it did, with time, become widespread as evidenced by the writing in teachers journals.

Another benefit of the change in the questioning process was a growth in student empowerment. With the teacher being more of a facilitator, students came to rely more on themselves and on their peers. The theme of student empowerment was a frequent topic in what the teachers shared, as explored by Linda:

This relates to the convergent versus divergent thinking in that if something organically goes where it was unexpected it may lead to new discoveries and the students can be the experts showing each other with less teacher scaffolding which I think will mean more and they will own it more.

Who says in another entry:

If I tend to sit back, the students tend to take more ownership and strive to want to be the experts and teach each other. The students love when I say that I had not thought of something in that way...I call it "stumping the teacher"... "you thought of a way that I had not even thought of...hooray!" Even that inspires others to try and share multiple ways to come up with the same answer so they can also "stump the teacher" and "think of other ways that Mrs. Griffin had not thought of!" This makes them far happier than if I am just lecturing during a mini-lesson.

Another teacher's journal entry shows a similar theme of the students leading, teaching the other students as well as the teacher as they learn together:

They are doing more ‘talking’ (I ask them to teach me) than I am. If I’ve set it up right (my job), they are doing most of the work in class (their job), and I’m there as the trail guide.

Not all teachers started the questioning process at the same level. Some came into the process with a clear understanding of what a good question was and when to employ what type of question. Others started with a less-concrete idea of good questioning, but built their understanding through the process of questioning, reflection, small-group discussion, trying out things in their classroom, and repeating this process. These teachers, the ones to whom much of the exploration of good questioning was new, grew the most; however all teachers stretched their skills and their understanding.

Careful Listening to Student Responses and Reasoning

Of course, good questioning techniques mean little if no one is listening to the responses, or if one is not listening with an open mind. Our professional development examined the role of listening on many levels. Listening is an important source of information for informal assessment, helping the teacher determine where her students are and what they need next; listening is important as it honors the student in the learning process; listening is important, too, in that it may lead to breakthroughs in teachers’ own understanding of how students learn math as well as the teacher’s own understanding of math concepts. Based on the reading I had done and some prior research I had participated in, I believed that teachers could extend their own understanding of math through the process of listening and contemplating what their students were saying (Smith & Stein, 2011; Di Teodoro et al, 2011).

The value and power of listening was something the teachers recognized frequently in their reflections. Although I had anticipated some answers, I was struck by the number of

teachers who connected a listening environment to students' feeling of connectivity to the classroom, to their classmates, and to the teacher: "When students feel listened to it deepens the student's learning and when the teacher listens they can better understand how the student made meaning of what they learned."

Listening doesn't always mean listening only to what the students are saying about their math learning, but also listening to how they want to structure the learning. Listening can be opening the class to student input at all levels, which gives the students a sense that the class is not just the teacher's classroom, but belongs to the whole class, a common theme:

My students requested a full day of math. We had been using a pipecleaner man appropriately named, Matt the Mathematician to jump around the number grid, and one student said we should create a "Matt appreciation day". I polled the class for ideas and we ended up with a beautiful review day of all the skills we had been working on. Students and myself were traveling the room looking for answers to math riddles, we did number grid activities, and ended with a school store using real coins and they were able to purchase real items. The kids were very excited and so was I, and we now use this same technique at the end of our units for review.

Careful listening wasn't something to be embraced by the teacher only; students were encouraged and supported to improve their listening skills, with an emphasis on listening to each other. One teacher wrote about the importance of creating a learning environment where everyone listened to one another, and through this process learned from each other. Through changes in practice and reflection on the process, she began to see the value of students' ability to explain things in a different way than she could, allowing students in the classroom alternate gateways to learning. This quote from her journal addresses the idea of opening the listening and questioning process as a way to increase access to more students.

I took away that having kids share what they know or wonder about is a great way to move the learning process forward. Kids like listening to their friends explain how they

got an answer. They like to share how they got their answers. And when we give kids the opportunity to ask questions for all the class to hear all those other kids who had the same questions but were too afraid to ask it, get a better understanding of what is being taught.

Mrs. Wilkinson touched upon the many reasons to listen to one's students in one of our discussions. She stated that listening provides insight into what the students are thinking, and also that it gives them a voice, and thereby a sense that the learning is their own, that it is a "powerful validation" of who the students are individually. She spoke about the importance of listening as the key to understanding students' thinking. But, she stated, the most valuable return on listening carefully to one's students is that it builds relationships; it says "I see you and I hear you." The benefit of classroom cohesion resulting from creating a listening atmosphere in the classroom was one that was referenced a number of times by the study participants.

Improving Teacher Understanding of Mathematics by Listening to One's Own Students

One of my main objectives in doing this training and research was to explore the opportunity that teachers would have to learn from their students, not only about how to structure the learning to be more effective, but also to learn more about math concepts by opening their minds to the ways that young children talk and think about math. This became something that was hard to find solid evidence to support. I found I had to extrapolate, and look more deeply at teachers' comments to see it, adjusting the microscope between each view. My expectation was that teachers would say things like, "I used to view fractions this way, now I see that you can also view them this way." Often teachers would say things that indicated, loosely, that their understanding of math had been deepened by what their students were saying, but they very

rarely gave the concrete examples I had initially expected. For example, in a group interview of the Kindergarten and first grade teachers, a Kindergarten teacher stated:

Sometimes I just assume things but when I take time and give them an opportunity to explain more I learn a lot more.

Did this teacher mean that she learns a lot more about her students themselves, or how they learn, or did she learn a lot more about math?

Another teacher wrote in her journal:

. . . in many instances, the students have truly surprised me in their ability to grasp a new strategy, or at least take some aspect of the strategy and integrate it into their own tool bank. We've been working on partial sums addition lately and I've seen a couple students do this. They have been able to take this strategy and tweak it so that they are comfortable with it. I think that is what it comes down to; what strategy are you comfortable with? How can you adapt something so that it makes sense to you? I was missing this when I was younger. I thought that there was one sole way to answer a problem and I would practice and practice problems so that I knew that strategy cold. However, it didn't give me a lot of flexibility. I think seeing my students use a variety of strategies to answer a question reaffirms this and gives me the opportunity to grow as a math learner as well.

Teachers may not have stated specifically what the growth was, but this teacher felt that listening to her students had indeed helped her grow in her understanding of mathematics. She sees an increase in her flexibility as a math thinker as she progresses with her students.

Another teacher hearkened back to her own days as a student, with her father as her guide. Again, no specific references to a concrete math concept, but obviously illustrating her growth as a learner, and thinker, of math through trying to view mathematics in the way that her students do, she wrote:

As a kid, my dad taught me lots of tips and tricks for remembering my multiplication facts, and as someone with a strong memory, this worked for me. However, I was never exposed to the strategies which some of my students have picked up easily and use fluently, such as break-apart or helper facts. My dad tried to explain these strategies to me, but I had a difficult time grasping the meaning of what he was saying.

Now, I am in awe of how many of my students visualize numbers and problems. It has changed the way I think through mental math.

This same teacher again wrote about how her students did something differently than the way she had learned as a student, and how both she as well as other students in the class had learned from those experiences:

Listening to students' responses gives me an opportunity to analyze and fix any misconceptions my whole class or individual children may have about a skill. It is also a chance for my students and myself to learn from each other. There are plenty of instances in which a student has taught us all about a new way to approach a skill or problem. For example, many of my students tackle double digit addition problems by deconstructing the number in their heads. This was something I never learned as a child and it amazes me when they can do this.

A closer look at the journal entries does show frequent mention of learning from one's students, as well as students learning from one another. Entries that include statements such as "The students took it in several different directions or made connections that I had not even thought of" and "[listening to my students] gives me the opportunity to grow as a math learner as well" may lack explanations of specific strategies, but does indicate that teachers were learning from their students, that they were thinking about math differently than they had before. Teachers were clearly open to learning from their students, and often found opportunities "for my students and myself to learn from each other."

Other teachers share similar sentiments and discoveries in their journals:

Student's thinking also shows you another way of looking at a math problem. I have noticed in my classroom that I may present a problem with a particular solving strategy in mind but the students may look at the problem and use a different strategy-one that I didn't even think of.

Again, when she writes "particular solving strategy", she is not specifically naming the strategy or giving any details beyond that. In retrospect, I think it was unrealistic for me to think that

teachers would go into that type of detail in their journals. Given the number of times teachers mention different student's strategies, and then comment on how it was different than the ones the teachers had learned themselves or had in mind, it is evident that teachers were thinking deeply about different strategies, how students employ these strategies, and how those strategies are different from their own. Here is another example from a teacher's journal: "I had not thought of JM's strategy at all so it showed not only his classmates a completely different way but an additional way to do so that I had not even covered or shared." Again, the idea that the strategy is different than the teacher's, and that other students may be benefitting. These themes show up repeatedly in teachers' journals: "Students have helped me to look at problems from different perspectives and they've helped each other."

Sometimes the teacher might not be able to completely figure out the strategy or approach a child is using, but there is still value, and even adventure, in the process of trying to figure it out; in realizing that a student who is not following a traditional route will often get to the same destination, seeing different things along the way. And, as this teacher mentions, can have fun in the process:

I often like to hear how DT solves math problems in his mind. He is a very creative thinker, and rarely writes any of his strategies down. He can easily tell you how he solved a problem, and often can teach students his methods as well. I have tried to follow his lines of thought, but usually get lost, as he goes for the creative and long approach to a problem. I am a straight forward problem solver. If there is a formula, that's how I solve it. He and I have very different ways of thinking, which can be fun to learn about.

The sense of adventure and fun are apparent in this journal entry from another teacher, who also explores the theme of students thinking about math differently than the way she thinks about it.

The students love when I say that I had not thought of something in that way...I call it “stumping the teacher”... “you thought of a way that I had not even thought of...hooray!” Even that inspires others to try and share multiple ways to come up with the same answer so they can also “stump the teacher” and “think of other ways that Mrs. Johnson had not thought of!” This makes them far happier than if I am just lecturing during a mini-lesson.

Reduction of Anxieties through Purposely Designed Professional Development

What we can do as teachers I think is offer ways to reduce anxiety around math by making it fun, offering games, offering multiple ways to show a student understands and make a comfortable environment for them to share even if they do not understand they can ask a friend or ask a Teacher anything anytime!

When this study began, it was not set up to intentionally mirror what good teaching should look like in the classroom, but as the work progressed and Cheryl, Becky, and I had the opportunity to read teachers’ journals and listen to their discussions (although there were many that we didn’t listen to; more on that later), the parallels between good instruction in the classroom and good professional development became more apparent. I started this section with the quote from a teacher’s journal, as it is a good representation of what a teacher can do in her classroom to reduce anxiety, while also showing some of what we did in our design of the professional development to reduce teacher anxiety.

Our design of small group discussions was one way we approached the learning experience with the goal of reducing anxiety. We tried to keep it fun. We offered multiple learning opportunities so that teachers could choose what they read or listened to. We were accessible to teachers, open to any questions they had for us. We worked to make the professional development comfortable, yet kept the focus on the learning. Although this teacher was talking specifically about her classroom practice, this quote would also apply to our attempts

at designing professional development that worked to intentionally reduce anxieties, as illustrated by this teacher's journal entry: "Having informal conversations and creating a safe environment can lessen math anxiety."

And anxiety was there, varying from teacher to teacher, but certainly a factor in their approach to learning and teaching mathematics.

Honestly, math has never been my forte. It hasn't come naturally to me and I have had to work at it - a lot. I am sometimes hesitant with a lesson because of my past hang ups and I worry about how my students will respond to it. I found myself saying at times, "seriously? You want me to teach it like that?"

Teachers wrote about anxiety quite frequently in their journals, but the writing was often about their students, not about their own anxieties. However, there were consistent themes running through what they wrote about doing in their classrooms in their attempts to reduce anxiety which mirrored approaches we were taking in our design and implementation of our professional development. As mentioned earlier, the insights teachers gave us about what they were doing in their classrooms often reflected the same approaches we were taking in our attempts to reduce teacher anxiety.

Anxiety or stress comes up a lot with the math students that I work with. Occasionally, a student specifically says that they feel stressed by math. Constance has said she gets a stomach ache. I've seen her sit under the table when she finds something hard. That she can recognize signs of her anxiety is probably good. Other students say things like ... " I like doing math in your room better [than their regular classroom] because I can do your math. It's fun". Another student, Bart, starts making loud noises and says he is bored when he appears to be anxious about a math task. I realize that math is hard for my students. Knowing that something is difficult and feeling that you are not good at it definitely causes stress . . . when it appears to them that all of the other students get it - and they don't. . . . I try to really set these kids up for success so they will not just learn math skills, but build confidence. I want them to feel safe enough that they can ask a lot of questions, make mistakes, talk about their ideas, but not feel self conscious about what they may not be able to do. Ultimately, if

a student is constantly feeling anxiety about math, they are not going to be open or available for learning.

Again, another teacher writing about how she says open-ended questioning as leading to anxiety, because students couldn't be sure they had the correct answer, explored how to lessen math anxiety in her classroom:

Open-ended questions or divergent questions I think can lead to a lot of anxiety which could look like many things such as: being quiet/not offering responses, shutting down, not looking like one is paying attention, etc. To reduce anxiety around Math, try and work our way up...scaffold to the harder concepts, provide a lot of feedback from peers versus just Teachers, try to make connections to the World, practice a lot, use games to make it fun, etc.

This quote illustrates a classroom approach which was mirrored in much of what we were trying to do to lessen the potential of anxiety related to the professional development. We definitely started out slowly and worked our way up. Feedback from peers was a major focus; in fact, when I mentioned earlier that we did not always know what teachers were saying, it was because much of the discussion took place in small-group breakout sessions which we purposefully stayed out of. The parallel to the teacher trying "to make connections to the World" was our use of the classroom as our lab; we structured the learning so that teachers could, and even had to, try out what we were talking about in their classroom, and make connections between what we were learning and what they were teaching in the classroom.

Although the comfort with the design of professional learning this past year was mentioned frequently, there was also mention of the difficulties of learning, both professionally and in one's classroom, that surfaced in teachers' journals relative to the COVID pandemic:

- I would definitely prefer working in-person with grade level teachers rather than zoom meetings, but I realize that was not possible this year.
- I would much prefer to do something in person in the future, but we were making the best of the situation! Sharing student work via video is helpful.
- I feel like it was hard for me to learn new things this year, just being overwhelmed with all of the newness of Covid protocols, etc - I didn't have as much brain space for new ideas.
- There was simply too much going on this year to really give a decent amount of time to anything in particular.

Providing effective learning experiences was definitely made challenging by the pandemic.

Design Elements of the Professional Development and their Benefits

The Power and Benefits of Reflection:

Reflection was foundational to all we did in our professional development, from start to finish.

Literature points to the power of reflection in the learning process, especially with regards to adult learners (Garet et al, 2001; Mewborn & Huberty, 2004; Drago-Severson, 2009). Teachers reflected regularly in their journals. Each professional development session was followed by asynchronous learning experiences which included readings and responding to prompts in individual journals. Each teacher had an electronic journal in which to share reflections.

Teachers reflected on the readings, what they had learned in the preceding professional

development sessions, and what they were doing in their classrooms. Reflection also permeated the actual professional development sessions. Teachers shared their learnings with one another, recording their collective reflections on Jamboards that the developers had set up for that purpose.

Reflection led to changes in how teachers thought about the process of teaching math. They changed their thinking about the way they were structuring and leading the math learning in their classroom. Oftentimes this led to changes in practice, or at the very least a *desire* to change practice. These reflections often informed the discussions that took place during professional development, allowing the reflective process to be collective as well as individualistic.

In my routine classroom visits, I began to see practices that we had discussed in our professional development showing up in the classroom. “I wonder”, “tell me more”, and “what do you notice” were all phrases that became more common in classrooms as the trimester progressed. Student voice became more prominent. Questioning techniques veered away from the mundane, procedural-focused questioning common in the past to questions that elicited deeper thinking on the part of the student, and which required stretching the intellect and the application of knowledge.

Teachers wrote about how what they were reading and what they were learning during the professional development sessions was changing the way they thought about teaching math and the way that students learn math best. Oftentimes this reflection was very extensive, with most teachers taking the reflection time as an opportunity to really explore their own thinking,

how it played out in their classroom, and what was of value and worth keeping as well as what changes they saw as necessary in the advancement of their practice.

I definitely thought, and am thinking a lot, about the way that I ask questions in math class and really reaching all of my students, and sometimes that can be challenging, especially where I have three or four outspoken ELP [Extended Learning Program - formerly Gifted and Talented] students who are happy to share their thoughts and a few who are happy to just kind of sit back and have someone else start the conversation so I am really trying to work them into the conversation. They aren't as interested in speaking to the whole group but at least talking to them one-on-one. I don't want to make them uncomfortable but I definitely want to [continue] questioning more with them to get that deeper understanding. I mean I've just been reflecting on my math teaching this year a lot anyway, switching over to the everyday math-driven curriculum rather than the units we've been working on before. I think making that switch and doing this PD has really worked hand in hand. Because the Everyday Math is so structured I can then use that as a bouncing-off point for the questions that we've been talking about, the reflections that we've made.

Changes in thinking, ideally, lead to changes in practice. Those changes become cemented when teachers reflect on what they do in their own classrooms. The moments of revelation show up in the teachers journals, as this third grade teacher explains:

I noticed that some of the students were well versed in our math classroom norms. There was evidence of some excellent mental math skills. Others blurted out a lot, really stopping other students thinking. It felt a bit competitive at some points. I wonder if slowing down the questioning a bit would be effective.

Change does not occur without some premeditation. The opportunity to write about what was happening in one's own classroom and wonder how it might be better was a catalyst for change.

And, again, the opportunity to share with colleagues what you were doing, and listen to what they were doing, was an effective way to strengthen teacher understanding of pedagogy.

What worked well for one teacher was spread to the other teachers through conversations and sharing, as illustrated by what Mrs. Green had to say about the professional development during an interview:

I really liked how this professional development was a lot more reflective and introspective. I think that really helped me and I know that it helped my colleagues as well be able to take the time to look at our own practices, rather than a lecture approach, was really helpful. That was my big take away, was that reflection time.

Mrs. Green was not alone. Another teacher, of second grade, had this to say in her journal:

My biggest takeaway from the asynchronous readings about questioning or the conversations thus far would be that we can read, think, mull it over and have it in the back of our minds while we are teaching and then be able to reflect in our journaling and share out with Mrs. Tapley, Mrs. Tobey and Mr. Widmer in the breakout rooms and have “ah-ha” moments with each other’s help!

The value of collective reflection and sharing in small groups was mentioned frequently, even by those teachers whose journal entries were minimal. Some teachers explored its value more deeply, but those teachers were either the ones I interviewed, giving me a much richer sense of what they were thinking about the process, and those teachers whose written reflection was extensive and detailed.

Value of Sharing in Small Grade-specific Groups:

Although reflection was chiefly an individual process, there were many opportunities for sharing in small groups. This allowed the teachers to share the learning that was evolving through their personal reflection and writing in their journals with their colleagues, with teachers benefiting from listening closely to what their peers had to say and learning from one another in much the same way their students learned from one another. This was a value of the small group discussions, which most often occurred in grade-level or grade-span groups and without a professional development facilitator in “the room”. (All but our final session of professional development took place virtually.) This benefit is illustrated by a short comment by a second-

grade teacher as we closed out one of our sessions: “ I liked today, having time to reflect with colleagues is meaningful and has my gears turning!”

When asked to reflect on the value of the professional development experience of this winter and spring, there was almost universal agreement that one of the things that was most beneficial was being able to meet in grade-level specific groups, especially on the part of the classroom teachers; the special education teachers did not laud that part of the experience to the same extent as the classroom teachers but also did not participate to the same extent due to other professional development obligations. Not only did the classroom teachers appreciate the opportunity to get together with one another, they seemed to appreciate the opportunity for similar reasons.

One third grade teacher explained, both in her journal and when I interviewed her, the relevance of the small group discussions during our professional development activities. As she explained in our interview:

I really liked that piece [small group discussion]. I really enjoy working with everyone in my wing anyway but I felt like it was a lot more appropriate and it made sense to me to be working with the second grade teachers and other third grade teachers because we are all within the same realm of teaching. I definitely value working with the other grade levels, but being able to really focus on our grade level has been really helpful.

This sentiment was also echoed in her journal: “I appreciated the time we were given to discuss our practices with our teams. I felt this was the most beneficial use of our time.”

And in the journals of many others. This second grade teacher wrote about setting aside structured time to meet with peers was valuable, especially given how busy every one was:

I really liked meeting in grade-specific groups. It is very meaningful to talk with your peers and have your ideas/concerns validated. In addition, we are so busy in our own classrooms that giving us a chance to talk in a structured time is very valuable.

Not only were busy schedules a reason for needing to meet, but this past year provided its own challenges with regular live interactions with peers, both formal and informal, being limited. Teachers not only valued the small groups for meeting to talk about math, but sometimes simply for the value of being able to interact with their peers: “Small break out groups especially in our Grade Level are helpful since COVID prevented Common Planning Time (CPT) together weekly or whatnot.”

These quotes speak for themselves about the value of sharing in small groups.

Although many of these quotes are not significant on their own, the number of teachers with similar sentiments is noteworthy.

Rebekkah wrote:

I did like the small groups, it made things more intimate and less intimidating. Also, working with my 2nd grade team was very helpful. The experience as a whole was very valuable but at times very overwhelming.

Samantha was another teacher who commented on the benefit of structured time to work as a team: “I did like working with my grade level as we don’t get a lot of time to reflect as a team with feedback.” All three fourth-grade teachers shared similar thoughts about the experience: “I greatly valued the time that [we] worked together”, “I did like being able to work in a small group, with my fourth grade team in particular. It was nice to have the time together to find out new math ideas”, and “ I like the way that we did professional development this year, specifically with the small grade-specific groups.”

Not only did teachers enjoy the approach we used, but so did the presenters. One of the facilitators wrote to me about how she thought it was going well: “I like small groups. Participants are more willing to talk and share with fewer people.”

Classrooms as Learning Labs:

Originally, the intent of the professional development design was to allow teachers to get into one another’s classrooms and see what was going on. With the onset of COVID procedures and protocols, specifically having classrooms cloistered and operating as “pods”, it became counter to the intent of the protocols to have teachers visiting one another’s classrooms. Therefore, we employed videoing of classrooms to allow the sharing of what was happening in different classrooms. The sharing of classroom video allowed teachers to both reflect on what was happening in their own classroom, as well as the classroom of others. As this entry illustrates, this first grade teacher not only examines her practice, but identifies the value of having other colleagues viewing her teaching and providing feedback:

We talked a lot about when it was good to self correct the student. Is it something that you do immediately after the error or do you use a prompt to try and direct them to see their error or do you have another student model and hope it evolves naturally? I don’t think there is necessarily a right answer. I did like Becky’s idea of comparing the two visually and seeing what the rest of the class thought. I wonder if I had asked Sara immediately to show me her counting on the number grid if she would have self corrected? Was it just the way she was organizing her information? It was good to have another’s insight and also see how another person might prompt the student. The next step would be to try more problems like this and see how my students solve them. I want . . . to experiment with different ways to prompt or guide them to the correct answer or at least help them become more aware of errors/self corrections.

Teachers’ reflections were most often based on what they observed in their classrooms, either anecdotally or after viewing the videos of their classrooms. There were also journal entries

which referenced the readings the teachers did. Often, the teachers who referred to a journal article made connections between what they had read and what was occurring in their own classrooms:

The article from Resilient Educator lists several reasons why listening to students is important but for me the most important one is validation and relationship building. When students feel that their words matter they, I think, are more involved in the learning process. As a teacher I am able to learn about their understanding of a topic as well as misconceptions which I can hopefully head-off at the beginning of learning.

The use of classrooms as learning laboratories was definitely impacted by the pandemic this past year. The sharing that occurred was through classroom video, which was not the same experience. However, the ability to archive the moment and revisit it, both by the individual teacher and by her peers, provided an unanticipated benefit that we may not have recognized had we not been forced to employ it.

Value of Partnering with an Organization that Specializes in Your Area of Need:

The theme of the value of working with an organization that specializes in the topic being explored is more from my perspective than from the perspective of the teachers we worked with. There were many areas where I saw the benefits of this relationship.

The first area was related to time. As Becky and Cheryl's expertise was teaching adults to better understand both math and math pedagogy, they already had a significant head start relative to what a lay person or person with sundry and myriad responsibilities would be capable of when it comes to crafting meaningful learning. I was able to dedicate three to five hours per session planning for the next session. In addition to the time planning, I spent time managing the journals: Reading journal entries, responding, and planning out prompts for the next session.

This was a significant tax on my abilities to address other areas of need in my school. Most of the technical parts of the professional development - setting up Jamboards, identifying different options for readings and podcasts, and organizing all this into a cohesive experience - was done by Becky and Cheryl. My part was to work out the rough structure and give us a direction; none of what we did would have been anywhere near as effective without Becky and Cheryl's extensive knowledge base and ability to dedicate time to planning and preparation.

Becky and Cheryl were knowledgeable in both the realm of math as well as the realm of adult learning. Working at the Maine Math and Science Alliance (MMSA), they specialize in both mathematics and professional development. They have a solid understanding of not only math concepts, but also math pedagogy specific to the elementary classroom. Furthermore, they understand where the average elementary school teacher is coming from, both in relation to their understanding of math and the pulls on their time. Becky recently came to MMSA as a Maine elementary school teacher from a rural school, so her understanding of the needs of teachers was particularly strong. Cheryl has extensive experience designing math professional development, having come to her position from the Maine Department of Education, where she was the elementary math specialist.

There was a value in having Becky and Cheryl as partners in the process of doing my research as well. We discussed ideas frequently and these discussions helped me determine how to plan out next steps in my work. Their suggestions and affirmations were invaluable to my progress in my work, giving me practical ideas as well as the energy that comes through working on something in partnership with someone else.

Finally, there was value in having a trusted individual from a highly-recognized organization delivering the professional development. Teachers recognized Becky and Cheryl as authorities in the realm of mathematics, both math itself as well as math pedagogy, and in the realm of professional development. Teachers readily accepted what Becky and Cheryl had to offer, and implemented their ideas.

Improvement of the Student Learning Experience

With changes in questioning practices, as well as in other practices examined during our professional development experience, teachers reported that the student experience evolved and improved. Students did better on all counts, formal and informal, in their academics and in relation to their attitudes. The success of the professional development sessions was reflected in the classroom as illustrated in this teacher's journal entry:

My class was successful in math this year, and the learning we have done through professional development has aided this. This is the most prepared class I have instructed as they move up to the fourth grade. Informally, my students were less anxious when it came time to assess than they were at the beginning of the year. They are more confident in their abilities and enjoy the challenge of math.

Another third grade math teacher agreed that his students were doing better, both by formal and informal measures of their abilities, as well as their attitudes toward and enjoyment of math. His response to the question about students performance and attitude addressed both:

Yes. Got better. This could be shown in a number of ways. Formally, we have the NWEAs and the unit assessments. Informally, you can see how the attitudes of the students changed.

Perceived changes in student affect were widespread, with teachers discussing this during our professional development sessions and writing about it in their journals. This from a teacher who works with students with identified needs for extra support:

Informally, I noticed that students were eager to come work with me out of their regular classroom. They enjoyed feeling successful with the tasks that I gave them. They were not expected to read or write much, which I think was helpful as these same students struggle with literacy. Overall, I noticed gains with all aspects- math skills, especially number sense, and ability to talk and share their math thinking.

Although most classrooms improved in their NWEA scores, there were some classrooms which were home to large populations of students with learning challenges, an outgrowth of our attempts to “pod” students this year because of concerns around COVID: Special education students frequently traveled together. This is a practice we will not continue with in the future, as many students in these classrooms, especially those with identified challenges, did not progress as much as their peers. Despite the challenges, this teacher, who had a classroom with almost half of the students receiving services, recognized the value of all students sharing their thinking with one another:

Even though my [students’] NWEA scores were not high achieving, there was high growth for my math students. I felt that the math playing field was evened out a bit when more students were able to share their thinking.

Although most classrooms saw growth in their NWEA scores, the real goal of the focus on questioning was to enliven and enrich the math classroom, to create a vibrant, dynamic space where students' interest in math was cultivated and celebrated. Cyndi’s comments catch the realization of that goal:

Yes, I saw incredible growth in how my students came to love math. It was their favorite subject by the end of the year. We got into a rhythm and we worked together to help each other. Such incredible growth. So proud of my kids.

Although teachers made a lot of progress in their thinking, leading to changes in what they were doing in their classrooms, the progress varied. Sometimes the changes were in

thinking, but did not always translate to changes in practice. Or, at least the changes were a process that happened one step at a time, as outlined in the journal of this fourth-grade teacher:

The article was interesting and I found parts of myself in it. I used to be the teacher that just said - ““Right, the answer is 7.” Over the course of time, I have gradually become the teacher who asks “How did you get 7?” more often. However, I rarely ask “I wonder if that solution always works?” I think this would be my next step as a learner.

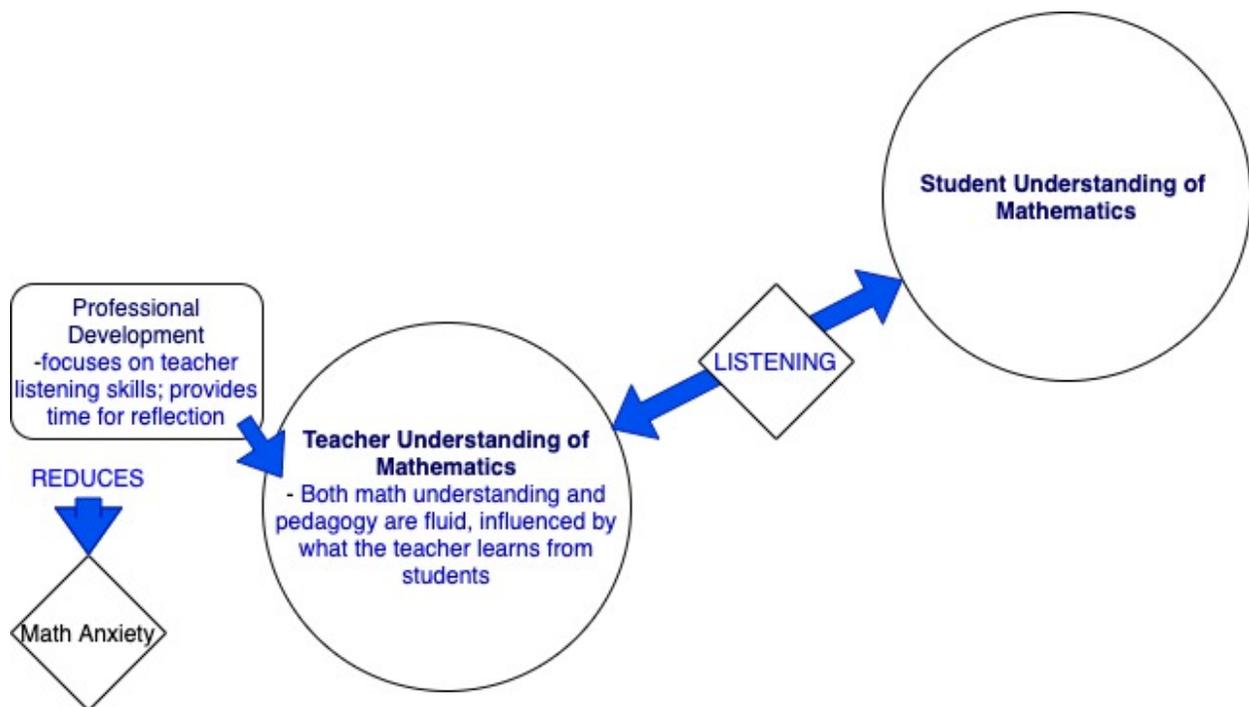
Closing Thoughts

One word that occurred frequently in the teachers reminiscences of the professional development was “enjoy”. At Captain Albert Stevens School we put a large emphasis on the value of student enjoyment of the learning process. We want students to find joy in learning. From the comments teachers made about their experiences with the professional development, there was a level of enjoyment that was noteworthy: “I enjoy being able to discuss this topic with my colleagues!” and “I enjoy talking in a small group and then sharing out “bullets” of important information”, and “ I really like the writing piece of the PD. And smaller groups are better, I think.” and “I find the breakout room model very effective and enjoyable. I appreciate the time I have to discuss the prompts with my peers.” Student enjoyment, whether in the elementary school classroom or of the professional development for teachers, is something to foster as enjoyment of the process is foundational to improvement of student learning.

CHAPTER V: DISCUSSION

The purpose of this qualitative case study is to determine how to structure professional development in mathematics and mathematics pedagogy for elementary school teachers in a way that allows for the teachers to learn from one another and from their students. Within this purpose is the goal of designing professional development that takes into account teacher anxiety around math. Because this study was initiated at the peak of the Coronavirus 19 outbreak, there was a significant amount of anxiety related to that as well. Therefore the intended focus on addressing math anxiety broadened to an examination of reducing anxiety in general.

This chapter is organized around the conceptual framework that I created to represent the work I intended to do and my research question in relation to the literature I studied to inform my research.



The themes I will explore in this chapter include the design of effective math professional development for teachers. Under this umbrella, I will look at reflection, expressive writing, and journaling as a way for teachers to learn about math pedagogy and concepts. There were two reasons for adopting these methods: First, reflective and expressive writing have both been shown to be effective approaches to professional learning (Turner, 2016; Meth, 2003) and, second, reflection and expressive writing have also been shown to be effective in reducing anxiety (Kunzig, 2020; Park et al, 2011.) Another theme looks at teachers' listening skills. Tied to this is the idea that teachers, by carefully listening to what their students are saying, can not only learn about what their students know, but can also broaden their own understanding of mathematics. This chapter looks at these themes in relation to the literature. The chapter concludes with a discussion of the study's limitations and possible next steps.

Research Question:

How does professional development with a focused integration of reflective and expressive journal writing with small groups of elementary teachers impact, a) Teachers' ability to carefully listen to what students say to explain their thinking; b) Teachers' understanding of mathematical concepts; and, c) Teacher anxiety?

I was able to gauge the impact of the professional development in the areas of my conceptual framework and in relation to my research question by collecting and analyzing data from the teachers' journals, the field notes I took when the professional development was taking place, and interviews with six teachers. The findings supported the value of professional development done in small groups of teachers who teach the same, or very similar, curriculum, which incorporates reflection and journaling, and that is sustained over a period of time. I was

also able to assess anxiety levels around math, and anxiety in general, as well as how the design of the professional development dispelled anxiety. Finally, I set out to assess how listening carefully to what one's students were saying and then actively reflecting on this could serve to increase teachers' understanding of both math pedagogy and math concepts.

Interpretations of the Findings

The themes represented in my conceptual framework and related to my research question include the design of effective mathematics professional development experiences for elementary school teachers, with an emphasis on listening to what students are saying about their math experiences, reflecting on what the students say, as well as on other significant occurrences in the classroom, and how to structure learning in small groups of teachers to optimize the learning. What teachers learn from their students is another theme. The final theme is related to anxiety, both in regards to math and in general.

Design of Professional Development

This case study confirmed the findings from much of the research I consulted before beginning the study on what makes for effective professional development for elementary school teachers of math, specifically creating a trusting environment where teachers felt comfortable sharing, doing this in small groups, using the classroom as a lab, and reflecting on the process both through journaling and collective reflection with peers. (Louks-Horsely et al, 2010; Drago-Severson, 2009; Mewborn & Huberty, 2004; Garet et al, 2001) . Teacher reception of the professional development was favorable, with all but one teacher reporting an overall favorable assessment of the process. The one teacher who did not give an overall positive response stated, "There was simply too much going on this year to really give a decent amount of time to

anything in particular.” The “too much going on” referred to the impact of the Coronavirus, which was a frequent theme in teacher responses. However, most teachers were able to contextualize the experience with consideration of the impact of COVID, disconnecting the professional development experience from experience of life during a pandemic.

My findings confirmed much of what Louks-Horsely et al (2010) established as essential qualities of effective math professional development. My research showed that making connections between teachers' existing ideas and new ones through active engagement, discussion, and reflection helped the teachers question old ideas and create deeper understanding (Louks-Horsely, 2010). Another key component from Louks-Horsely's findings was ensuring that the learning was situated in a context the teachers were familiar with, essential for helping teachers make connections in a lasting way (Drago-Severson, 2009). This meant working in groups with teachers who shared a similar curriculum and taught students of a similar age. As our school is relatively small, this also meant that teachers were going to be working in small groups, an approach identified as both effective learning-wise and effective in minimizing feelings of anxiety when it comes to learning about math (Jameson & Fusco, 2014; Garet et al, 2001) The value of the small group in terms of comfort and the small group discussions being an effective means of professional learning surfaced in over half of the teachers journal entries.

Questions and Answers - Designing and Implementing Listening Classrooms

The material we reviewed as a group was often more about pedagogy than about learning math concepts. There was a focus on how the process of teaching connected with the understanding of math concepts, rather than a focus solely on math concepts. We dedicated time to the study of best practices in mathematics, connecting to the NCTMs eight effective practices

laid out in their guide *Principles to Actions* (NCTM, 2000.) Within this context, we focused on teachers' listening skills and the quality of the questions they were asking, one of the essential practices outlined in the book. We also knew that the quality of the questions being asked would have an impact on the quality of the responses, so we spent time looking at what quality discourse was, referring to the NCTM's eight essential practices. Both practices of facilitating meaningful mathematical discourse and posing purposeful questions (NCTM, 2000) were integral to our study. Furthermore, the practice of eliciting and using evidence of student thinking (NCTM, 2000) would help teachers understand the thinking of their students more thoroughly, helping them to correct misunderstandings, reinforce the successful learning, and plan out next steps. (Jacobs et al, 2010; NCTM, 2000.)

We explored the role of the teacher as a listener, with emphasis on the importance of the teacher listening to what the students were saying about their learning, then using this information to build the subsequent steps based on what the student's know and understand. As Hintz et al (2019) found, teachers must listen carefully to what their students are saying to understand where they are, as well as to build relationships that are the foundation of strong learning communities. Di Teodoro et al (2011) add an additional dimension, exploring the importance of purposely designed questions which elicit discussions that will best highlight student thinking. Jacobs et al (2010) outlined three steps to facilitate the listening and planning process: 1) Attending to the strategies students are using; 2) interpreting their understanding; and then 3) deciding how to respond.

Listening was a frequent theme when teachers were writing in their journals. One teacher wrote: "It is very important to think about "how" we listen and what we may be using

that information for,” a recognition which was echoed in a number of teachers’ journals. The “what we may be using that information for” was most often to determine what the students knew and how they were thinking about math, according to teachers’ journals.

Beyond listening to what students are saying to figure out where they were and how they were thinking about math was the revelation that listening to students created a deep layer of respect and helped propagate positive relationships between teachers and students. One teacher commented on how listening to her students “strengthens the learning relationship” while another teacher wrote: “I listen to them any time I work with them. Relationships are the most important part of teaching. There is no way to teach if you have not developed a relationship with the students in [the] room.”

The Power of Reflection

The process of reflection gave teachers an opportunity to pause and think about their classroom practice, the experiences their students were having, and the growth in understanding of math in both their students and themselves in a personal, unthreatening way. The power of teachers reflecting on their own practice, both individually and with colleagues, has been investigated and confirmed through the studies I consulted (Neumann, 2014; Mewborn & Huberty, 2004.) Research supports that the reflective process, especially when done with an emphasis on expressive writing, prompting the writer to explore his or her feelings in relation to the experience, both supports learning as well as reduces anxiety (Jameson & Fusco, 2014; Garet et al, 2001; Meth, 2003.)

Loucks-Horsely and colleagues (2010) talk about the reflective process changing attitudes in an iterative manner. Teachers do the work based on their current thinking, reflect on

the process, which changes their current thinking, and then they head back into the classroom with updated beliefs which in turn lead to updated practice. Discussions with peers and the learning that results from those discussions also impact the reflective process (Drago-Severson, 2009).

This process played out throughout the six months of professional development. Teachers were regularly reflecting in their journals, as well as when they met in their small group to discuss their thoughts. The reflective process was done both on an individual level, and then extended to group reflection when we came together. Teacher practice progressed as a result of both reflective exercises.

Journaling

We chose journaling as the method we would employ to facilitate the reflection process. Working within Google Classroom, I created a new prompt for each session. Literature suggested that journaling was not only an effective process to facilitate teacher reflection, but also an organized way to collect data on the thoughts of one's subjects (Turner, 2016; Meth, 2003.) This excerpt for one of the teacher's journals is a clear testament to not only the advantages of journaling, but to the whole reflective process:

My biggest takeaway from the asynchronous readings about questioning or the conversations thus far would be that we can read, think, mull it over and have it in the back of our minds while we are teaching and then be able to reflect in our journaling and share out with Mrs. Tapley, Mrs. Tobey and Mr. Widmer in the breakout rooms and have "ah-ha" moments with each other's help!

Expressive Writing

Beyond just journaling, we took an expressive writing approach to the reflective writing process. Teachers were encouraged to not only explore the concrete, but to explore their feelings

around math and pedagogy. Research has shown that expressive writing can reduce anxiety (Park et al, 2011) as well as have an impact on positive behaviors (Kunzig, 2020; Park et al, 2011) as the writer processes feelings along with actions.

The Rights of the Learner (Kalinec-Craig & Robles, 2020) extended Moll's "funds of knowledge" concept (1992), with the intent of liberating the learner in the classroom, but also having applications to the learning experiences of the teachers themselves. We extended these rights - the right to be confused, the right to claim a mistake, the right to speak, listen, and be heard, and the right to write, do and represent only what makes sense to you - to the professional learning environment. Like much of what we did, we found many opportunities to apply what we were learning about quality instruction in the elementary classroom to the learning taking place with the teachers. Furthermore, by ensuring these rights were adhered to, we created a safe learning environment for the participants, something deemed essential when planning learning experiences for adults (Drago-Severson, 2009; Heifetz, 2009.)

Small Group Settings

Teachers liked that the professional development was site-based, that it was done in small grade-similar groups, and that it used the classroom as the "lab" in which teachers did their research. (Neumann, 2014; Mewborn & Huberty, 2004) Consistent with the Neuman (2014) and Mewborn and Huberty (2004) research, teachers placed a high value on the opportunity to meet and discuss practice with small groups of teachers who were having similar experiences. A third-grade teacher described the approach as "beneficial", saying he was "comfortable in small groups.". A second-grade teacher expressed a similar sentiment, writing, "I enjoy talking in a

small group.” Twelve teachers mentioned “small groups”, “grade-level teams”, or, specifically by name, their teaching team as being significant to their learning.

The small group approach was important for a few reasons. One, it allowed all voices to be heard. In groups of three, it is difficult to remain distanced from the discussion, especially when the learning is structured to include everyone’s voice through the prompts and design of the learning exercises. Second, because these groups were all with teachers at similar grade levels, it allowed for a commonality of experience that bound the teachers together. They all taught a similar curriculum and worked with students who were developmentally similar. The third benefit of the small group was that it provided for a level of comfort that would not have existed in a larger forum.

Learning from Our Students

Although some teachers were already embracing practices that facilitated two-way discussion and learning in their classrooms, where the students were learning from the teacher while the teacher was also learning from the students, all teachers benefitted from reflecting on where they were, what was working and what needed updating. Students weren’t the sole learner during the classroom experience; rather the teacher was learning from the student by *carefully listening* to what the student had to say, confirming the research of Kalinec-Craig & Robles (2020) and Jacobs et al (2010.) Teachers learned not only about what the students know about math, but also about individual strategies and ways of thinking about math. Ideally teachers are not only building understanding of the students’ needs by listening, but *also coming to see math differently as they themselves contemplate how math functions and how math concepts are related.*

This idea of learning from our students was a key focus of my research. My goal was to find a way that teachers could explore concepts and learn new strategies alongside their students. I posited that through some of my own research for a paper with the Maine Department of Education (Widmer, 2009) that teachers could learn different strategies and approaches to math by listening to what their students were saying, and that because it was coming from their students would lessen the teacher's anxiety related to learning math. What I did find is that a number of teachers said they had learned about new approaches to math, but they spoke about it in very general terms. The most general response I got to the question about learning about math itself from your students was, "Yes but I can't think of an example." Although other positive responses were numerous, they also were fairly general:

- [listening to my students] gives me the opportunity to grow as a math learner as well.
- A chance for my students and myself to learn from each other
- . . . something I never learned as a child
- Student's thinking also shows you another way of looking at a math problem. I have noticed in my classroom that I may present a problem with a particular solving strategy in mind but the students may look at the problem and use a different strategy-one that I didn't even think of.
- I had not thought of JM's strategy at all so it showed not only his classmates a completely different way but an additional way to do so that I had not even covered or shared
- the students took it in several different directions or made connections that I had not even thought of.
- The students love when I say that I had not thought of something in that way...I call it "stumping the teacher"... "you thought of a way that I had not even thought of...hooray!" Even that inspires others to try and share multiple ways to come up with the same answer so they can also "stump the teacher" and "think of other ways that Mrs. Johnson had not thought of!" This makes them far happier than if I am just lecturing during a mini-lesson.

- Students have helped me to look at problems from different perspectives and they've helped each other.
- I often like to hear how DT solves math problems in his mind. He is a very creative thinker, and rarely writes any of his strategies down. He can easily tell you how he solved a problem, and often can teach students his methods as well. I have tried to follow his lines of thought, but usually get lost, as he goes for the creative and long approach to a problem. I am a straight forward problem solver. If there is a formula, that's how I solve it. He and I have very different ways of thinking, which can be fun to learn about.

Because of the numerous responses from teachers stating that students had helped them look at math differently, and from different perspectives, and think about math in ways they had never thought of, it is clear that teachers saw their understanding of math changing as a result of what their students were saying and doing.

Anxieties

Research shows that teacher anxiety around math, especially at the elementary level (Beilock et al, 2010; Hembree, 1990), is both common and counterproductive to the learning process when it comes to professional development. Teachers in their journals did talk about their “past hangups” with math, their “difficult time grasping the meaning”, with one teacher stating she was “anxious and uncomfortable” sharing her math videos. Although anxiety was something teachers wrote about a lot in their journals relative to their students, as well as ways to reduce anxiety in their classrooms, not a lot of teachers wrote about their own anxiety. However, there was extensive discussion around the design of the professional development that led teachers to talk about how comfortable it was for them. Initially, I failed to pick up on the statements about comfort as being the antithesis to anxiety, and there were a number of comments about the small groups of like-minded individuals teaching a common subject as a comfortable way to learn. As one teacher pointed out, “having informal conversations and

creating a safe environment can lessen math anxiety”, which was in relation to her own approach to teaching math, but also applies to the approach we were using within our approach to professional development.

In addition to anxieties around math, there was a substantial level of anxiety around coronavirus. Coronavirus created anxieties on many levels (Wakui et al, 2021). Teachers were worried about catching the virus, about teaching a class where students were regularly absent, and about threats to safety associated with in-person teaching causing a shift to remote learning. One teacher commented that she had “too much going on this year” to focus on any one thing.

Teachers writing in journals through the process of expressive writing has not only been shown to further teacher understanding of pedagogy, concepts, and student readiness for learning, but has also been shown to reduce teacher anxiety (Park et al, 2011) . This definitely was true of the experience of the teachers in this study. The process of reflection not only helped teachers make sense of their students individually and their class as a whole, but also reduced feelings of anxiety. Understanding their students’ needs, as well as reflecting on how to best meet their needs, met a real need in the lives of the teachers, quelling teacher anxiety. Again, there was a strong parallel between what we were attempting to do with the teachers - reflecting on the work we were doing with them and how to meet their needs - and the work the teachers were doing as part of the professional development. The benefits of these parallel experiences were multiple. First, it was a prime example of modeling the type of learning that we were advocating for their students and classrooms; although not explicit, teachers were living through an experience that was similar to what their students were experiencing in their classrooms. Second, it worked well in our attempts to forge effective professional learning experiences; by reflecting

and assessing teacher needs we were better able to create something that was meaningful to the teachers. Third, the process of modeling helped us better understand the model; although we were teaching, we were simultaneously creating a learning experiment.

The process of teachers meeting in small groups of peers in similar grade levels, with similar teaching experiences, also helped reduce anxiety. These discussions helped teachers learn from one another in a non-threatening way; teachers knew each other well and felt comfortable discussing their learning, as well as the roadblocks they were encountering, either in their thinking or in their practice. “Collective intelligence of a team emerges most strongly when group members share a high average sensitivity and an equitable amount of conversational air time.” (p. 73 Drago-Severson & Blum-DeStefano, 2018)

This approach not only increased teachers’ feelings of comfort and reduced anxiety, but it also proved to be an effective way for the teachers to learn. They appreciated sharing ideas with one another and building upon one another’s learnings and comments. As Drago-Severson & Blum-DeStefano explain:

Collegial inquiry involves the purposeful exploration of our own and others’ thinking, perspectives, beliefs, and assumptions. . . it involves educators caringly and intentionally *coming together* to explore important aspects of their work. . . learning from others’ viewpoints and ideas - invites each of us to consider a whole new world of possibilities, because considering others’ perspectives helps us expand and better understand our own thinking. (P. 81)

Limitations

One limitation is that the study was based solely on one mid-size elementary school in central Maine. The study looked at data from sixteen classroom teachers, one Title I intervention teacher, and sporadically special education teachers, as these teachers sometimes had conflicting

professional responsibilities and weren't always able to attend. This is a fairly limited source of data, as the number of participants was low, and there was only one school involved in the study.

Another limitation of the study was that it was administered by the school administrator, who is also the supervisor and evaluator of the individuals involved. Although I did what I could to flatten this effect, it was impossible to do so completely. Understandably, my role as evaluator made it difficult for the teachers to be completely candid; was what they were saying influenced by our relationship as employee and employer?

The fact that we were doing this professional learning during a crisis was another limiting factor. Everything the teachers had to do, both in relation to professional development and their work lives, was more difficult than usual. Not only that, but teachers' personal lives were more chaotic, as teachers found themselves searching for childcare when it didn't exist, or having to call in sick due to COVID protocols when they otherwise may have been in school. Beyond these immediate challenges, there was the challenge of the unknown. No one knew when the crisis would end, what the real threats were, or how it would impact self and family and society.

CHAPTER VI - IMPLICATIONS

This case study showed that small groups of teachers working together to increase their listening and response skills, experimenting in their classrooms, and then reflecting on the experience both individually and in their small groups led to a great sense of efficacy on the part of the teacher. Partnering with an organization that is an authority in the realm of the subject being studied added legitimacy to the process. The case study also indicated that the anxieties associated with math learning, and in this particular case, the COVID 19 pandemic, were greatly reduced by having the learning take place in small groups, where teachers worked together to establish common understandings. Finally, teachers indicated that by listening closely to what their students were saying, the teachers were expanding both their knowledge of math pedagogy as well as their understanding of math itself.

This final chapter examines the way this study of math professional development might impact the practice of teachers and school leaders, as well as the design and planning of professional development, policy development, and further research. The structure of this chapter is organized around these different areas, looking at general implications as well as implications specific to my own practice, and ends with concluding remarks.

Implications for Teachers

The benefit of small professional learning groups of teachers who are teaching similar subject matter was frequently mentioned in the literature as effective practice. This was something that definitely was supported by the findings of the study: Teachers found this approach worked well for them, as they felt more comfortable discussing their experiences with

other teachers who were working in similar environments, with similar students, covering similar curricula. The teachers felt that this small-group learning environment was not only comfortable for them, but that it maximized their learning.

Early on in our professional development sessions, we decided that teachers would be more candid if the facilitators provided ongoing opportunities for the participants to work in small groups without the presence of the facilitators. This did create a dilemma around the question of how to get data from these small group discussions if we weren't there, but this was solved by having prompts to which the group responded, recording their answers using Jamboard.

The evidence provided through the interviews, journals, and field notes all indicate that small group professional development including frequent opportunities for discussion and reflection is beneficial to teachers and their practice. Reflection that utilizes journaling, with an emphasis on expressive writing, along with opportunities to reflect in small groups, all strengthen the teachers' understanding of mathematical concepts.

Teachers can and do learn from one another. Not only do they learn from one another, but the learning is more meaningful when it is related to the work one is doing in the classroom and the work one's peers are doing in their classrooms. Therefore, teachers should seek out each other on a regular basis to discuss ideas, explore successes, and work through challenges together. This does not need to happen only through professional development. Although having it intertwined with professional development does provide the space and time, often lacking in a teacher's day, to dedicate to these explorations, there should be other opportunities for teachers to meet in small groups to discuss practice, both formally and informally.

Teachers benefit from interacting with each other on many levels, so making sure these interactions continue is something that school leaders, as well as the teachers themselves, should work to preserve. Teacher anxiety and stress were greater this year than in past years due to the influence of the Coronavirus pandemic, but teachers frequently mentioned the significance of small groups of supportive colleagues helping them through the learning process as a comfort. Having extended this practice this year to other realms of professional development, and getting feedback from teachers on what is working, the overwhelming response I am receiving from teachers is the benefit of opportunities to discuss practice with small groups of teachers.

Implications for Leaders

School leaders are busy. Designing professional development takes time. Partnering with an organization that specializes in the area that is the focus of the professional development is both time-saving and allows for an expertise that a busy school leader may lack. Finding time to build the expertise is difficult, so working with an organization that has this expertise solves some of these dilemmas.

Furthermore, working with an outside organization lends legitimacy to the process . Teachers not only accept the instruction from authorities who are fully dedicated to the subject matter, but also appreciate that the task of finding techniques and strategies to be more effective in the classroom is enhanced and ameliorated by these experts (Mitra, 2010). It reduces some of the work that the teacher might otherwise have to do on her own. In turn, this also reduces some of the anxiety that the teacher would otherwise experience.

Dedicating time to professional development, and figuring out which times work best, is an important part of the work of the school leader. In this case, having monthly meetings worked

well for a few reasons. One, it gave the school leader and outside facilitators time to reflect on the previous session and the comments of the participants and plan accordingly for the next session; although there was an outline for the whole process, this outline was frequently adjusted as the work progressed.

Implications for Professional Development

At my school, we will continue to structure professional development in small groups, whether the learning be focused on social-emotional learning, English language arts, or any other subject area that is in need of improved teacher understanding and/or performance. The small group experience was referred to often as a positive experience for the teachers, a sentiment that continues to be upheld; in a reflective group last week working on mindframes, I asked teachers to give feedback at the end, citing one positive aspect of the hour-long session. These reflections were done privately. Significantly, every one of the ten teachers in the group mentioned the major benefit of the training being the ability to work in small groups with their colleagues, discussing practice.

Teacher reflection is another experiment which proved fruitful. It was obvious through the review of teachers' journals that all teachers were spending the time to consider their practice, try new things in the classroom, and then reflect on how their practice improved as a result of the changes they were making in their teaching. Again, this was something that was supported by both literature and the work I did with my teachers. The benefits of reflective practice have wide applications to teaching development in all subject areas (Veine et al, 2019). Furthermore, reflective practice, and in particular expressive writing, have the benefit of being a stress reducer, something that these days in particular we, as administrators, need to be aware of.

In my school, we will continue to weave reflective practices in any situation for which it would be appropriate. It is already a part of our evaluation and supervision process, but after seeing how it works in the professional development realm, and seeing how teachers were able to best reflect, I can see how I would change some of the prompts to deepen the reflective process. For example, trying out something in one's classroom and then immediately reflecting on how it went was much more powerful than general reflection. Teachers had something concrete to reflect on and could tie their reflection to very real experiences. As this was an iterative process, there were continuing changes in the classroom which led to ongoing reflection on the part of the teacher.

The writing that teachers did in their journals was grounded in expressive writing; teachers not only explored what they were doing on a technical level in their writing, but also how they felt about it. Their reflections were holistic and therefore more meaningful and heartfelt. I think that this approach is something that has applications across subject matter as well as in reducing teacher anxiety in areas that transcend the technical learning aspects of their practice.

Professional development experiences which utilize small groups of teachers using the classroom as a laboratory, and where the teachers build upon one another's expertise, is effective, both according to the research I did and the research I read. Not only is it effective, but teachers value this approach to professional development. It feels more like it is their own learning, rather than learning forced upon them. Giving teachers more ownership and voice in their professional development was a key learning from my case study and one that would apply to other professional learning experiences in other schools.

Implications for Policy Makers

Teachers benefit from well-planned and well-executed professional learning. As a result, student growth is greater in classrooms where teachers are exploring new approaches to teaching. Therefore, policies that support professional development should be instituted by school boards nationwide. Many districts show this support by creating a school calendar with regular opportunities for staff to gather and learn, either through the creation of staff-development days, regular student half-days so that teachers have an afternoon or morning on a regular basis dedicated to professional learning, or contractually guaranteeing that teachers have time after school to improve their practice through professional development experiences. This opportunity is something that local school boards hopefully recognize as important if they want their teachers to continuously improve their practice, essential if they are going to improve instruction in their classroom.

In the district in which this study took place, there is dedicated time each Friday afternoon, supported by student half-days, for teachers to participate in professional development. Teachers can improve their practice more significantly if they have the time dedicated to study, reflection, and planning. It was very clear in this study that having this dedicated time relieved some of the stress that teachers frequently experience. There is also time twice a month in this district for afterschool professional development built into the teacher contract. It was during this afterschool time that this particular professional development took place. Although the training took place after school, the fact that some of the other initiatives taking place in the district were covered during the Friday professional development time rather than expected to be done individually and independently, at other times after school helped make

the Wednesday afternoon work feel more manageable. Creating, *and preserving*, time for professional development is essential.

On a higher level of policy support, policies providing funding at the state and foundational level for outside organizations to partner with schools allow school districts to improve their professional development offerings. Partnerships with outside organizations are beneficial but also costly. Lately, there has been an influx of government funding to cover school districts' myriad needs resulting from the pandemic, but these resources will run out with time. Mitra et (2010) in their report *Providing Spark and Stability*, which explores the role of intermediary organizations in helping schools, recognize the value of target training for adults; organizations with specialized focus can help public schools, whose missions are as wide-ranging as the populations they serve. Ultimately, it will be up to legislators and others who wield the controls at the state and federal levels, as well as the local levels, to recognize the worth of beneficial partnerships and provide adequate funding to secure the continuity of these partnerships.

Implications for Further Research

Some of the questions I set out to answer warrant further exploration. Although many teachers indicated that they had learned how to think differently about mathematics from their students, they were vague in their responses to how their thinking had changed. The specifics of the differences between how teachers thought about mathematics before and how their perceptions changed after listening to their students can be mined more deeply. This could be done through a careful anecdotal sampling at the start of a study and again at the end, with specific prompts measuring perceptions before and after, or through a survey given both prior

and after the study. More creative, but maybe harder to interpret, might be a series of math scenarios given to teachers before and after, requiring them to think inductively, and measure the difference in how teachers approach the problems before and after they have completed the training.

Another area that would benefit from more attention is how the changes in professional development impacted student performance. Most of the classroom impact for this study was anecdotal, based on what teachers reported was changing in their classroom and the benefits associated with these changes. How students performed on standardized and classroom assessments was not part of the evaluative process of this study intentionally, as part of the focus of the study was a reduction of teacher anxiety; having student data factored in as a measure of the success of the process would be a probable cause for an increase in teacher anxiety, thereby conflating the findings. However, it would be beneficial to determine whether there were actual increases in student performance as an additional measure of the success of the work we all did together.

Student perception of their learning, and their learning environment, are other areas that would benefit from more research. How did changes in classroom practice impact how students viewed their classrooms? What were their thoughts on the increase in discussion? It may be difficult to assess this as the students may not see differences in how learning was before and after, as they have yet to be habituated to what school is all about; their ability to gauge change is hampered by their age and experience, or lack thereof. However, their general feelings about math class, and about the subject of math, would add insight relative to the effectiveness of our

changing approach to teaching math. Unfortunately data do not exist to help us gauge student feelings about math in our school from previous years, so a comparison would be infeasible.

Next Steps

Our next steps include expanding this model of professional development to include other subject areas, in particular language arts. We realized through this experience that teachers *can and do* learn much from each other, especially when partnered in small groups of teachers who teach similar subject matter. Not only can they learn from one another, but they enjoy the practice and value it beyond more traditional approaches to professional learning. The reflective practice of writing individually in journals and participating in reflective discussions in small groups seemed to resonate with teachers, as well as provide evidence that teachers were thinking about their practice and how to improve it. Another facet of this experience that is worth preserving and applying to similar situations is using teachers' classrooms as learning labs. This meshed well with the reflective practice, as teachers were reflecting on what they were doing in their own classrooms allowing them to make connections between theory and practice.

One of my objectives going into this research posited that teachers, through listening to their students talk about math, could deepen their own understanding by seeing math through the eyes of their students. As mentioned many times, I began to see many parallels between what we were advocating teachers try in their classrooms and the work we were doing with our teachers. I see a huge opportunity in refining the approach to professional development where the voice of the learner, in this case the teachers, is central to the work, and where teachers' funds of knowledge (Moll, 1992) is integral to every facet of the exploration. It is the leader's work to structure the experience so this fund is not only accessed, but leveraged to maximize the

outcomes. This will have the immediate impact of strengthening the professional learning, but also the impact of creating a stronger school culture. Just as teachers noticed a deepening sense of community in their classrooms because students felt listened to and valued for their input, the teaching community can be strengthened, with an increase in feelings of belonging and mutual respect, an auxiliary benefit of future professional development endeavors that make teachers the center of the professional learning experience.

Concluding Remarks

Our professional development work began with an exploration of the role of listening in the teaching and learning process. Much of our first two sessions with teachers was dedicated to looking at how teachers ask questions and solicit responses, how teachers set up discourse in the classroom, and what teachers can learn about their students through this process. As our study progressed it became apparent that there were many parallels between what we were asking teachers to do in their classrooms and what we were learning about effective professional development. Our professional development became an opportunity for us to model techniques we were asking teachers to try out in their classrooms. Sometimes the discussions we had, the listening we, as facilitators, did with our teachers helped us to better understand teachers' needs and restructure our professional development accordingly, just like we hoped teachers would do in their classrooms. This relates to the convergent versus divergent thinking we explored in our sessions with teachers: If something organically goes where it was unexpected, it may lead to new discoveries. We espoused this approach for the teachers' classroom practice, but soon recognized both the importance and return on the investment of utilizing this approach in our own work we were doing with the teachers. One teacher had written in her journal about how "the students can be the experts showing each other with less teacher scaffolding"* in relation to the student in the elementary classroom, but ultimately I realize that this same theory applies to professional development; teachers have abundant understanding of how to teach well, with each

*This relates to the convergent versus divergent thinking in that if something organically goes where it was unexpected it may lead to new discoveries and the students can be the experts showing each other with less teacher scaffolding which I think will mean more and they will own it more.

teacher having their own “fund of knowledge” (Moll, 1992). This collective fund of knowledge is much more important than any financial fund in supplying the resources needed for transformational change. Ultimately, because of its authenticity and its foundation in the wide range of teacher experience, it may be the only fund that is required.

I’m an avid outdoor sportsman, with a keen interest in biking, skiing, and paddling. It has taken me many years to hone my skills in these endeavors, to proceed from novice to advanced. In many of these sports, the ability to see ahead and anticipate is a necessary skill, whether it be seeing a line through a glade when backcountry skiing, seeing the challenges on a mountain bike trail before you encounter them, or reading a series of rapids before paddling them. It has taken years to reach the point where I can do this instinctively and automatically. I realized with this study that I started out much the way I did when I started any of these sports, on a relatively gentle slope thinking the work was fairly straightforward: You make your way down the course, but as you do you begin to realize there is a lot more to it than is initially evident. Having descended the course a bit I now realize that there is much more to experience, and that the more difficult routes are the more interesting. I have many routes to explore. Embarking on this study taught me much, most importantly that there is much more to see and that the harder routes are, ultimately, the more satisfying they are when you are able to successfully navigate them.

REFERENCES

- Ball, D. L. (1988). Unlearning to Teach Mathematics. *For the Learning of Mathematics*, 8(1), 40-48.
- Beilock, S. L., Gunderson, E. A., Ramirez, G., & Levine, S. C. (2011). Female teachers' math anxiety impacts girls' math achievement. *PsycEXTRA Dataset*. <https://doi.org/10.1037/e634112013-097>
- Boaler, J., & Dweck, C. S. (2016). *Mathematical mindsets: unleashing students' potential through creative math, inspiring messages and innovative teaching*. First edition. San Francisco, CA: Jossey-Bass; a Wiley Brand.
- Di Teodoro, S., Donders, S., Kemp-Davidson, J., Robertson, P., & Schuyler, L. (2011). Asking good questions: Promoting greater understanding of mathematics through purposeful teacher and student questioning. *Canadian Journal of Action Research*, 12(2), 18-29.
- Drago-Severson, E. (2009). *Leading adult learning: Supporting adult development in our schools*. Corwin Press.
- Garet, M. S., Porter, A. C., Desimone, L., Birman, B. F., & Yoon, K. S. (2001). What makes professional development effective? Results from a national sample of teachers. *American Educational Research Journal*, 38(4), 915-945. <https://doi.org/10.3102/00028312038004915>
- Heifetz, R. A. (2009). *Leadership without easy answers*. Harvard University Press.
- Hembree, R. (1990). The nature, effects, and relief of mathematics anxiety. *Journal for Research in Mathematics Education*, 21(1), 33-46. <https://doi.org/10.5951/jresmetheduc.21.1.0033>
- Hintz, A., Tyson, K., & English, A. (2019, April 14). Teaching is a listening profession. *Teaching Channel*. <https://www.teachingchannel.com/blog/teaching-is-a-listening-profession>
- Jacobs, V. R., Lamb, L. L., & Philipp, R. A. (2010). Professional noticing of children's mathematical thinking. *Journal for Research in Mathematics Education*, 41(2), 169-202. <https://doi.org/10.5951/jresmetheduc.41.2.0169>

- Jameson, M. M., & Fusco, B. R. (2014). Math anxiety, math self-concept, and math self-efficacy in adult learners compared to traditional undergraduate students. *Adult Education Quarterly*, 64(4), 306-322. <https://doi.org/10.1177/0741713614541461>
- Kaiser, G., & Presmeg, N. (2019). *Compendium for early career researchers in mathematics education*. Springer.
- Kalinec-Craig, C., & Robles, R. A. (2020). Classroom rules Reimagined as the rights of the learner. *Mathematics Teacher: Learning and Teaching PK-12*, 113(6), 468-473. <https://doi.org/10.5951/mtlt.2019.0140>
- Krathwohl, D. R. (2009). *Methods of educational and social science research: The logic of methods* (3rd ed.). Waveland Press.
- Kunzig, R. (2020, November). Let's not waste this moment. *National Geographic*, 238(5), 76-89.
- Loucks-Horsley, S., Stiles, K., Mundry, S., Love, N., & Hewson, P. (2010). *Designing professional development for teachers of science and mathematics*. Corwin Press.
- Lloyd, C. (2014, March 10). *Why our smartest students are failing math*. Parenting. <https://www.greatschools.org/gk/articles/why-americas-smartest-students-fail-math/>
- Malzahn, K. (2013). *2012 National survey of science and mathematics education: Status of elementary school mathematics teaching*. Horizon Research, Inc. <http://2000survey.horizon-research.com/>
- Maxwell, J. A. (2005). *Qualitative research design: An interactive approach*. SAGE.
- Meth, P. (2003). Entries and omissions: Using solicited diaries in geographical research. *Area*, 35(2), 195-205. <https://doi.org/10.1111/1475-4762.00263>
- Mewborn, D. S., & Huberty, P. D. (2004). A site-based model for professional development in mathematics at the elementary school level. *Pythagoras*, 0(59). <https://doi.org/10.4102/pythagoras.v0i59.126>
- Mitra, D., Sanders F., & Perkins, D. (2010). Providing Spark and Stability: The Role of Intermediary Organizations in Establishing School-Based Youth-Adult Partnerships, *Applied Developmental Science*, 14:2, 106-123, DOI: [10.1080/10888691003738285](https://doi.org/10.1080/10888691003738285)

- Moll, L. C., Amanti, C., Neff, D., & Gonzalez, N. (1992). Funds of knowledge for teaching: Using a qualitative approach to connect homes and classrooms. *Theory Into Practice*, 31(2), 132-141. <https://doi.org/10.1080/00405849209543534>
- National Council of Teachers of Mathematics. (2012). Mathematics education in the United States 2016: A capsule summary fact book. Reston, VA: NCTM.
- National Council of Teachers of Mathematics.(2016). Mathematics education in the United States 2016: A capsule summary fact book. Reston, VA: NCTM.
- National Council of Teachers of Mathematics. (2000). *Principles and standards for school mathematics: An overview*. Reston, VA: NCTM.
- National Council of Teachers of Mathematics. (2014). *Principles to actions: Ensuring mathematical success for all*. Reston, VA: NCTM.
- Park, D., Ramirez, G., & Beilock, S. (2011). Put your math burden down: Expressive writing for math anxiety. *PsycEXTRA Dataset*. <https://doi.org/10.1037/e683152011-502>
- Pollan, M. (2019). *How to change your mind: What the new science of psychedelics teaches us about consciousness, dying, addiction, depression, and transcendence*. Penguin Books.
- Ramirez, G., Gunderson, E. A., Levine, S. C., & Beilock, S. L. (2013). Math anxiety, working memory, and math achievement in early elementary school. *Journal of Cognition and Development*, 14(2), 187-202. <https://doi.org/10.1080/15248372.2012.664593>
- Saldana, J. (2012). *The coding manual for qualitative researchers*. SAGE.
- Schifter, D., Bastable, V., & Russell, S. J. (1999). *Number and operations: Building a system of tens. Part I*. Dale Seymour Publication.
- Schoenfeld, Alan. (2022). The math wars. EDUCATIONAL POLICY. 18. 253-286. 10.1177/0895904803260042.
- Smith, M. S., & Stein, M. K. (2011). *5 practices for orchestrating productive mathematics discussions*.
- Turner, D. (2016, April 21). Participant diaries for qualitative research. *Quirkos*. <https://www.quirkos.com/blog/post/qualitative-participant-diaries>

- United States House of Representatives, Committee on Education and Labor, & Congress, U. S. (2019). *The national mathematics advisory panel report: Foundations for success*.
- Veine, S., Anderson, M. K., Andersen, N. H., Espenes, T. C., Søyland, T. B., Wallin, P., & Reams, J. (2019). Reflection as a core student learning activity in higher education - Insights from nearly two decades of academic development. *International Journal for Academic Development*, 25(2), 147-161. <https://doi.org/10.1080/1360144x.2019.1659797>
- Wakui, N., Abe, S., Shirozu, S. *et al.* Causes of anxiety among teachers giving face-to-face lessons after the reopening of schools during the COVID-19 pandemic: a cross-sectional study. *BMC Public Health* 21, 1050 (2021). <https://doi.org/10.1186/s12889-021-11130-y>
- Widmer, G. (2019). *Formative Evaluation Report on Numeracy4ME Pilot, 2018-2019*. Maine Department of Education.

APPENDICES

Appendix A - Letter of Explanation of Study and Invitation to Participate

January, 2021

Dear Captain Albert Stevens School Staff:

As many of you know, I am past the halfway point in my doctorate work, having recently made the jump from doctoral student to doctoral candidate. What this means is that I have largely finished my coursework and now am embarking on the research part of my doctorate. My plan is to do my research project this winter and spring. During this time I will collect data. This is followed by an analysis of the data, where I look for trends, and hope that what I see aligns with my hypothesis. Then, over the course of next year I continue to read more literature and work on finalizing the data analysis. This whole process culminates in my dissertation; I submit the written part, and then defend it, in 2022.

My hypothesis is that if quality professional development is structured around teachers reflecting on the statements that students make about math, paying close attention to how their students learn and think about mathematics, teachers will not only learn much about their students, but will also learn much about themselves as mathematicians. Teachers who listen carefully to what their students are saying can begin to expand their own understanding of the many ways to approach math concepts and learning. This will benefit the teachers through not only their own increased understanding of mathematics, but also an increased understanding of how to best teach mathematics to a wide variety of students with myriad needs and ways of thinking about mathematics.

I will be doing this research in our professional development groups and invite you all to be a part of the process. I have been planning the Wednesday afternoon professional development for the rest of the year with Becky Tapley and Cheryl Tobey. We will be inviting people to journal about what you are seeing and hearing in your classrooms, as well as what you feel you are learning yourselves, as you go through the professional development process. The data that I will use for my project will be culled from teachers' journals (the ones who agree to let me do this, that is), notes on the discussions that take place during the professional development sessions, from interviews with teachers who are willing to be interviewed, and notes on what is happening in classrooms. Most likely, the classroom part will be based on classroom video, as it will be difficult on a number of levels for us to all do classroom observations of one another's classrooms in person this year.

I recognize that being involved in a research project may be a new thing to many of you, and hope you will consider it. The potential risks would be a possible sense of discomfort in having me and your peers observing your teaching. Furthermore, there would be fifteen minutes of writing between the five professional development sessions we have planned, so there would be the loss of the time used to write in your journals. The benefits would be to extend your learning around math and math pedagogy and take your teaching to the next level. I also see potential benefit in that you will find yourself more deeply connected to our collegial learning community.

I am excited to be doing this work with all of you. Just yesterday, a CASS teacher was talking about the things that her young students were saying and how she was amazed at the things her students seem to know naturally. I feel that there is a lot that students bring to the math class and that through this work together we will be able to learn more about and access that natural understanding of math that students have.

At the end of the study, I will invite all who are interested to preview my work before it is finalized. This process, called “participation validation” ensures that everyone’s voice is heard and that the work I do is transparent.

To summarize what it would mean to participate in this study: All teachers will be writing in journals during professional development, but I would only use data from those who choose to participate in my study. There would be an additional fifteen minutes of journaling per month outside of the professional development for those who agree to be part of the study. We will all be sharing two to three video vignettes from our classrooms during our professional development, but I would use data only from the classrooms of the teachers who agree to participate. I am also seeking four to five teachers who would be willing to participate in an interview with me at the end of the process, which would take between forty and sixty minutes.

Sincerely,

Glen

Appendix B - Informed Consent Form

Informed Consent to Participate in Glen Widmer's dissertation study on Teacher Listening and Reflection as a Way to Broaden Teacher Pedagogical and Conceptual Understanding of Mathematics

You are invited to participate in this study, being conducted by Glen Widmer, a doctoral candidate in the University of Maine's Educational Leadership program. The purpose of this research study is to assess to what extent teachers actively reflecting and journaling about students' discussions of math strategies and math in general broaden their understanding of math pedagogy and concepts.

Should you decide to participate, you will be asked to reflect in a journal about things students say and do in your classroom. Participants will share their practice with peers and the researcher through at least a couple videos of their classroom or through classroom observations. We estimate that the journaling will require 15 minutes of your time during one 1 hour professional development session per month, February - May 2021, and as little as 15 minutes per month outside of the professional development time. Should you find it a useful practice you could certainly journal beyond that length of time. You may also be invited to participate in an interview with the researcher, which should last approximately an hour.

The benefits of this study is an opportunity to take a deeper look at your math practice and be guided through a process of making your practice stronger through professional development and shared observations. Not only will you learn through your own reflection, but you will also learn from your peers through observing one another's classrooms. Furthermore, this research may help the general educational community by revealing better ways to structure professional development.

The potential risks are stresses that result from observation of one's teaching. With this in mind, participants may video their teaching and show specific vignettes from their teaching as opposed to a whole lesson. The researcher understands that there is the additional stressor of a pandemic. Due to the current environment, the researcher has intentionally created learning experiences designed to lessen anxiety and promote collegiality.

Data collected will be stored in a password-protected computer which will be with the researcher or locked in a room. Anonymity of participants in the study will be protected, with pseudonyms used to protect identities of those who participate.

I understand that my participation in this project is completely voluntary, and I am free to stop or withdraw my participation at any time, without any penalty.

I understand that all of my responses in this study are completely confidential, and will be used only for research purposes. If I have any questions about this study or want more information, I am free to contact: Glen D Widmer, glen.widmer@maine.edu, University of Maine.

Research Supervisor: Catharine Biddle catharine.biddle@maine.edu, University of Maine

Sign and date here:

All signed forms will remain confidential. Participants may keep a blank form if desired.

Appendix C: Interview Protocol

Introductory paragraph: Thank you for agreeing to participate in my research. The most valuable pieces of information I can garner will most likely come from the conversations I have with people who have participated in the professional development, tried out different approaches in the classroom, and reflected on what has worked and what has not. I truly appreciate your input and your time into making this project something of value. Your insights and your experiences are hugely important.

Questions will be drawn from these prompts. Follow up prompts are listed under each primary prompt if needed. Each interview will be 45-60 minutes in length:

- One of the goals of this project is to make professional development more meaningful to teachers, both personally and professionally. Can you talk a bit about how this professional development was different, paying attention to both the ways that it worked for you personally, as well as the ways that it could have been better?
 - What about the pace of the PD? Was meeting once a month, trying things out in your classroom, reflecting on the experience, and then discussing it a month later a good process?
 - Can you talk a little about writing about what you wanted to get from the experience before each professional development session? Was that useful?
- A major focus of the professional development was on reflection: You reflecting on what you were doing in your classroom, what the students were saying, how you responded to what they were saying, etc.
 - Did the process of reflection lead to a change in your teaching?
 - In which ways?
 - Did the process of reflection lead to change in your thinking about, and understanding of, mathematics?
 - In which ways?
 - Would you just speak to all of that for a while?
 - Did having an intentional structure for reflection help in the reflection process?
- A lot of people feel anxious when it comes to talking about mathematics, and these days just anxious in general given all the issues around the pandemic. Would you please talk about how the structure of the professional development impacted any feelings of anxiety?
 - Were there any parts of the way the professional development was designed that lessened feelings of anxiety?

- Any parts that increased anxiety?
- One goal of the professional development was to explore questioning techniques, with a focus on questioning practices which promote divergent thinking on the part of the students, where the answers weren't anticipated and the students were encouraged to explore. Would you talk about how this technique played out in your classroom?
 - Can you talk about any surprises or learnings that resulted from asking questions which were more open-ended?
 - Did anything that you heard students say about math change your own thinking about math?
- How has teaching math changed for you in the past few months? In the past year?

Thank you for participating in the study. As I mentioned, your input is paramount to my understanding of what works and what doesn't work in the realms of professional development and math teaching.

BIOGRAPHY OF THE AUTHOR:

Glen Widmer is an elementary school principal who has been working with children for thirty years. He has taught mostly in Maine, although he and his wife taught for three years at the Lincoln American International in Buenos Aires. He was an elementary school principal in RSU #3 for five years before coming to Captain Albert Stevens School in Belfast, where he has been principal for the past five years. His interests are in integrating learning experiences into experiential adventures, harnessing the power of school gardens and outdoor education to fuel student interest and learning. Although passionate about math, he sees an intersection of all subject matters as the sweet spot where true learning occurs. Glen lives in the woods and fields of Montville with his wife, his two nearly grown sons, and his dog. Glen is a candidate for a doctoral degree in Educational Leadership from the University of Maine in May, 2022.