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IMPLEMENTATION OF NUMBER TALKS TO SUPPORT NUMBER SENSE AND FLUENCY, INCLUDING AUTOMATICITY

Janel Koenig

IMPLEMENTATION OF NUMBER TALKS TO SUPPORT NUMBER SENSE AND FLUENCY, INCLUDING AUTOMATICITY

by

Janel Joy Koenig

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Hamline University

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Capstone Project Facilitators: Jennifer Carlson & Kelly Killor
Content Expert: Kayti Bjorklund-Strandlund
Peer Reviewer: Katy Gross

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CHAPTER ONE

Introduction

Overview

Rote memorization of facts and formulas through repetitive and timed tasks was how I approached and completed math classes. As research in the teaching and learning of mathematics has evolved, this approach is no longer viewed as beneficial for students. Including mathematics, information is better retained by making connections and associating ideas. Upon this foundation is what number sense is based. Deep understandings within mathematics are created by examining and discussing the relationships between numbers and applying these relationships to various operations. This development of number sense is critical for the continued success in higher level mathematics (Boaler, 2015; Dehaene, 2011).

Presented in this chapter are the personal and professional experiences that have sparked the shift in my mathematical mindset and instructional decisions. A rationale developed from these experiences are also provided. I was recently introduced to Cognitively Guided Instruction (CGI) while pursuing my elementary education license. This CGI framework provided by Carpenter, Fennema, Franke, Levi, & Empson (2015) offered ideas related to number sense and uncovered teaching and learning strategies that were new to me. As I began my teaching career, efforts were made to incorporate these strategies into my classroom as I viewed this approach as something that would benefit my students.

In my second year of teaching, Number Talks were a district wide initiative within the math curriculum. A personal goal was to learn more about Number Talks while still focusing on the ideas presented to me in CGI. At this point, I had already acknowledged that number sense was a necessary foundational skill for all mathematical skills. However, I was curious about how number sense may link to fluency, including automaticity, and how important these were to continued success in mathematics. Emphasis on all of these concepts guided my capstone project and shaped the formation of my research and essential question: *How can implementation of Number Talks support elements of number sense and fluency, including automaticity, for elementary students*?

Personal Context

Throughout my schooling years, memorization of facts, rules, formulas, and the systematic completion of computations was how I tackled mathematics. In elementary school, I listened and watched the teacher demonstrate a strategy and reproduced what was given on worksheet after worksheet. Timed tests were also given. It was fortunate that my coordination was developed and my fingers were nimble as I used them as the only tool to quickly produce answers for addition and subtraction problems. I do not recall any discussions focusing on the relationships between numbers and operations to introduce and examine various strategies for solving problems.

As the years went on, I continued to rely on the teacher as the main source for my mathematical knowledge. On paper, it would appear that I understood skills and concepts being taught. In reality, much of the information stuffed into my brain quickly retreated to make room for the next series of facts, rules, formulas, and computations to be applied. I viewed units in isolation, and the goal was to use the one appropriate strategy to obtain the correct answers. The process was important because it was a methodical approach to reach this correct answer. The process was not something that could develop my reasoning, logic, or problem solving skills. I knew I was able to use my short term memorization skills to get good grades in math but did not view myself as a math person.

In college, I attempted a statistics class but within the first two weeks became panicked as the content left me feeling completely lost and overwhelmed. I knew the concepts and pace of this course would require more than memorization. Unfortunately, my fear of failure was of no benefit in viewing this as an opportunity to grow math skills in a new direction. I had already defined myself as “not a math person” so avoided math classes from this point on until much later in my life.

While getting my teaching license, I was faced with the fact that a math methods course would have to be taken. On the first day, we were given a double-digit addition problem and were told not to use a standard algorithm to solve. Even though it was fifteen years after my brief encounter with statistics, a bit of anxiety began to surface. While sharing out strategies, the concept of integrating Cognitively Guided Instruction (CGI) into a math curriculum was introduced. This instruction engages students with their thinking and allows students to build on current understandings while focusing on number sense. Throughout the course, we used CGI to explore math concepts including basic math facts, fractions, and geometry. Concepts and problems were presented in a context that provided accessibility to the math through story problems, visual images, and manipulatives. The process was an important aspect of solving each problem, but I experienced and defined the process in a new way. It now included discussions of various strategies that explored the relationships between numbers and flexibly applying this knowledge between operations and concepts. Building number sense was a focal point. Strategies were not presented by the professor; the professor was the facilitator. Knowledge was developed through the sharing of various strategies and the connections made between them. For the first time, I was engaged in constructing my mathematical understandings. Methods and strategies that made the most sense to me were being utilized, and I wanted this for my students!

Professional Context

Within my first year of teaching, this newfound appreciation for what math instruction could be was incorporated. While using the fifth grade math curriculum as a guide, I decided to focus on mindfully constructing how math warm-ups and tasks given to students were facilitated. Each lesson started with a math warm-up. This warm-up was presented using a story problem which highlighted one or two students and their interests or favorite things. For example, *Sue was getting ready for a sleepover with 7 of her friends. She baked 2 round cakes. How much cake will each person get at the sleepover?* Students were always excited to see who would be in the problem and what they would be doing. For these warm-up problems, all students worked individually on dry erase boards and manipulatives were accessible if desired. For the example problem above, foam fraction circles would have been available to students. As students finished solving, I purposefully looked for a variety of strategies and asked those students to put their strategies on the whiteboards around the room. Students would then explain their thought process while my role would be to facilitate discussions in making connections between the strategies.

Math tasks were also mindfully considered. We played many math games related to concepts and skills being learned. When math homework was given, assignments were adjusted using Google docs to better align with CGI and support the development of number sense. Homework was shortened, and many problems were presented using story problem formats to give a context and provide access to the math. Points were also given for showing work so ample space was provided between problems. This simple arrangement allowed me to better understand misconceptions and provide more valuable feedback to students as I could see where misunderstandings were occuring within each students' thought process.

It is important to mention this development of math warm-ups and math tasks was an evolution. In the beginning, math warm-ups were continually introduced with modeling and examples. With the support of learning about a growth mindset, students gradually became more comfortable in sharing strategies as our classroom community grew over the first few months. With this growth, students also became more confident in trying out new strategies and seeing mistakes as learning opportunities. Again, with consistent practice, students were able to improve their ability to scribe and explain their thinking not only in math warm-ups but also in math tasks assigned.

Rationale

In my second year of teaching, I moved to a second grade classroom in a district that implemented Number Talks. Number Talks were a new teaching practice for me so I wanted to understand how and if they fit into the ideas introduced to me in CGI with number sense being the focal point. If so, I wanted to create a project using Number Talks that would engage students while still focusing on developing number sense through the exploration and discussion of various strategies.

In addition to number sense, I was also pondering the importance of fluency and automaticity. In the previous year of teaching fifth grade, I noticed many students struggled to solve problems involving fractions because they could not quickly and efficiently solve the many basic math equations that were required for these higher-level problems. While going through the second grade Minnesota Math Standards, Benchmark 2.1.2.2 within the strand of Number and Operation specifically states, “Demonstrate fluency with basic addition facts and related subtraction facts” (Minnesota Department of Education, 2007). After reading this and observing the struggles with basic operations in a fifth grade classroom, the importance of creating a strong foundation in number sense to build fluency in early elementary grades was apparent. From personal experience, I felt this early attention to number sense and fluency would indeed support continued mathematical successes as more complex problems are introduced.

In the fall, automaticity was assessed for each second grade student using a Fastbridge assessment. Each student completed the four-minute assessment from both the Level One and Level Two. Level One addressed basic one-digit by one-digit addition and subtraction facts, and Level Two utilized up to two-digit by two-digit addition and subtraction. I was coming to believe the idea that fluency and automaticity would develop as number sense increased. However, I wanted to further understand the role and importance of fluency and automaticity in learning mathematics.

Summary

Math was something I got through and was not interesting or engaging. I simply memorized and applied the necessary procedures to complete each course. Although still somewhat of a surprise, these experiences have contributed to my newfound desire and interest in creating meaningful and engaging math experiences for my students. Each year, I have selected tasks related to the math curriculum to help develop what I have learned regarding effective teaching and learning strategies in mathematics.

Chapter two provides a literature review of topics related to the essential question: *How can implementation of Number Talks support elements of number sense and fluency, including automaticity, for elementary students*? This review includes research concerning number sense, fluency and automaticity, and Number Talks. Chapter three provides a deeper understanding of the project being created. An outline provides the rationale for the project, frameworks used to guide the development of the project, a project description, an overview of the participants and setting, and finally a timeline for the project. Chapter four is a critical personal and academic reflection of the capstone and project.

CHAPTER TWO

Literature Review

Overview

To develop continued growth and success in mathematics, students need to have a solid foundation in flexibly understanding the relationships between numbers in order to support various applications of efficient computation strategies (Tsao & Lin, 2012). These foundational skills correlate to number sense, fluency, and automaticity, a component of fluency, which are regarded as critical components of mathematical knowledge (National Council of Teachers of Mathematics [NCTM], 2000). To ensure students are receiving learning opportunities to build these skills, pedagogy must align with them. Number Talks are a pedagogical practice that appear to correlate with the three core components of mathematical knowledge listed above: number sense, fluency, and automaticity. These three components will be examined within this literature review to further investigate the essential question: *How can implementation of number talks support elements of number sense and fluency, including automaticity, for elementary students*?

To begin this review, various concepts related to number sense are explored. Although the essential question sought information regarding the possible connection of Number Talks to number sense and fluency, including automaticity, it is important to first understand what number sense entails. Therefore, a definition of number sense and a description of components using The Components of Number Sense model developed by Cain, Doggett, Faulkner, and Hale (2007) are offered. To further explore the deeper essence of number sense, the review examines the relation of number sense to continued success in math by focusing on cognitive research. Taking these topics of number sense into consideration, this review then analyzes the eight effective mathematical teaching practices provided by the National Council of Teachers in Mathematics (NCTM, 2014).

Next, this review explores the remaining components of mathematical knowledge outlined in the essential question, fluency and automaticity, to ultimately assess their possible correlation to number talks. Fluency and automaticity in math is the ability to accurately and quickly retrieve math facts and use them to efficiently solve math problems. Along with definitions, research is presented that suggested how these skills of fluency and automaticity affect students' learning related to mathematics. Again, cognitive research findings are used to explain how students' mathematical knowledge can be hindered or supported by abilities in fluency and automaticity.

Finally, the pedagogical practice of Number Talks is reviewed. To build an understanding of Number Talks, an analysis outlining what number talks are and types of Number Talks are given. A preliminary investigation of the essential question is then reviewed by exploring research linking the benefits of Number Talks to number sense, fluency, and automatically.

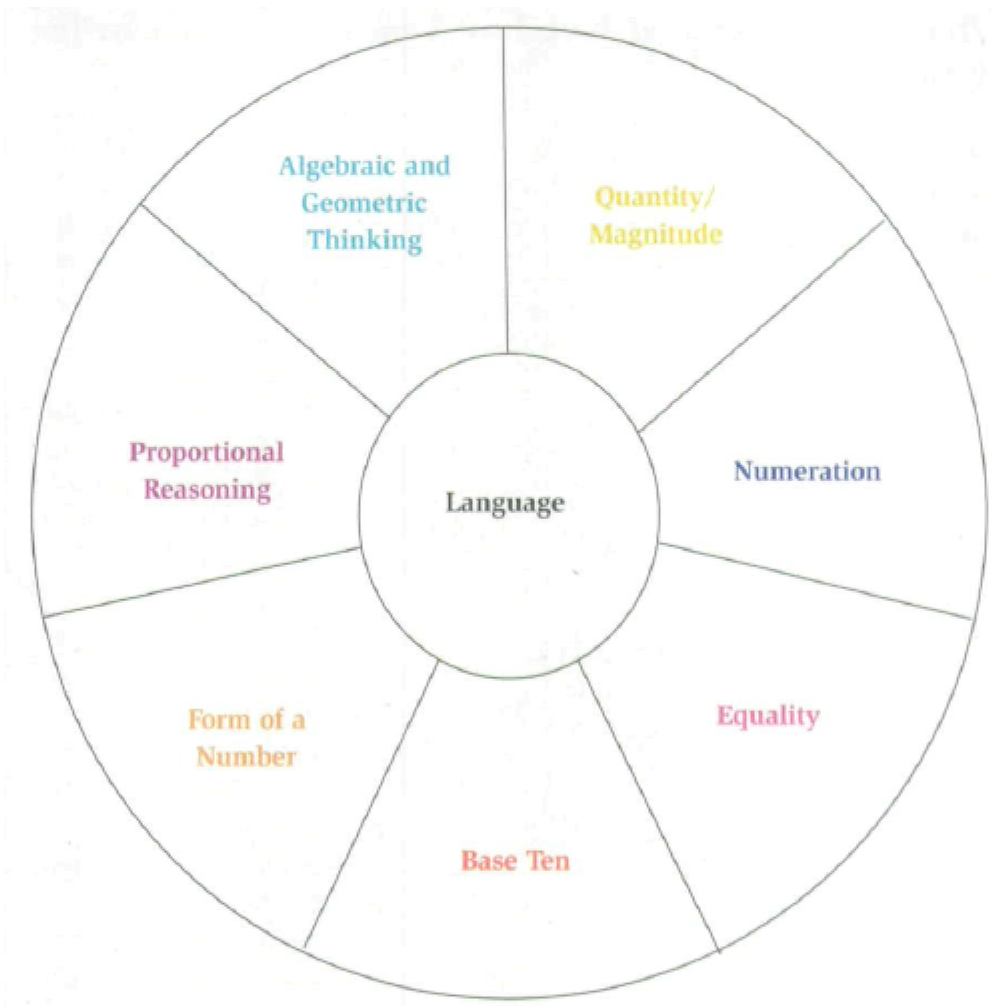
Number Sense

Definition and components. Number sense is the ability to understand the relationships between numbers and quantities and how they are affected by operations. This knowledge is then used mentally and flexibly to expand abilities in applying various strategies when solving mathematical problems (Frisco-van den Bos, Kroesbergen, & Van Luit 2014; McIntosh, Reys, & Reys, 1992; Toll, Kroesbern, & Van Luit, 2016). Attributes of having good number sense include abilities in: fluently estimating and judging quantity and magnitude, reasoning and recognizing if answers are logical, using mental strategies flexibly, moving fluidly between various mathematical representations, and selecting representations that are efficient (Kalchman, Moss, & Case, 2001). Although these are some indicators of having number sense, how to create teaching and learning experiences to develop number sense remains a difficult question for teachers to navigate (Faulkner, 2009).

To help in the development of instruction that supports number sense, Cain, Doggett, Faulkner, and Hale (2007) designed The Components of Number Sense model. It consists of seven components: quantity, numeration, equality, base ten, forms of a number, proportional reasoning, and algebraic and geometric thinking. The Components of Number Sense is a circular model and should be implemented with a spiral approach. Components are continually revisited within each math lesson. In addition, connections between components should be taking place as students will need to utilize multiple components when solving mathematical problems (Cain et al., 2007). A brief analysis of each component is laid out next.

Figure 1

The Components of Number Sense



The idea of quantity is to understand how numbers can be linked to various visual representations of the same quantity set and to comprehend that quantity may be nonsymbolic (Friso-van den Bos et al., 2014). Quantity is a real-world application for mathematics, not just numbers (Faulkner, 2009). Problems using quantity would be considering how to divide a pizza equally when working with fractions or examining functions by looking at miles per gallon to measure the efficiency of different automobiles.

Numeration is the ability to decode mathematical language and apply it within our numeration system which groups at a rate of ten (Faulkner, 2009). In order for students to develop this language, they need to be given opportunities to work within it. Children first interact with mathematical language using concepts and strategies involving smaller numbers. These learning experiences develop into slightly more advanced computations including operations involving multi-digit numbers, multiplication, and division. Here is when children deepen understandings in numberation involving base-ten concepts (Carpenter et al., 2015), another component of number sense.

Base-ten is the decimal system we use and has ten digits to represent all numbers (Cain et al., 2007). Developing abilities of counting increasing units of ten, just as we count individual units of one, is a foundational understanding needed to comprehend our base-ten number system (Carpenter et al., 2015). The use of expanded notation and regrouping to make base-ten numbers through composing and decomposing provides experiences in understanding this foundation of the base-ten system which is comprehending a group of ten as a unit (Carpenter et al., 2015; Faulkner, 2009).

Equality is represented by the equal sign. It shows that two mathematical expressions have the same value (Falkner, Levi, & Carpenter, 1999). However, students have misconceptions around this meaning. Many see the equal sign as showing two things that are the same, instead of equal in value (Faulkner, 2009). Another common misconception is that the equal sign is viewed as a directional symbol, meaning the answer always appears on the right. Again, losing the meaning that the equal sign is showing an equal value (Faulkner, 2009).

Forms of a number are closely tied to equality in that numbers can be represented in various forms without changing their value (Faulkner, 2009). For example, a number can be expressed using standard numerical form, written form, expanded notation, or a visual representation such as a dot pattern. Faulkner (2009) brought to light that students should always be asking, “Do I like the form a number is in?” With this question in mind, students can change the form of a number to make it more friendly or easier to work with. This happens in various levels of mathematics, including regrouping to add multi-digit numbers, simplifying expressions, or converting mixed numbers to fractions greater than one (Faulkner, 2009).

Proportional reasoning requires examining the similarities and differences between numbers in quantities and comparing numbers within quantities (Faulkner, 2009). Offering authentic opportunities to think logically about ratios, rate, quotients, and fractions can build these skills related to proportional reasoning (Lesh, Post, & Behr, 1988). However, in order to support this component within the realm of number sense, instruction and tasks involving proportional reasoning need to again involve real-world proportional relationships, not simply learning procedural equations (Faulkner, 2009; Lesh et al., 1988). Solving ratio and proportion problems while finding best prices for grocery items or analyzing measurements within a recipe would foster number sense within proportional reasoning.

Algebraic thinking involves multiple skills. It incorporates abilities in examining and recognizing patterns, analyzing and representing relationships, making generalizations, and assessing how things change (Schielack & Seeley, 2007). These skills needed to develop algebraic thinking should not be thought of in isolation, as advanced goals within an algebra class. Instead, they need to be a continuous evolution of skills and concepts from prekindergarten on in order to develop number sense (Faulkner, 2009; Schielack & Seeley, 2007).

Geometric thinking can be outlined using the Van Hiele theory (1957). This theory incorporates a progression through five levels of geometric thinking involving visualization, analysis, abstraction, deduction, and rigor where each level incorporates its own language and symbols (Van Hiele, 1999). Again, in order to build number sense, children need to be given consistent interaction with these skills starting with early introduction through play in geometry (Van Hiele, 1999). Exposure should occur with all of the components within The Components of Number Sense model, not just in relation to algebraic and geometric thinking (Carpenter et al., 2015; Faulkner, 2009; Lesh et al., 1988). This practice has been shown to lead to continued, and greater, mathematical success in higher levels of mathematics which are discussed in the next section.

Importance to continued success in math. Correlations have been made to early development of number sense and later success in mathematics (Bellon, Fias, & De Smedt, 2019; Moffett & Eaton, 2019). Flexibly understanding the relationships between numbers and operations including addition, subtraction, multiplication, and division are needed foundational skills for development into higher level mathematical concepts (Bellon et al., 2019). The Components of Number Sense model can be correlated to this claim. For example, the components of quantity, forms of a number, and base-ten are utilized when understanding that 32 + 23 = 55 can also be expressed as 30 +2 + 20 + 3 = 55.

Growth in mathematical development can be further understood by examining cognitive factors (Bellon et al., 2019). Executive function skills include the ability to maintain focus, attention, and monitor behavior while choosing appropriate steps to complete a task. Working memory is also an aspect of executive function skills that enable individuals to hold and work flexibly with several pieces of information to reason and solve problems (Braddeley & Hitch, 1994; Diamond, 2013). Freeman, Karayanidis, and Chalmers (2017) found that increased ability in solving tasks involving working memory related to academic achievement.

Strong associations have been made between executive functions, specifically working memory, and number sense abilities as a predictor of continued mathematical achievement (Bull & Scerif, 2001; Toll, Van der Ven, Kroesbergen, & Van Luit, 2011; Van der Ven, Kroesbergen, Boom, & Leseman, 2012). Working memory plays an increasingly important role when solving mathematical problems. Working memory allows pieces of information to be stored and evaluated while determining appropriate strategies. With development, inefficient strategies such as joining all where students use objects or fingers to represent each addend as they count one by one are discarded. Instead, they are replaced with more efficient strategies such as counting up, counting down, analyzing and holding place value information, or making a new ten. As more advanced problems get introduced, working memory also aids in mentally managing the multiple calculations necessary to solve these problems such as multi-digit multiplication or operations involving fractions (Bellon et al., 2019; Frisco-van den Bos et al., 2014). Understanding the longevity of number sense within mathematics, while remaining mindful of The Components of Number Sense model, can further assist in determining the best instructional strategies used to develop number sense. In the next section, focus is brought to this topic.

Instructional strategies to develop. Various instructional strategies can be implemented to support number sense including problems that use subitizing to elicit visual patterns related to numbers or using ten frames to relate numbers to five and ten. Whichever strategies are selected, it is important to consider researched-based teaching practices. National Council of Teachers of Mathematics (NCTM) connects high quality mathematics education to eight effective mathematical teaching practices in *Principles to Actions: Ensuring Mathematical Success for All* (2014). These eight effective mathematical teaching practices include: establishing mathematics goals to focus learning, implementing tasks that promote reasoning and problem solving, using and connecting mathematical representations, facilitating meaningful mathematical discourse, posing purposeful questions, building procedural fluency from conceptual understanding, supporting productive struggle in learning mathematics, and eliciting and using evidence of student thinking.

Figure 2

Effective Mathematics Teaching Practices

Effective Mathematics Teaching Practices
Establish mathematics goals to focus learning. Effective teaching of mathematics establishes clear goals for the mathematics that students are learning, situates goals within learning progressions, and uses the goals to guide instructional decisions.
Implement tasks that promote reasoning and problem solving. Effective teaching of mathematics engages students in solving and discussing tasks that promote mathematical reasoning and problem solving and allow multiple entry points and varied solution strategies.
Use and connect mathematical representations. Effective teaching of mathematics engages students in making connections among mathematical representations to deepen understanding of mathematics concepts and procedures and as tools for problem solving.
Facilitate meaningful mathematical discourse. Effective teaching of mathematics facilitates discourse among students to build shared understanding of mathematical ideas by analyzing and comparing student approaches and arguments.
Pose purposeful questions. Effective teaching of mathematics uses purposeful questions to assess and advance students' reasoning and sense making about important mathematical ideas and relationships.
Build procedural fluency from conceptual understanding. Effective teaching of mathematics builds fluency with procedures on a foundation of conceptual understanding so that students, over time, become skillful in using procedures flexibly as they solve contextual and mathematical problems.
Support productive struggle in learning mathematics. Effective teaching of mathematics consistently provides students, individually and collectively, with opportunities and supports to engage in productive struggle as they grapple with mathematical ideas and relationships.
Elicit and use evidence of student thinking. Effective teaching of mathematics uses evidence of student thinking to assess progress toward mathematical understanding and to adjust instruction continually in ways that support and extend learning.

The following analysis briefly considers the purpose and the teacher's role for each of these teaching practices drawing from *Principles to Actions: Ensuring Mathematical Success for All* (2014). Establishing mathematics goals to focus learning is the first effective teaching practice. The purpose is to clarify learning objectives for students and to guide instructional decisions. The teacher should not only determine learning objectives but consider why they are important and how to best support students in understanding current knowledge as well as desired extensions.

The second effective teaching practice considers how to implement tasks that promote reasoning and problem solving. The purpose is to engage students in exploring mathematics using strategies that connect to their understandings. The teacher should select mathematical tasks that not only build on current understandings but allow students to use a variety of strategies from various entry points (NCTM, 2014).

Using and connecting mathematical representations is the third effective teaching practice. The purpose is to provide a variety of physical and abstract representations of mathematical concepts. These representations should develop number sense which will grow to assist in effective procedural skills. Learning tasks provided by the teacher should encourage students to make connections between various representations through the use of models, pictures, words, and numbers (NCTM, 2014).

The next effective teaching practice is facilitating meaningful mathematical discourse. The purpose is to deepen mathematical thinking and understanding by sharing, explaining, and defending mathematical strategies with classmates. Discussions should be facilitated by the teacher with the goal of engaging students in articulating their mathematical logic and reasoning. Connections should also be made between strategies and representations presented to strengthen understandings (NCTM, 2014).

Posing purposeful questions is the fifth effective teaching practice. The purpose is to encourage students' mathematical discourse in a way that requires elaboration and clarification. Along with wait time, open-ended questions that extend thinking should be offered by the teacher that allow the math to become more visible and accessible to all (NCTM, 2014).

The sixth effective teaching practice is to build procedural fluency from conceptual understandings. The purpose is to build number sense by allowing students to flexibly utilize strategies that make sense to them in order to build mathematical understandings. The teacher should provide opportunities for students to walk through their procedures while reflecting on logic as to why they work. In this strategy, the teacher should also be drawing connections between strategies to reveal efficient procedures (NCTM, 2014).

The purpose of the seventh effective teaching practice, supporting productive struggle in learning mathematics, is to provide students with opportunities and time to make sense of new mathematical ideas and concepts. Again, open-ended questions should be offered that support the importance of the process rather than the answer (NCTM, 2014).

The final effective teaching practice is to elicit and use evidence of student thinking. The purpose of this practice is to effectively assess knowledge and use this information to make further instructional decisions to support students' mathematical growth. Teachers should look beyond the answer to consider reasoning and possible misconceptions to help develop next steps (NCTM, 2014).

These eight effective teaching practices outlined by NCTM (2014), provide insights when examining possible associations between Number Talks and number sense development in the essential question: *How can implementation of number talks support elements of number sense and fluency, including automaticity, for elementary students*? Later in this chapter, an analysis of Number Talks is provided. First, a literature review of fluency and automaticity, the remaining elements in the essential question, are presented.

Math Fluency and Automaticity

Definitions of fluency and automaticity. Fluency in mathematics is the ability to solve math problems accurately. Another component of fluency is automaticity. This is the ability to quickly recall facts. Fluency and automaticity work together and are an integral component when efficiently solving higher-level math problems that demand multiple steps to complete (Poncy, Skinner, & Jaspers, 2007). One may ask, if students can develop number sense and use strategies flexibly to solve mathematical problems, why is fluency and automaticity important to mathematical learning? As with number sense, cognitive research will be used to investigate this question in the next section.

Fluency and automaticity effects on students' mathematical learning. Only so many cognitive processes can take place while completing multiple tasks at the same time. Cognitive research shows that when fluency and automaticity in math facts are developed, less parts of the brain are used. This means that when higher-level math problems are introduced, students will not deplete mental resources in solving the many basic operations necessary to complete these types of problems because they will be easily retrieved from long-term memory, freeing up working memory (Dahaene, 2011; Poncy et al., 2007).

Metacognition is another cognitive aspect that needs to be considered when trying to understand varying mathematical abilities (Bellon et al., 2019). Metacognition involves one's ability to actively monitor their mental process, or thinking, to gain knowledge (Vo, Li, Kornell, Pouget, & Cantlon, 2014). When looking at metacognitive ability, specifically in numerical domain, Bellon, Fias, & De Smedt (2019) conducted a study that suggests children’s knowledge of mathematics is dependent on metacognitive abilities. There is also a relation between metacognition and increased abilities in mental arithmetic, as well as increased speed and accuracy with basic arithmetic (Bellon et al., 2019; Rinne & Mazzocco, 2014).

Number Talks

What are Number Talks? Number Talks were created by Ruth Parker and Kathy Richardson (Hughes, 2019). They are a short, ten to fifteen-minute discussion focusing on one mindfully created math problem. Problems are solved mentally and strategies are shared out. This format allows students to initially solve math problems individually using strategies that make sense to each. When sharing strategies, students explain their mathematical reasoning behind solutions and peers are able to learn from, and build on, strategies presented (Humphry & Parker, 2015). With this approach, Number

Talks help to reveal math as something meaningful and fun (Humphry & Parker, 2015; Parrish, 2011). Number Talks move away from instructional methods that require a series of rules and procedures using rote memorization. Instead, they require students to investigate number and operation relationships and are encouraged to build number sense (NCTM, 2000; National Research Council [NRC], 2001).

Number Talks consist of five essential components: classroom environment and community, classroom discussions, the teacher's role, the role of mental math, and purposeful computation problems (Parrish 2010). Building a safe classroom environment and community is what allows students to feel comfortable sharing and questioning all strategies and solutions presented. Teachers model this norm when doing Number Talks by recording all solutions generated by the class for a given Number Talk problem without showing verbal or nonverbal agreement. Knowledge is not provided by the teacher but instead by the conversations among students in defending their answer by explaining thinking and strategies (Parrish 2011).

Classroom discussions are the second key component that should be present in Number Talks. Communication occurs throughout all stages of a Number Talk. Beginning communication includes the teacher writing a problem on the board, students putting up fingers to indicate how many strategies they have to solve the problem, and when almost all have nonverbally shown that they have at least one strategy, the teacher records all possible answers regardless of correctness. The nonverbal communication and wait time is important as it allows all students to participate. Those with lower processing speeds are given wait time and those who quickly find a solution are challenged to continue to come up with multiple strategies (Parrish, 2011). Verbal discussions then begin as students pick and defend an answer. This communication of sharing strategies provides various mathematical advantages which are examined in the next section, benefits of Number Talks.

The teacher's role is another component of Number Talks. Number Talks should ultimately increase students' abilities in understanding mathematics by examining mathematical relationships (Humphreys & Parker, 2015). Therefore, the focus is on the process, rather than on the answer. To support this, the teacher's initial role is to simply scribe strategies exactly as they are verbally explained by students. After multiple strategies are recorded, thoughtful and open-ended questions can be posed by the teacher and students that create connections between strategies (Humphreys & Parker, 2015; Parrish 2011). The teacher should be viewed as a facilitator of discussions, not as the one teaching during these discussions (Parrish, 2011).

The role of mental math is the fourth component of Number Talks. Mental math aligns with the goal of Number Talks to build efficient, flexible, and accurate strategies by using number relationships. Without paper and pencil, mental computations support students in using what they understand about numbers and how they are related instead of resorting to traditional procedures and U.S. algorithms (Parrish, 2011).

Purposeful computation problems is the final component of Number Talks. Teachers should mindfully select a series of problems with a goal in mind. This can be done by presenting problems that could possibly draw out desired strategies to be developed or involve problems that students are struggling to solve (Parrish, 2011).

These five components of Number Talks provide the outline for their implementation within a classroom. Equations are not the only format used when presenting Number Talks. In the next section, a brief description of the different types of Number Talks are presented.

Different types of Number Talks. A Number Talk problem can be offered in various forms. When starting, dot patterns are recommended because students are required to not only explain but to link a visual representation of a number which develops number sense (Humphreys & Parker, 2015). Students are asked to tell how many dots they see without counting each dot individually. The teacher then displays connections to the patterns, or groupings, of dots to numbers and operations when recording students' explanations. In the book, *Classroom-Ready Number Talks for Kindergarten, 1st and 2nd Grade Teachers*, Hughes (2019) offers a variety of additional visual, and pictorial, Number Talks such as dominoes, number lines, ten-frames, and connecting cubes that aim to elicit reasoning strategies.

Doubling any number, halving any number, and getting to the next larger power of ten are three foundational arithmetic strategies that can be used as a Number Talk (Humphreys & Parker, 2015). The selection of numbers for each will vary depending on grade level. However, using these three foundational arithmetic strategies in Number Talks will help to develop students' understanding of numbers when working with all operations (Humphreys & Parker, 2015).

Equations are another format that can be used in Number Talks. Number Talks are powerful in that they support students in looking at the relationships in numbers and operations. So, equations should be written horizontally as this will encourage students to move away from traditional algorithms that may have been taught (Humphreys & Parker, 2015). Number Talks encourage students to work with numbers using various representations that make sense to them. Due to this, all representations to solve equations should be scribed including open number lines, decomposition strategies, or counting on strategies. When using equations, it is important to remember that equations should be purposefully selected to possibly elicit certain strategies that will fit the needs of students (Humphreys & Parker, 2015). With foundational understandings of Number Talks in place, the next section will address why Number Talks should be incorporated into math instruction by examining the benefits.

Benefits of Number Talks*.* As mentioned above, active participation through communication is an integral part of Number Talks. During verbal sharing of strategies, students make sense of mathematics by creating understandings that focus on the process rather than the correct answer. (Humphreys & Parker, 2015). With this focus, participation increases as students become more comfortable with the idea that mistakes are part of the process in developing mathematical knowledge (Huinker, 2018; Sun, Baldinger, & Humphreys, 2018). Students are provided with opportunities to verbally communicate ideas, clarify understandings, and offer learning opportunities for all by sharing aloud. This fits with the fourth effective mathematical teaching practice offered by The National Council of Teachers of Mathematics (2014), facilitating meaningful mathematical discourse. In reflecting back on the importance of developing metacognition to build number sense, fluency, and automaticity, this active communication also allows children to practice articulating their thinking to build metacognition skills (Lee, 2015). The teacher can also provide opportunities to develop metacognition by posing open-ended questions during and after Number Talks such as, *What strategy made the most sense to you and why?* or, *What strategy helped you get a better understanding and why?*.

As participation increases, more students will see themselves as capable mathematicians. Math becomes accessible when all explanations and strategies are valued which makes math more equitable (Baldinger et al., 2018; Huinker, 2018). For example, English Language Learners (ELLs) will also benefit from the communication structure of Number Talks (Baldinger et al., 2018). When sharing strategies, ELL students not only communicate strategies but get visual feedback from the teacher as their strategies are scribed. In addition, ELL students are hearing and seeing other strategies recorded to increase academic language in mathematics (Moschkovich, 2013). This framework for accessibility and equity within mathematics not only provides opportunities for all students to engage in developing mathematical concepts but encourages teachers to view all students as capable participants in mathematics (Huinker, 2018).

Number sense is a skill that is not only required in elementary mathematics but in higher-level mathematics as well. Many errors in higher-level mathematics, including algebra, geometry, trigonometry, and calculus occur because students do not use numbers and operations flexibly by identifying relationships (Baldinger et al., 2018; Humphreys & Parker, 2015). Without number sense, students inattentively rely on surface knowledge of procedural algorithms and rules without considering the logic of answers (Hibert, 1999; Humphreys & Parker, 2015). Introducing a variety of strategies to solve mathematical problems is a key component of Number Talks. Teaching mathematics using various strategies rather than procedural, rote memory, or drill-and-practice methods, has also been linked to higher performance in mathematics (Tournaki, 2003).

An additional benefit of Number Talks is the impact on math mindsets. The belief about abilities in how and what you can learn is your mindset. It is now known that the brain has the ability to grow, adapt, and change which correlates to the idea of a growth mindset (Dweck, 2016). Having a growth mindset means you believe abilities can change through hard work and practice. Mistakes are simply opportunities to grow. Contrary, a person with a fixed mindset believes they are born with abilities that cannot change, and mistakes are signs of failure (Dweck, 2016). Boaler (2016) found that students' negative thoughts about mathematics can be so harmful that it is important to focus on the idea of developing mathematical mindsets.

Overuse of traditional algorithm instruction can skew beliefs in mathematics as being rule-based, an activity reserved for school, or only for those with natural talents in mathematics. These beliefs can lead to disengagement or avoidance of math tasks (Lampert, 1990). Instead, engaging in authentic math instruction and activities can help to develop positive mathematical mindsets, diminishing the idea of not having a "math brain" (Boaler, 2016). Six questions offered by Boaler (2016) should be considered when striving to create engaging math tasks: *Can you open the task to encourage* *multiple methods, pathways, and representations?, Can you make it an inquiry task?, Can you ask the problem before teaching the method?, Can you add a visual component?, Can you make it low floor and high ceiling?, Can you add the requirement to convince and reason?* These questions have strong correlations to the first, second, and fifth essential components of Number Talks offered by Parrish (2011) earlier in the review: classroom environment and community, classroom discussions, and purposeful computation problems. These questions also align with many of the effective teaching practices offered by NCTM (2014) previously discussed, particularly practices two, three, four, and eight: implementing tasks that promote reasoning and problem solving, using and connecting mathematical representations, facilitating meaningful mathematical discourse, and eliciting and using evidence of student thinking.

Summary

To investigate the question: *How can implementation of Number Talks support elements of number sense and fluency, including automaticity, for elementary students*?*,* this chapter explored current research related to the key elements within the question: number sense, fluency, automaticity, and Number Talks. To develop understandings relating to number sense, a definition and description of components was given. The Components of Number Sense model developed by Cain, Doggett, Faulkner, and Hale (2007) was used as a framework to provide an understanding of number sense components. Cognitive research related to executive function skills, focusing on working memory, offered information linking number sense to continued success in math. Additionally, eight effective teaching practices developed by NCTM (2014) were analyzed to provide research-based teaching practices that can be implemented to support number sense. The purpose of each effective teaching practice was highlighted along with what teachers should be doing within each.

Next, research related to the second key element within the essential question, fluency and automaticity, was investigated by providing definitions and again examined cognitive research findings to explain how abilities in fluency and automaticity can affect students' mathematical knowledge. As with number sense, correlations were given between mathematical abilities and working memory. In addition, links were presented between abilities in fluency and automaticity in relation to metacognition.

Number Talks were the final key element reviewed to provide possible answers to the essential question. A look into the pedagogical practice of Number Talks was given including an outline for implementation and different types of Number Talks. Benefits of Number Talks were also specified by pulling from previous research given in the chapter related to number sense, fluency, and automaticity.

In this literature review, connections have surfaced suggesting that Number Talks will increase elements of number sense, fluency, and automaticity. In chapter three, an outline, rationale, and description of a project to be implemented in a second grade classroom is provided. The project is a digital resource that can be utilized during Number Talks in efforts to increase number sense, fluency, and automaticity.

CHAPTER THREE

Project Description

Overview

In chapter two, a review of literature and research provided a more in-depth understanding of key topics including number sense, fluency, automaticity, and Number Talks. Chapter three provides an outline of the capstone project which included a series of visual Number Talks to be used in a second grade classroom to address the essential question: *How can implementation of Number Talks support elements of number sense and fluency, including automaticity, for elementary students*?

In the outline, a rationale explains why this topic was selected. The framework discusses the teaching practices and theories used to guide the project. A project description explains the format. Finally, an overview of the participants and setting of the project are provided along with a timeline.

Rationale

Early and continued development of number sense is critical for ongoing success in mathematics as it is the foundation for higher-level mathematical skills and problems (Bellon et al., 2019; Feikes & Schwingendorf, 2008; Moffett & Eaton, 2019). Number Talks are an engaging and meaningful way to build number sense and fluency in that the process invites students to explore the relationships between numbers using various strategies. It does not rely on rote procedures or memorization (Boaler, Williams, & Confer, 2015). An essential purpose of this project was to offer a series of Number Talks that could be implemented in a second grade classroom to support this development of number sense and fluency in an engaging way.

Another rationale for this project was based on experiences when beginning Number Talks within a second grade classroom. Number Talks can be presented in various forms. In my second grade classroom, I observed students struggling to articulate and produce various strategies for Number Talks that were being presented using expressions involving just numbers. With this observation, dot patterns were introduced which allowed students to use subitizing skills by quickly seeing the patterns in numbers and assigning a numerical value to them. With these visual dot patterns, students were more easily able to see, articulate, and solidify the various relationships between quantities and number representations using math language. They were developing and using number sense while engagement and excitement increased. The incorporation of visual pictures from the book, *The Grapes of Math*, written by Tang (2001) was then implemented during Number Talks. Again, excitement increased and more students were offering ideas and strategies in how they mentally formulated answers. Visual images appeared to support this group of students. Therefore, the project created offers a collection of real-world images to support the conceptual understanding of various number pattern representations to quantity. This visual aspect also supports the communication of strategies by using and developing math language.

The rationale for this project came from two different sources: one being research-based, the need to continually support development in number sense and fluency for success in higher-level mathematics, and the second stemming from experiential observations within a second grade classroom; Number Talks using visual representations support connections and articulation between various number representations and quantity. Discussed next is the frameworks used to help create the scope of the project .

Framework

Elements from The Components of Number Sense model created by Cain, C., Doggett, M., Faulkner, V., & Hale, C. (2007) and ideas defined in the eight effective mathematical teaching practices outlined by the National Council of Teachers of Mathematics (2014) guided the development of this project. Both provide practices that support the development of number sense and fluency that are incorporated into the creation and implementation of Number Talks.

Although a single Number Talk can, and should, include discussions involving many of the elements in The Components of Number Sense model, the needed skills for my second grade classroom helped to define two specific goals within The Components of Number Sense model, quantity and form of a number (Cain et al., 2007). The first goal was to build conceptual understanding of numbers by creating links to quantity. This was done by offering Number Talks using visual representations, or non-standard units and expressions. Presenting, 8 + 9 may appear to be a simple equation but if students in these early elementary grades do not have a conceptual understanding of what eight or nine is, they will not be able to transfer knowledge to new situations and apply it in new mathematical contexts, such as doubles plus one. Instead they will view the expression 8 + 9 as an isolated fact.

The second related goal was to increase understanding when considering form of a number, or to understand that a number can have various visual representations and numerical representations without changing the value. This strongly correlates to the first as it requires students to use conceptual understanding to apply various representations to a number. Foundational understandings involving these two elements within the Components of Number Sense model are important as they support skills and concepts within a second grade math curriculum such as drawing hundred squares, ten sticks, and one cubes to represent a number, writing a number using expanded notation, or measurements (Cain et al., 2007).

In examining the framework of the eight effective teaching practices outlined by NCTM (2014), Number Talks provide a platform to support these teaching practices. In chapter two, connections to these teaching practices and Number Talks were discussed. Therefore, strong correlations can be made that the implementation of Number Talks align with the eight effective teaching practices.

The Components of Number Sense model (Cain et al., 2007) and the eight effective teaching practices (NCTM, 2014) were frameworks used in the development of this project. Within The Components of Number Sense, quantity and form of a number were the focused goals as I feel they provided foundational learning experiences in building conceptual understandings that support the ability to transfer knowledge when moving to expressions involving numbers, or other representations as well. Further details of the project format follow in the project description.

Project Description

Research and the specific needs of my second grade classroom helped shape this project, digital math tasks using visual Number Talks. It consisted of various real-world images that are intended to be used when implementing Number Talks in the fall and intermittently throughout the year to reignite engagement for any second grade classroom. Fuson (2019) found that visual images can be especially helpful for younger students who are still creating conceptual understandings as they help to reveal the various number partners hiding within totals to support addition and subtraction skills as well as the relationship between the operations. Additionally, Carpenter, Fennema, Franke, & Empson (2015), found that early elementary students are still learning how to verbalize and communicate mathematical strategies they *just knew*. Using relatable real-world contexts can offer connections to mathematical language. To increase engagement, students were involved in the creation. Students walked around the school and took pictures that comprised the visual Number talks. Students were directed to look for visual patterns that could spark addition or subtraction Number Talks including lockers, arranging unifix cubes, bricks on the wall, book bins on the bookshelf, or holes in a pegboard.

Google slides were the platform used so images could be projected onto a Smartboard and strategies could be scribed by the teacher for all to see. Each slide contained a different visual image using real objects to inspire addition, subtraction, and possible beginning multiplication conversations utilizing skip counting. The progression of slides does not need to be done starting from the first working through each one. Instead, the teacher can select the slide that best meets current needs of students. A visual Number Talk instruction Guide was created to support implementation. Main ideas were taken from *Making Number Talks Matter* (Humphreys & Parker, 2015) and my district's curriculum website. See appendix A for the visual Number Talk instruction guide.

This format was selected focusing on two ideas: one, to create engagement and two, to provide a relatable context to access the math. Next is a description of the participants and setting for the project.

Participants and Setting

The resource created was implemented in a second grade classroom consisting of twenty-five students. The class was 48% girls and 52% boys of which 84% identify as Caucasian, 8% as Hispanic, 4% as African American, and 4% as two or more races. National percentile ranks for the 2019 - 2020 FastBridge aMath fall scores show results of: 28% as "high risk" (0 - 19.99%ile), 24% as "some risk" (20 - 29.99%ile), 40% scored within 30 - 84.99%ile, and 8% in the 85%ile and above. The school is a public school located in a second-ring northern suburban area with an enrollment of just under 400 students for kindergarten through 6th grade. There are 25% of students that qualify for free/reduced lunch and 16% receive special education services. Number Talks are a required part of the district's math curriculum with implementation of three to five consecutive days each week.

In this second grade classroom of twenty-five students, over half, 52%, fell within "high risk" and "some risk" after taking the FastBridge aMath assessment. Being that the district requires number talks, it was fitting to develop a project that would help these participants using Number Talks. A discussion involving assessments used to reflect on the effectiveness of the project is offered next.

Assessment

With implementation of these visual Number Talks, a variety of formative assessments provided opportunities for reflection regarding their effectiveness in relation to the essential question, *How can implementation of Number Talks support elements of number sense and fluency, including automaticity, for elementary students*? A visual Number Talk strategy checklist was created. The front side provided a table to document which strategies surfaced during Number Talk discussions including: counting on, counting down, part-part-whole, use of doubles, compensation, skip counting, and other. The back side provided a table to document any notes or additional observations from the Number Talk implemented. See Appendix B for the visual Number Talk strategy checklist. Visual Number Talk assessment forms were created using the format from dot pattern and equation Number Talk assessment forms from my district's curriculum website. These were used at the beginning and end of the four-week visual Number Talks digital series. Students were provided five boxes on the assessment form to scribe different strategies used to solve the visual number talk presented. This provided information related to developing number sense by monitoring abilities in using various numbers and operations flexibly for a single dot pattern. It also gave insights to developing understandings in transferring quantity to numbers. See Appendix C for visual Number Talk assessment forms. Additionally, an automaticity progress monitoring assessment within FastBridge was available to discover possible links to increased automaticity. Next, a timeline for completion and implementation is given.

Timeline

The project was completed in the spring of 2020. Implementation was ready for the 2020-2021 school year. This project was intended to be used in the fall for a four-week period when number talks are being reintroduced to students. Fall was selected for the initial starting point as I have found the visual formatting sparks engagement and supports conversations related to developing number sense. However, any of the visual Number Talks created in this series could be intermittently used throughout the year to bring variation into daily Number Talks and respark engagement.

Summary

In this chapter an outline for the project was given. The rationale involved research-based evidence that number sense and fluency are essential foundations for continued success in mathematics. The rationale also centers around observations concerning the needs of my second grade students. Frameworks for the project utilizes ideas from The Components of Number Sense Model (Cain et al., 2007), focusing on quantity and form of a number, as well as the eight effective mathematical teaching practices. A project description was provided describing the mindful use of real-world visual images to initiate addition and subtraction strategies. Finally, an overview of the participants in a second grade classroom and school setting along with a timeline for completion and implementation was provided. Chapter four provides a critical reflection of personal and academic learnings that occured from the creation process of the capstone project.

CHAPTER FOUR

Reflection

Overview

To begin this chapter, a reflection expresses personal learnings and growth as well as an explanation for the development of the essential question: *How can implementation of Number Talks support elements of number sense and fluency, including automaticity, for elementary students*? This essential question guided the literature review and the project development. Key information from the literature review is presented next, followed by the project description. Implications to the teaching and learning of math are then offered. Finally, limitations of the project to consider are discussed.

Personal Reflection

The teaching profession encompasses many facets. Before productive learning can take place, teachers must start to build relationships with students and consider how to create safe and respectful learning environments. It is true that today's teachers still need to consider standards, curriculum, and align learning objectives to these. Yet, at the same time, continuous reflection and learning should be occurring to meet the needs of students. This reflection and learning can lead to a variety of creative and engaging learning experiences of concepts for students. It is this practice that I find most interesting about the teaching profession.

I entered this exciting and challenging profession only two years ago as a career change later in life. Due to this, I have been inundated with teaching practices and theories that can help to create engaging, more meaningful, learning experiences. Interestingly, feelings of frustration have surfaced as my mind recognizes that I am building a foundation of knowledge and resources in these first years of experiences and continued education, but I sometimes wish the processes could be accelerated to assist me in developing my skills as a teacher. It is the realization and slow acceptance that this process cannot be accelerated that has motivated me through this process of obtaining my Master of Arts in Teaching degree. Continued education will always be a necessary part of my teaching career as it will continually improve my skills as a teacher and expose new and exciting teaching and learning practices.

Throughout this process, I have been given opportunities to develop knowledge and teaching practices by examining current research. Creating the project allowed me to further expand understandings related specifically to essential skills that contribute to continued success in mathematics such as number sense and fluency, including automaticity. I was also able to deconstruct the components and benefits of Number Talks. This was particularly important as my district implements Number Talks as part of math instruction. In addition, the process of reviewing literature related to these topics guided reflection on how math was being presented to students in my classroom. Were lessons and activities best supporting the needed skills of number sense, fluency, and automaticity? How could I enhance or modify the given curriculum to better meet these skills and the needs of my students? Current understandings of Number Talks when beginning this project led me to believe they could be an enhancement to the math curriculum to support the needed skills of number sense, fluency, and automaticity. To investigate this belief, the essential question emerged: *How can implementation of Number Talks support elements of number sense and fluency, including automaticity, for elementary students*?

Literature Review

Research in the literature review was guided by the essential question: *How can implementation of Number Talks support elements of number sense and fluency, including automaticity, for elementary students*? To explore this question, the research investigated the importance of developing number sense and fluency, including automaticity in correlation to Number Talks. This correlation was important as Number Talks were the intended instructional format for the project. To further understand correlations, literature related to developing instruction to support number sense, fluency, and automaticity became a focal point, as well as cognitive factors.

Various literature concluded that number sense, the first element in the essential question, should be developed early to support continued growth and success of mathematics in upper elementary grades and beyond (Bellon et al., 2019; Moffett & Eaton, 2019). When considering content and instruction that supports the development of number sense, I found two pieces of literature to be particularly valuable: The Components of Number Sense Model created by Cain, Doggett, Faulkner, and Hale (2017), and the eight effective mathematical teaching practices outlined by NCTM in *Principles to Actions: Ensuring Mathematical Success for All* (2014).

The Components of Number Sense Model brought focus to seven areas of mathematics that help to develop number sense: quantity/magnitude, numeration, equality, base ten, form of a number, proportional reasoning, and algebraic and geometric thinking (Cain et at., 2017). The eight effective mathematical teaching practices outlined instruction that should be implemented to support high quality math instruction: establishing mathematics goals to focus learning, implementing tasks that promote reasoning and problem solving, using and connecting mathematical representations, facilitating meaningful mathematical discourse, posing purposeful questions, building procedural fluency from conceptual understanding, supporting productive struggle in learning mathematics, and eliciting and using evidence of student thinking (NCTM, 2014). From these pieces of literature, I made inferences that these eight effective mathematical teaching practices should be applied when giving instruction within the seven areas of The Components of Number Sense model. Furthermore, these findings helped to guide future research in Number Talks as I wanted to investigate ways of melding elements in The Components of Number Sense model and the eight effective mathematical teaching practices with Number Talks.

Fluency and automaticity were the next elements within the essential question that directed the literature review process. As with number sense, it became evident in the research that development in fluency and automaticity play an essential role in abilities to solve higher-level mathematical tasks (Poncy et al., 2007). Additionally, the literature revealed cognitive factors, particularly working memory, as a common predictor of continued growth in mathematics related to not only fluency and automaticity but number sense as well (Bull & Scerif, 2001; Dahaene, 2011; Poncy et al., 2007; Toll et at., 2011; Van der Ven et at., 2012). When examining working memory in connection to fluency and automaticity, mental resources are not depleted when solving higher-level math problems if basic operations can be retrieved from long-term memory (Dahaene, 2011; Poncy et al., 2007). When examining number sense, increased capabilities in working memory allow inefficient strategies to be replaced with efficient ones (Bellon et al., 2019; Frisco-van den Bos et al., 2014).

Metacognition was another cognitive function that arose in the literature associated with mathematical aptitudes. Increased metacognition, or ability to actively monitor thinking to gain knowledge, can expand abilities in mental arithmetic as well as fluency and automaticity, or speed and accuracy with basic arithmetic (Bellon et al., 2019; Rinne & Mazzocco, 2014; Vo et al., 2014). This research again sparked thoughts of possible connections to Number Talks as Number Talks require students to use mental math while thinking about their thinking, or use metacognition skills, when communicating strategies.

After the elements of number sense, fluency, and automaticity were explored in literature, research associated to Number Talks needed to be examined in order to address the essential question: *How can implementation of Number Talks support elements of number sense and fluency, including automaticity, for elementary students*? In the literature review of Number Talks, the five essential components of Number Talks were identified: classroom environment and community, classroom discussions, the teacher's role, the role of mental math, and purposeful computation problems (Parrish, 2010). In reflecting on these components, I was able to make significant connections to prior literature discussed.

Connections to the eight effective mathematical teaching practices outlined by NCTM (2014) and the five essential components of Number Talks outlined by Parish (2010) are particularly noteworthy upon further reflection. These connections demonstrate the implementation of Number Talks work in conjunction with the eight effective mathematical teaching practices (NCTM, 2014). Table 1 highlights principal themes I identified as connections between these two outlines. It is important to note that even more connections could be identified as these two work so fluidly together.

Table 1

Themes Connecting Number Talks and Eight Effective Mathematical Teaching practices

Connecting Theme	Five Essential Components of Number Talks (Parrish, 2010)	Eight Effective Mathematical Teaching Practices (NCTM, 2014)
create safe learning environments	classroom environment and community	support productive struggle in learning mathematics
support engaging and productive math discussions	classroom discussions	implement tasks that promote reasoning and problem solving elicit and use evidence of student thinking
facilitate discourse from student generated strategies	the teacher's role	use and connect mathematical representations elicit and use evidence of student thinking
build efficient, flexible, and accurate strategies	the role of mental math	implement tasks that promote reasoning and

		problem solving build procedural fluency from conceptual understanding
mindfully select mathematical problems to meet learning goals	purposeful computation problems	establish mathematics goals to focus learning

Project Description

The rationale and format of the project were developed as a continuous progression of information stemming from the literature exploring key elements of the essential question: *How can implementation of Number Talks support elements of number sense and fluency, including automaticity, for elementary students*? In developing the rationale for the project, I pulled two emerging themes from the literature that I viewed as important: one, there is a need for early and continued development of number sense and fluency, including automaticity, to support continued success in higher-level mathematics (Bellon et al., 2019; Feikes & Schwingendorf, 2008; Moffett & Eaton, 2019) and two, Number Talks build number sense and fluency by creating engaging and meaningful learning experiences as they require students to explore the relationships between numbers and operations by discussing and expanding upon various strategies offered by students (Boaler, Williams, & Confer, 2015).

The consideration of emerging literature related to the essential question also guided the format development of the project. The frameworks of The Components of Number Sense offered by Cain, Doggett, Faulkner, and Hale (2017), and the eight effective mathematical teaching practices outlined by NCTM in *Principles to Actions: Ensuring Mathematical Success for All* (2014) were influential in creating project learning goals and teaching practices for the project's format and implementation. All seven Components of Number Sense should arise at some point within Number Talks. However, I chose to identify quantity and form of a number as focused goals of the project based on my students' needs to build conceptual understandings. As previously discussed in the literature review, I would argue that all eight effective mathematical teaching practices are incorporated into the delivery of Number Talks.

Expanding on the needs of my second grade students helps to explain additional formatting decisions related to the project. My students were struggling to articulate thoughts and strategies using mathematical language when Number Talks were being presented in equation formats using just numbers. I began to expand Number Talks by incorporating visual images using dot patterns and *The Grapes of Math* book (Tang, 2001). When introducing these tasks, I observed engagement and abilities to identify and articulate various relationships between quantities and number representations and operations increase. Number sense was being applied.

Further research confirmed conceptual understandings are still being developed by younger students. This was true for my second grade students. Visual images can be helpful in developing these conceptual understanding as they reveal the relationships between number partners, patterns, and operations within addition and subtraction (Fuson, 2019). The literature revealed that another common struggle early elementary students have is articulating and communicating their thoughts using mathematical language which also aligned with my second grade students. Relatable real-world contexts can create personal connections to help develop these abilities (Carpenter, Fennema, Franke, & Empson, 2015).

With these observations, and further research, I decided to create digital mathematics tasks using visual Number Talks presented with Google Slides. To stay true to the idea of student-centered math activities, I had students take pictures of visual patterns around school that could spark addition or subtraction Number Talks. Their images were used to create the project. This resource was developed to be used in my second grade classroom in the fall to reignite number sense and fluency skills but could also be used throughout the year to spark engagement. Although intended for second grade, the project could be used in a first or third grade classroom as well.

Implications

I believe the most significant implication of this project relates to the structure of what a math curriculum can be and should include. Number Talks create new possibilities and push the boundaries of how we organization, arrange, and deliver math tasks to students. Number Talks shift focus from methods such as the gradual release of responsibility or drill and repetition. Instead, Number Talks create student-centered learning experiences where mathematical knowledge is built from current understandings and developed through discussions and connections of various strategies presented. As mentioned in the previous literature review and project description sections, Number Talks align with recent literature and research that support this student-centered teaching and learning shift in math instruction.

Limitations

The presented project had some limitations mainly when considering the forms of assessment. First, a small, not diverse, sample size was used for the implementation of the project. Twenty-five students created the population for the implementation of this project, 84% of them identifying as Caucasion. Another limitation correlates to the possible differences in home environments and unpredictable life events of participants. These differences and events could have impacted participation and engagement levels in Number Talks and overall growth within number sense, fluency, and automaticity. In assessing number sense, fluency, and automaticity, computer-based assessments in FastBridge were considered. This is important to mention in limitations as these computer-based measurements of success may skew actual growth due to various reasons including: fatigue, sickness, test anxiety, reading abilities, and engagement levels at the time of the assessment. An additional limitation is that other contributing learning activities relating to possible influences on number sense, fluency, and automaticity were not examined. Daily math lessons, games, and 3-Act Math Tasks were also implemented within the math curriculum.

Summary

This chapter was a reflection of the personal and academic learnings that unfolded throughout the process of creating this capstone project. To begin, a personal reflection discussed the learning opportunities this capstone project created and my knowledge of Number Talks in correlation to the development of the essential question: *How can implementation of Number Talks support elements of number sense and* *fluency, including automaticity, for elementary students*? Next, a review of the literature was provided that revealed significant findings corresponding to elements in the essential question: number sense, fluency, automaticity, and Number Talks. This was followed by a project description focusing on the rationale and format developed, again relating to elements in the essential question. Next, implications to math curriculums including teaching practices and types of learning activities are offered. Finally, some limitations associated with assessments of the project are provided.

I have been a part of various discussions that focused on incorporating math teaching practices and learning activities that stem from a student-centered or constructivist approach, an approach providing opportunities for students to get actively involved in creating, developing, exploring, and building upon their mathematical knowledge. Aligning with these discussions, I have noticed a growing online math community of experts that are not affiliated with a curriculum but rather offer math activities related to these types of student-centered learning experiences. In the literature review process, I believe research supports this movement in creating a variety of new and engaging math tasks that better meet the needs of students and support a deeper understanding of mathematics.

After reviewing literature and creating this capstone project, I would claim that Number Talks are one of these math activities. Therefore, in considering a response to the essential question: *How can implementation of Number Talks support elements of number sense and fluency, including automaticity, for elementary students*? I would argue that the structure and delivery of Number Talks encompass all that current research advocates in supporting the necessary skills of number sense, fluency, and automaticity for continued success in mathematics. Due to this, I claim the pure implementation of Number Talks will support elements of number sense and fluency, including automaticity in whatever form they take, visual or other.

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APPENDICES

Appendix A

Visual Number Talks Instructional Guide

A Number Talk is a 10-15 minute whole class conversation that allows students to share mental math strategies and reasoning. Teachers intentionally select problems that invite a variety of solutions. Teachers scribe strategies and facilitate discussions to include different ways of thinking, justify reasoning, and connect strategies to support metacognition.

<table>
<tr><td>Teacher presents the selected problem from Visual Number Talks Google slides
Read the questions on the slide, “How may ____ do you see?” “How do you see them?”</td></tr>
<tr><td>Teacher provides wait time until most students have non verbally indicated they are ready
Fist to chest → still thinking
Thumb up → one strategy
Each additional finger up indicates another strategy</td></tr>
<tr><td>Students share strategies
Read the question on the slide, “How many ____ do you see?”
Record all responses, correct and incorrect</td></tr>
<tr><td>Students share strategies and reasoning
Read the question on the slide, “How do you see them?”
Ask student which answer they are defending
Scribe strategy (steps below are specific to visual Number Talks)
Draw strategy/pattern described (link below offers example done by Boaler) https://www.youcubed.org/resources/jo-teaching-visual-dot-card-number-talk/
Write equation below pattern drawing as you go (note: this step is not shown in the video example by Boaler but helps to build conceptual understandings)</td></tr>
<tr><td>Teacher facilitates discussion using probing questions as strategies are shared and scribed
Can you tell me more about why you ____?
Can someone explain ____’s strategy in their own words?
Does anyone have any questions for ____?
Why does ____’s strategy make sense?
I really appreciate how you questioned [and/or responded to] ____’s sharing/thinking.
Did anyone see it a different way?</td></tr>
<tr><td>Teacher offers closing turn and talk prompts
Which two strategies were similar and why?
Were any strategies confusing and why?
Which strategy was the most interesting and why?</td></tr>
</table>

Appendix B

Visual Number Talk Strategy Checklist: Front and Back

Visual Number Talk Strategy Checklist

		Strategies Used					
Date	Number Talk slide #	counting on / counting down	Part-part-whole	use of doubles	compensation	skip counting	other

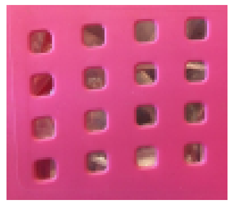
		Notes / Observations
Date	Number Talk slide #	

Appendix C

Figure C1: Visual Number Talk Assessment Forms

NAME:____ **DATE:__________________**

How many squares do you see and how do you see them? Show each way in a different box.



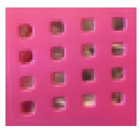
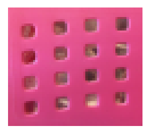
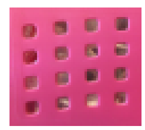
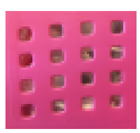
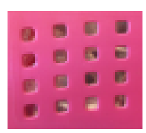
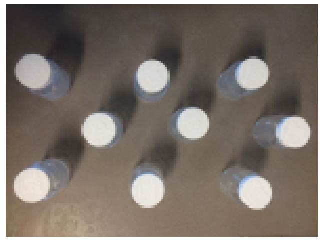
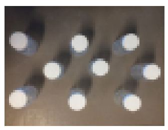
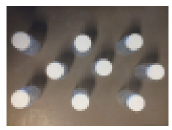
1. 	**2.** 	**3.** 
4. 	**5.** 	****If you can think of more than 5 strategies, continue to show me on the back of the paper until I tell you your time is up! Thank you :)**

Figure C2: Visual Number Talk Assessment Forms

NAME:_______________________________________ **DATE:**__________________

How many bottles do you see and how do you see them? Show each way in a different box.



1. 	**2.** 	**3.** 
4. 	**5.** 	****If you can think of more than 5 strategies, continue to show me on the back of the paper until I tell you your time is up! Thank you :)**