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Math in Nature: Expanding Fourth-Grade Students' Mathematics Knowledge through Nature-Based Learning

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by

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DEDICATION

To Norm. Thank you for your gift of The Lake. You taught me many lessons, the most important being a love of nature, the power of getting one's hands dirty, and a commitment to lifelong learning. May this work continue your legacy by inspiring the next generation to follow in your footsteps.

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CHAPTER ONE

Introduction

Overview

Nature-based learning is a growing topic of interest in the field of education. Families and educators are noticing the increasing need for children to spend time outdoors, as well as their need to engage in productive movement. Following multiple years of COVID-19-related quarantines, online learning, and social distancing, it is clearer now more than ever that children need movement, fresh air, sunshine, and community. Many caretakers turned to their own outdoor learning options during the pandemic. Some used outdoor learning spaces, and others traveled to local parks and forests. Each of these solutions are forms of nature-based learning, where the natural environment is utilized as both content and context for education.

As schools have returned to their new normal, some have opted to integrate nature-based learning into their practice. How can schools integrate quality educational practices they already engage into this approach? As a fourth-grade classroom teacher at a school that has shifted toward outdoor and nature-based learning, the specific question that I ask in this capstone project is: *How can fourth-grade mathematics instruction expand student knowledge by utilizing a nature-based approach?* I have created a digital toolkit to equip and empower educators to teach fourth-grade mathematics with both a standards- and nature-based approach. This toolkit is designed to serve any educator with access to a natural space, not exclusively those teaching in outdoor-focused or nature-based settings.

In this chapter, I describe the personal and professional experiences that have led me to pursue this topic. I also present the rationale for creating a toolkit of resources for providing fourth-grade math instruction in a nature-based manner.

Context

As a child, I was homeschooled for many years, and my parents capitalized on our flexible schedule by prioritizing time in nature. My siblings and I went on nature walks at nearby city parks and always enjoyed exploring the woods behind my grandparents' house. We would make forts, play pretend, and search for our new favorite tree on any given day. I have fond memories of annual trips to the shores of Lake Superior, where we would complete schoolwork on the lake's rocky shoreline. When at home, we would read books while laying on the trampoline and listen to history lessons while sunbathing on the driveway.

As we grew older, we participated in monthly courses run by naturalists at a nearby outdoor learning center. I learned about predator-prey relationships by playing games in the woods with my friends, and memorized certain animal tracks and scat types while hiking in the snow. Though I did not know it at the time, these courses were my first introduction to environmental education. These naturalists quickly became my heroes, and I eagerly found ways to volunteer alongside them as a middle schooler. I loved watching young children discover the joy of climbing over downed trees or spotting a woodpecker perched above their heads. Although I had no plans at the time to work as an environmental educator, these experiences were pivotal to my pursuit of an elementary education degree.

Student Teaching

As a student teacher, I was placed at an environmental magnet elementary school. I saw firsthand the power of integrating outdoor learning with core instruction. Students practiced their fourth-grade graphing skills while recording their pollinator observations in the garden behind the school. They enjoyed music class around a firepit at the nature center across the street. Students were fully engaged in their learning, to a degree that I had never seen in classrooms that only spent time inside their own four walls. Though I did not know it at the time, I was witnessing nature-based instruction in practice.

While at this school, I discovered the magic of walking through a forest with students and viewing the woods through their awe-filled perspectives. It was powerful to watch classroom teachers utilize their passion and creativity to create units that engaged their students by exceeding their baseline expectations. My year at this school inspired me to pursue the same level of passion and integration in my own teaching career. However, after graduation, I found myself in a very traditional classroom setting with little to no access to outdoor green space.

Classroom Teaching

In my first few years of classroom teaching, my passion for teaching students outdoors took a backseat while I found my way as a new teacher, developing my own system of classroom management, and adjusting to new curriculum. Whenever I did try to bring my class outdoors, I faced a great deal of pushback. Classroom teachers were required to obtain prior permission in order to simply take a walk around the building as a class, and we only had a few small patches of grass aside from the field used for physical education. I eventually grew tired of jumping through hoops, and instead focused

intensely on providing my fifth graders with the highest quality education of which I was capable, even if it had to happen solely indoors. I integrated technology, found exciting and engaging ways to meet Minnesota state standards, and built meaningful relationships with my students and colleagues throughout those first few years.

During the 2020-2021 school year, however, COVID-19 became an overwhelming presence in our lives. Instead of insisting *against* outdoor time, our administration strongly requested that teachers bring their students outside as much as possible. I jumped at the chance, but found it difficult to teach all subjects outdoors, especially after tailoring such exciting lessons to an indoor setting. We found that our devices would not work outdoors, and none of the mathematics lessons in our district-mandated curriculum translated well to our new setting. My students struggled to adjust to a new, unfamiliar space, and we experienced a steep learning curve when it came to handling bugs, heat, rain, and cold.

Eventually, my outdoor lessons began to consist of only quiet reading time, writing lessons, and science, depending on the unit. I was frustrated not being able to provide as much outdoor time to my students as I had hoped, but was constrained by time and resources. By the end of that school year, I began to look for a new teaching opportunity that would allow me more space, time, and resources to teach students in a nature-based manner.

Nature-Based Teaching

After a short period of searching, I found myself applying for (and later accepting) a classroom teaching position at a small and relatively new charter school in eastern Minnesota. This school prioritizes outdoor, environmental, nature- and

place-based education. Its campus consists of many old buildings from a former campsite, so students must utilize a system of outdoor pathways to move between buildings. We have access to miles of hiking trails, multiple nearby lakes, and each class has a designated outdoor classroom space.

This school was a far cry from my previous setting, but I still found myself struggling to teach some subjects in the outdoor space. I loved teaching my fourth-graders reading, writing, science, art, music, and social-emotional skills outdoors! In fact, it started to feel quite natural to create a nature-based poetry unit and discuss animal adaptations while exploring our wooded campus. However, teaching fourth-grade math while utilizing our forest surroundings felt much more difficult. I could set up my whiteboard easel and hand my students clipboards, but I knew there had to be a better option than simply sitting outside while conducting the same mathematics lesson I would have taught indoors. I wanted to integrate my mathematics instruction with the unique benefits of our outdoor space, and knew there must be a better way.

However, when looking for ideas, I could only find a handful of lessons published on blogs written by homeschool parents and forest preschool teachers. These ideas were fun, hands-on, and exactly what I was looking for, but were often geared toward younger students. Although I knew that my students and I needed something different, I had neither the time nor the resources to create nature-based mathematics activities by myself in the midst of an already busy school year.

In conversation with my co-workers, I found that almost every other teacher was facing the same problem. We had been learning, via trial and error, what strategies did and definitely did *not* work with our students, but none of our progress had been

research-based. Luckily for us, in the fall of 2022, our school was selected to participate in a series of nature-based education workshops led by a number of experts from the fields of education, psychology, and natural sciences. These workshops opened my eyes to the approach of nature-based learning, and the incredible benefits that it provides to learners. Finally, I found an answer to my dilemma!

Rationale

Unfortunately, there is still a lack of nature-based resources for upper-elementary educators, especially regarding mathematics. Furthermore, the resources that *do* exist are not aligned with the upcoming generation of Minnesota mathematics standards, which will be implemented within the next five years. That is why I have chosen this project as my capstone: to provide fourth-grade teachers with a toolkit of research-based, developmentally-minded, and nature-based learning activities that will align with the most updated Minnesota mathematics standards.

Research shows that children benefit from time in nature. Exposure to sunlight and dirt can boost children's immune systems, reduce stress, and provide more restful sleep (Mead, 2008; National Wildlife Federation [NWF], 2012; Dettweiler et al., 2017). Social skills such as conflict resolution and collaboration develop naturally (AIR, 2005). Additionally, time in nature benefits students' academic learning. Sustained attention, increased content retention, and increased enjoyment while learning are all benefits of nature-based instruction (Szczytko et al., 2018; Francis Norwood et al., 2021).

While many educators are not yet aware of the many benefits of nature-based learning, those who are often do not have access to outdoor learning spaces. My goal in creating this digital toolkit is to provide these educators with ideas and resources to help

them implement nature-based learning practices into their instruction, regardless of their physical spaces. Though less common, there are also classroom teachers who *do* have access to outdoor learning spaces but, like myself, don't know how to fully utilize those spaces for nature-based learning.

This digital toolkit will provide educators with a collection of quality nature-based resources and learning activities that are aligned with the newest generation of Minnesota K-12 Academic Standards in Mathematics that can serve as a starting point in their nature-based journey.

Summary

My personal experiences as a homeschooled child exploring the woods with my siblings and naturalists planted the seeds of a love for nature and learning outdoors. I have been privileged to learn from and teach alongside excellent educators who have seamlessly integrated content learning into an outdoor environment, and have worked with colleagues to create the type of educational experiences that we believe our students deserve. I have created this capstone project to equip and empower more educators to teach their students mathematics through a nature-based approach without sacrificing the quality educational practices that they already utilize.

` In the following chapters, I present a detailed review of the literature regarding fourth-grade development, mathematics instruction, and the merits of nature-based learning. I also outline the specifics of my capstone project, a digital toolkit that will include nature-based learning activities aligning with the next generation of Minnesota mathematics standards. Finally, I reflect on the process of researching, writing, and creating this capstone and project.

CHAPTER TWO

Literature Review

Overview

In seeking an answer to the question *How can fourth-grade mathematics instruction expand student knowledge by utilizing a nature-based approach?* one must understand how fourth-graders learn, the current best practices in mathematics education, and the benefits of nature-based learning. This information is synthesized to create a toolkit of high quality, developmentally appropriate, nature-based mathematics learning activities.

This literature review showcases the cognitive, social/emotional, and physical developmental stages of a common fourth-grader, as well as common diagnoses that may impact student learning. It also explores the current best practices of mathematics education in upper elementary as evidenced in contemporary research. The current and upcoming generations of the Minnesota Academic Standards are addressed. Finally, this literature review showcases the many benefits of nature-based learning: physical, social/emotional, and academic.

Portrait of a Fourth-Grader

Fourth-graders, considered to be in the middle childhood stage of development, experience significant neurological, physical, cognitive, social, and emotional changes. These development changes occur rapidly and often simultaneously, resulting in a tumultuous stage of life. Educators working with fourth-graders must be informed on these changes in order to better understand and instruct their students.

Middle childhood, often defined as ages 7-12, is a period of significant growth and change. Crucial social skills like identity formation and increased independence occur during this period (Tennessee Commission on Children and Youth [TCCY], 2018d). Brain development is also an incredibly important aspect of this stage of life. Children in middle childhood experience growth in their prefrontal cortex, right and left hemispheres, and myelination of pathways within the brain (Lally & Valentine-French, 2019). For many children, puberty begins within middle childhood, bringing along with it many physical changes. This section of the literature review displays a portrait of an average fourth-grader, age 10, and the research associated with the surrounding age range.

Physical Development

Fourth-grade students' significant physical developmental changes mean that they are able to engage in sustained outdoor and academic activities for a longer duration than in previous years. The most significant aspect of physical development in middle childhood is the onset of puberty. Puberty begins between the ages of 8-15 for most children, and is accompanied by a significant physical growth spurt (Collins & Shonkoff, 1984). This growth spurt can result in temporary clumsiness, but can also equip children with the strength needed to engage in more extended or strenuous activity.

Aside from puberty, middle childhood contains many other forms of growth and development. Children's brains develop to their adult size by age 7, but the prefrontal cortex continues to develop throughout middle childhood (TCCY, 2018a). The continued development of the prefrontal cortex aids one's attention span (Lazzara, 2020). Additionally, the brain's right and left hemispheres increase in coordination, which in

turn improves physical coordination ((Lally & Valentine-French, 2019; Lazzara, 2020). Within the brain, myelination occurs, strengthening neural pathways and increasing reaction time as well as memory capacity (Lazzara, 2020). Not only do neurological structures develop during this stage, so do physical structures. Fine and gross motor skills improve, allowing children to engage in activities like cutting their own fingernails (fine motor) and riding a bike (gross motor) (TCCY, 2018c). Children in middle childhood also experience gains in both physical stamina as well as academic stamina (TCCY, 2018c). For example, students in fourth-grade are capable of longer outdoor hikes as well as engaging in independent reading or problem solving for much longer stretches of time than in previous grades. These developmental changes indicate that students in the fourth-grade are a prime audience for outdoor education initiatives.

In light of the significant physical development occurring during middle childhood, educators and caretakers must be purposeful in the choices that they make for the children in their lives. Children in middle childhood should engage in regular physical activity as they continue to develop their musculoskeletal system (TCCY, 2018c). Physical activity can also mitigate the risk of obesity, which increases at this age. Once a child becomes obese, they are at a greater risk of physical injury, and may have more difficulty avoiding obesity in adulthood (Lazzara, 2020). Obesity may also increase the risk of cognitive decline later in life (Lally & Valentine-French, 2019). Enjoying a healthy diet is also important at this age, not only to avoid obesity, but also to properly fuel one's physical growth and development (TCCY, 2018c).

Children in middle childhood should engage in as little screen time as possible. Excessive screen time can lead to trouble sleeping, eating, and difficulties with attention

(TCCY, 2018b). The American Academy of Pediatrics (AAP) states that children spend an average of seven hours per day looking at screens (2021). The AAP recommends that families create a plan outlining how they will balance screen time with adequate sleep, outside time, and social time, aiming to decrease screen time per day (2021). In addition to less screen time, children in middle childhood should partake in 9-12 hours of sleep each night (Centers for Disease Control and Prevention [CDC], 2021b). This extended sleeping period will aid in physical development and emotional regulation.

Cognitive Development

While children in middle childhood are undergoing physical and neural development, their cognitive abilities are also developing. According to Jean Piaget's Theory of Cognitive Development, children ages 7-11 are in the Concrete Operational stage of development (Lazzara, 2020). In this stage of development, children are capable of understanding concrete events and logical analogies. They can use logic to solve problems related to their lived experience and the physical world, but struggle to solve abstract and hypothetical questions. Children at this age engage in inductive reasoning, or thinking that the rest of the world must reflect their specific lived experiences (Lally & Valentine-French, 2019). Piaget believed that children in middle childhood are developing their schema: a mental system through which individuals classify and understand new information and experiences (Lazzara, 2020).

Aside from Piaget's theories of development, researchers agree that children in middle childhood, which includes fourth-grade, grow in many cognitive abilities. Their critical thinking capacity increases, allowing them to engage in more complex problem-solving in academics and their personal lives (TCCY, 2018a). In addition to

critical thinking, children in middle childhood are also developing their abstract thinking abilities. Abstract thought allows children to participate in open-ended activities and projects, which are especially enjoyable and interesting to children in middle childhood (TCCY, 2018a). As mentioned previously, the continued development of the child's prefrontal cortex allows them a greater attention span in personal and academic contexts (CDC, 2021).

In middle childhood, a child's vocabulary continues to develop. By fifth grade, about age 11, the average child's vocabulary has grown to 40,000 words, adding around 20 new words a day (Lazzara, 2020). Their understanding of language becomes more sophisticated and nuanced, as they connect new vocabulary to previously known concepts. Children in middle childhood delight in wordplay, jokes, and puns, as they continue to explore their newly acquired lexicon (Lazzara, 2020).

As children at this age continue to discover their world and attempt to better understand their individual perspectives and point of view, they begin to ask more and more questions (TCCY, 2018a). They add their new learning to prior knowledge via schema, or mental categories (Lazzara, 2020). A widely-regarded theory regarding information storage is the Information Processing Theory. This theory posits that individuals have a sensory memory, a working memory, and a long-term memory (Lally & Valentine-French, 2019). Sensory input is first filtered through one's sensory memory, where information is subconsciously identified as meaningful or insignificant. Once input is determined to be meaningful, it passes into the working memory, where only a few pieces of information can be held. Information in the working, or short-term, memory must be connected to meaningful prior knowledge in order to be stored in one's long-term

memory. As children in middle childhood are exposed to more experiences and knowledge, they develop more connection points for new information storage (Lazzara, 2020). By comparing new information to past information, children at this age develop a better understanding of how they are performing in certain tasks and the relative level of difficulty of potential tasks. With this information, they can practice prioritizing tasks based on difficulty, importance, and time required. This process is a form of metacognition- thinking about thinking- and children will continue to improve on these skills over time (Lally & Valentine-French, 2019).

Differences in Childhood Cognitive Development. These systems of language development, information processing, and making connections sometimes work differently for different children. When these differences in function become significant enough to impact academic or social performance, children may be evaluated for specific diagnoses in order to determine the best services and supports for their individual experiences. Two common diagnoses school children receive are those of Attention-Deficit/Hyperactivity Disorder (ADHD) and Autism Spectrum Disorder (ASD). A 2016 study by Danielson et al. found that 7.7% of children ages 4-11 were diagnosed with ADHD, with the percentage rising to 13.5% at ages 12-17. Less prevalent, though still significant, is the diagnosis of ASD: As of 2018, only about 2.3% of school aged children are diagnosed with ASD (Maenner et al., 2021). Both diagnoses and their impact on learning are discussed below.

According to the CDC, “People with ADHD show a persistent pattern of inattention and/or hyperactivity-impulsivity that interferes with functioning or development” (2021c). Children with ADHD tend to experience difficulty paying

attention, inhibiting outbursts, and screening out distractions (Lazzara, 2020). Their brains work overtime to pay attention to all sensory input, leading to overstimulation, fatigue, and difficulty focusing on any one thing. Some studies suggest that ADHD is related to frontal lobe underdevelopment- the frontal lobe controls executive function, attention, planning, impulse control, motivation, and decision making. Each of these aspects of cognition can be difficult for those with ADHD (Lally & Valentine-French, 2019; Lazzara, 2020). Depending on the symptoms presented, three types of ADHD can occur: predominantly inattentive presentation, predominantly hyperactive-impulsive presentation, or combined presentation (CDC, 2021c). ADHD is often treated with Cognitive Behavioral Therapy or stimulant medications (Lazzara, 2020).

Autism Spectrum Disorder (ASD) is "a neurological and developmental disorder that affects how people interact with others, communicate, learn, and behave" (U.S. Department of Health and Human Services [HHS], 2022, para 1). ASD is considered a spectrum disorder due to the wide range of symptoms and variations in the severity of those symptoms that individuals experience (HHS, 2022). People with ASD typically have difficulty with social interactions and communication. They also tend to have restricted interests, sensitivity to stimuli, and repetitive behaviors (HHS, 2022; Lazzara, 2020). According to a 2018 CDC estimate, 1 out of 59 children in the US are diagnosed with ASD (Lazzara, 2020). Many children are not identified with an ASD diagnosis until school age, even though symptoms typically present before the age of three (CDC, 2022; Lazzara, 2020). The exact cause of ASD is not yet known, although studies suggest that both genetics and environment play a role (HHS, 2022). ASD is found in all racial and ethnic groups but is thought to be more common in boys than girls (Lazzara, 2020). Due

to the wide range of symptoms and severity within ASD, there is no one-size-fits-all treatment. Treatments commonly used include behavioral therapy, occupational therapy, speech and language therapy, explicit educational support, and social-relational supports like social stories and social skills groups (CDC, 2022).

Social/Emotional Development

In addition to physical and cognitive development, children in middle childhood undergo significant social and emotional development. Children at this age are highly motivated and influenced by peer relationships, using feedback from their peers to shape and determine their own identity (Lazzara, 2020). Body image, self-concept, and self-confidence continue to develop and strengthen during this stage as well.

Peer Relationships. According to Eriksson's theory of Psychosocial Development, children ages 7-11 face the developmental task of industry versus inferiority (Lazzara, 2020). Children in this stage are actively comparing themselves with their peers, working to determine how they measure up. If a child finds that they are comparable or superior to their peers in sports, schoolwork, social skills, or other skills, they will develop a sense of self-confidence and pride. However, children who do not find themselves comparable to peers will develop a sense of inferiority, which may last into adulthood (Lazzara, 2020). Aside from the act of comparison, children in this stage are very industrious and motivated, exploring their abilities and seeking authentic feedback from peers and adults. This feedback informs children's self-concept, leading to a modest and realistic understanding of one's skills (Lazzara, 2020).

The CDC states that children in middle childhood explore their independence from their families and place more importance on social relationships (2021b). Spending

more time with peers can aid children in developing social skills like problem-solving, compromising, and conflict resolution (TCCY, 2018d). However, more frequent peer interactions can also bring peer pressure and a higher likelihood of risky behaviors (CDC, 2021b).

Children in middle childhood begin to choose friends based on common interests, character traits, and humor, instead of simply befriending who is nearby as they did when younger (TCCY, 2018d). Within these friendships, children continue to develop their social language skills through long conversations and silly chatter (TCCY, 2018d). At this age, children long to be involved in groups and clubs, uniting over common interests and attributes (TCCY, 2018d). As a result of these increased social interactions, children in middle childhood continue to develop their sense of fairness, right versus wrong, empathy, and compassion: all of which will continue to serve them into adulthood (TCCY, 2018d; CDC, 2021b).

Interacting with peers informs children on how to act, what to wear, what to say, and who to listen to (Lazzara, 2020). At this age, peers serve as a judge of one's worth, competence, and attractiveness (Lazzara, 2020). Unfortunately, this desire for peer affirmation can result in comparison and competition (TCCY, 2018d). Children must learn how to become a good sport and a graceful loser amidst this desire for competition (TCCY, 2018d).

Self-Concept. In addition to the development of peer relationships, children in middle childhood experience development of their self-concept during these years. Self-concept is one's understanding and perspective of their own worth, skills, and capabilities. In middle childhood, a child's self-concept begins shifting from viewing

themself as the biggest, bravest, and best to a more realistic awareness of their limitations and strengths (Lally & Valentine-French, 2019). Children at this age are self-critical and care deeply about what peers and adults think (TCCY, 2018d). Messages from their peers and important adults directly influence one's self-concept, whether positively or negatively (Lally & Valentine-French, 2019). In light of this influence, adults who interact with children ages 7-12 should encourage them to explore their abilities and provide authentic feedback, as well as encouragement. These adults should keep in mind, however, that children in middle childhood can be sensitive, dramatic, and experience strong mood swings due to their changing hormones (TCCY, 2018d). Children at this age can be easily discouraged and more bashful, potentially leading to a hesitancy to try new things or fear of failure. Children should be encouraged and empowered to take on more responsibility in the home and at school (Lazarra, 2020).

Summary: Portrait of a Fourth-Grader

Fourth-graders, right in the midst of the middle childhood stage, experience an immense amount of change and development before, during, and after the academic year. These children undergo neurological, physical, cognitive, social, and emotional changes simultaneously. Educators working with fourth-graders must be aware of these changes, as well as their implications, in order to best serve and educate their students. When developing instruction and curriculum for fourth-graders, their increased physical stamina, newly developed critical thinking skills, and desire for peer relationships and adult support should all be considered. These attributes suggest that a highly interactive, complex, and physically engaging framework be utilized.

The following section of this literature review details commonly agreed-upon best practices in mathematics education. When combined with knowledge of the physical, cognitive, and socio-emotional status of a fourth-grader, this information can prepare educators to effectively support their students.

Best Practices in Mathematics Education

Upper elementary, which at my school is considered to include grades 3-5, is a stage of education upon which significant mathematical foundations are being laid. Students learn the basic concepts of fractions, develop a deeper understanding of whole numbers, and explore more complex problems utilizing the four mathematical operations: addition, subtraction, division, and multiplication. Effective mathematics instruction during these years is key, as the skills developed in upper elementary are built upon and referenced throughout the rest of a student's formal education. This section will outline the current state of U.S. elementary mathematics education, emphasizing both the important content that must be covered as well as the best pedagogical practices as agreed upon by experts in the field.

Elementary Mathematics Content

A 2008 report prepared for the U.S. Department of Education by the National Mathematics Advisory Panel [NMAP], stated that educators need to better prepare students for algebra before they reach high school (U.S. Department of Education [USDE]). Across the board, students in the United States struggle with this important strand of mathematics, an issue that the NMAP suggests can be prevented with focused K-8 instruction (USDE, 2008). The report stated that educators' main goal for students in the United States should be to develop a comprehensive understanding of fractions in

grades K-8. In order to achieve this goal, students need to be educated in whole numbers, geometry, and measurement (USDE, 2008). Other researchers present more specific guidelines, suggesting that mathematics instruction in grades K-5 should be focused on an in-depth study of whole numbers, while instruction in grades 4-8 should address rational numbers such as fractions and decimals (Gersten et al., 2009). Fourth-grade sits at the threshold between these two stages of instruction and therefore serves as an introductory year to rational numbers as well as a culmination of whole number instruction.

Upper elementary mathematics instruction should also include the explicit study of the underlying structures of word problems (Gersten et al., 2009). In order to confidently complete word problems, students need to know the vocabulary, question types, and goals of questions they will encounter. One common word problem type is a change question, in which an amount is changing in some way. For example, *Jennifer has 35 jelly beans. If she gives 10 jelly beans to her brother, how many will she have left?* Another common word problem type is a comparison problem. For example, *Gertrude has 2½ apples, and Brian has 3¼ apples. Who has more apples?* Common vocabulary terms that upper elementary students must become familiar with include the standard outcome words for each operation: sum, product, difference, and quotient; as well as key terms and phrases: each, per, fewer, more than, left over, together, combine, equal groups, and share.

Students in upper elementary grades should develop strong fact fluency, which is the ability to quickly recall the products of single-digit multiplication equations (Gersten et al., 2009). This fluency is instrumental in overall math achievement, as equations

utilizing fractions, decimals, measurement, multi-digit multiplication, and division all require some level of single-digit multiplication.

Another skill that upper elementary mathematics instructors should explicitly introduce is the appropriate use of visual representations of abstract mathematical concepts. Visual representations include manipulatives, drawn models, and concrete models. These models provide students with concrete ways to interact with the problem that they are solving. The goal of teaching visual representations is for students to become familiar with the concrete, tangible representations so that they eventually can create their own mental models, allowing them to connect their content knowledge with the abstract mathematical symbols that most equations utilize (Gersten et al., 2009). However, these visual models must be taught clearly, and students must use them accurately. Boonen et al. found that students who create accurate visual-schematic representations are more likely to solve word problems correctly when compared to peers who do not use visual representations (2014). Additionally, students who used inaccurate visual models and representations were much less likely to solve world problems correctly (Boonen et al., 2014).

Minnesota Academic Standards. The Minnesota Department of Education (MDE) publishes academic standards of all content areas for each grade level K-12 in an effort to implement consistent learning expectations state-wide (Minnesota Department of Education [MDE], 2022a). These standards are research-based and vertically aligned to prepare all students for success after graduation. Standards like these are intended to guide educators and schools in their instruction, ensuring that all children, regardless of their socioeconomic status, school setting, or location, receive a quality education. These

standards are reviewed and revised on a ten year cycle (MDE, 2022a). MDE is currently reviewing and revising their K-12 mathematics standards, with intentions of implementing the new set of benchmarks and standards in the next few years (Minnesota Department of Education [MDE], 2022b). For the purpose of this literature review and capstone project, I review the commonalities and significant changes between Minnesota's current mathematics standards, which were adopted in 2007, and the most recent draft of the revised mathematics standards.

Minnesota's current 4th grade mathematics standards consist of four overarching strands: Number and Operation, Algebra, Geometry and Measurement, and Data Analysis (Minnesota Department of Education [MDE], 2007). Within these strands lie six standards, and under these standards there are a total of 27 benchmarks. These benchmarks provide detailed skills that students must acquire or tasks they should complete during their fourth-grade year. The newest draft of mathematics standards from MDE restructures this format significantly, forgoing strands in favor of an expanded list of anchor standards. There are a total of 11 anchor standards, with 72 benchmarks (MDE, 2022c). These benchmarks are much more specific than those in the 2007 standards, and notably include the language of traditionally softer skills, such as compare and contrast, justify, and discuss. A number of standards regarding the Dakota and Anishinaabe Tribal Nations (the two largest Indigenous people groups in Minnesota) are also included (MDE, 2022c).

Although the format differs significantly between these two editions of the standards, the general skills that fourth-graders are expected to learn have not changed. Minnesota's current standards expect fourth-graders to utilize their knowledge of place

value and the base ten system to solve multiplication, division, addition, and subtraction problems (MDE, 2007). Students should also be able to engage in solving real-world word problems requiring multiple steps and multiple operations (MDE, 2007). In the newest version of Minnesota's revised mathematics standards, skills such as decomposing numbers and representing one's thinking using a variety of models, are added (MDE, 2022c).

Fractions and decimals are also prominently featured in Minnesota's current and revised academic standards. In the current standards, students should be able to represent fractions and decimals using a variety of models (¼, a quarter, one-fourth, shown in a circle, shown in a fraction bar, shown in a pile of items, etc.) (MDE, 2007). Utilizing fractions and decimals in real world word problems also appear in this portion of Minnesota's current standards (MDE, 2007). In the revised standards, students will additionally be asked to accurately draw representations of fractions and decimals, as well as utilize mental visualizations to estimate the sums and differences of fractions (MDE, 2022c).

In addition, fourth-grade students are expected to represent and interpret data in a variety of graphs and tables. Minnesota's current standards only refer to data and graphing in a singular standard, asking that students display and understand a variety of graphs (MDE, 2007). In the revised standards, however, a total of nine standards are devoted to data and graphing (MDE, 2022c). These standards include classifying probability, selecting the proper representation for a data set, creatively presenting data, critically analyzing data utilizing graphs and tables, and making predictions based on data (MDE, 2022c). Further, students are asked to select, design, and create a data collection

to answer a statistical question, then interpret their data to support or disprove a claim (MDE, 2022c).

Geometry standards play a large role in Minnesotas' current standards. Fourth-grade students must describe, classify, and draw quadrilaterals and rectangles, as well as recognizing these shapes in a variety of contexts (MDE, 2007). Students should also be able to decompose shapes into rectangles in order to measure the area and perimeter of said shapes (MDE, 2007). Additionally, students learn how to transform shapes utilizing translations, rotations, and reflections, while recognizing that congruence still remains even after a transformation has been completed (MDE, 2007). In the revised version of Minnesota's standards, students are additionally tasked with calculating the volume of a cube, as well as visualizing different views of multiple 3D shapes (MDE, 2002c). Measurement standards appear in both the current and revised versions of Minnesota's academic standards, emphasizing the measurement of distance and angles using tools like rulers and protractors (MDE, 2007; MDE, 2002c).

The newest draft of Minnesota's mathematics standards includes two new concepts: financial literacy and probability (MDE, 2002c). The probability benchmarks cover the concepts of impossible, certain, probable, not probable, likely, unlikely and equally likely. The financial literacy benchmarks encompass credit, interest, decision-making, and the purposes of financial institutions. Students are also expected to make change up to $20 (MDE, 2022c).

Each of the Minnesota academic K-12 standards align with the research reviewed earlier in this chapter, and combined with the broader body of research on necessary

mathematics instruction, should inform fourth-grade Minnesota mathematics educators in their instructional practice.

Pedagogy

Along with research-based content expectations, educators must also consider the best pedagogical practices. The term *pedagogy* refers to the methods and practice of teaching, and can vary greatly depending on student age, educational context, and educator background. In their report prepared for the U.S. Department of Education, the NMAP concluded that mathematics instruction should neither be fully student-driven, nor should it be fully teacher-led (USDE, 2008). They suggest that a mix of both methods be employed, with educators serving as both a leader and a guide. This allows students to receive correct and factual instruction while also being given room to explore and problem solve independently (USDE, 2008).

Conceptual Thinking. The National Council of Teachers of Mathematics [NCTM] suggests that students who master skills utilizing a conceptual framework are better equipped to translate those skills into new kinds of tasks (NCTM, 2007a). Conceptual understanding is critical, especially when learning foundational skills such as those taught in fourth-grade (NCTM, 2015a). Another way that educators can support students' mathematics learning is to create connections to students' prior knowledge (NCTM, 2015a). Students are actively building and utilizing their mental schema during their elementary years, connecting new learning with previously stored information. Educators can facilitate students' connections between new and previous learning. Additionally, presenting mathematics equations and concepts in real-world contexts allows students to find meaning and purpose behind their work (USDE, 2008). NMAP's

report found that children who learned mathematics concepts in *real-world* contexts performed better on assessments that also utilized true-to-life scenarios.

However, the study's subjects did not demonstrate the same success on assessments that did not employ real-world contexts (USDE, 2008). Considering that elementary students will eventually need to utilize their mathematical skills in real-life situations, incorporating real-life scenarios into their education is a strategic move toward their future success. Students in upper elementary must be taught reasoning and problem-solving skills (NCTM, 2015a). These are forms of metacognition, which is thinking about one's own thinking. Determining whether or not an answer is reasonable is an important step in self-evaluation, and can lead to a more in-depth understanding of a problem. Students who can show evidence of their thinking as they problem-solve will be better equipped to adjust their work and find potential errors (NCTM, 2015a).

Classroom Culture. Educators who create a positive classroom culture set their students up for success, especially in regards to mathematics (NCTM, 2013). Creating a space where students can fail, take risks, and learn from their own mistakes allows for a more genuine learning experience. NCTM encourages educators to utilize discussion as an instructional tool, allowing student thinking to shape conversation (NCTM, 2013). Discussion can lead to students engaging in higher-level mathematical tasks, exploring incorrect solutions, and drawing connections between their thinking and that of a peer. Engaging in productive struggle with one's peers can create a supportive and productive learning environment (NCTM, 2015a). Additionally, developing a positive learning environment can support individual learners' mindsets toward mathematics. The NMAP's report for the U.S. Department of Education stated that when students believe that their

hard work makes them smarter, they tend to show greater persistence when solving difficult problems (USDE, 2008).

Formative Assessment. One way that educators can contribute to classroom culture, mindset, and student success is by practicing frequent formative assessments (Nagro et al., 2016). Formative assessments are informal checks of student progress, skill, or understanding and can occur in a variety of ways. Teachers may simply glance at a student's work to assess whether or not they need more support. Class discussions can also serve as formative assessments. Nagro et al. encourage educators to find ways for all students to respond in group conversations, especially students who are more reserved or who require more time to process (2016). Whole group hand signals, such as showing a 1-5 on fingers, can quickly and discreetly show teachers which students need more support, as well as provide students with an opportunity to self-evaluate (Nagro et al., 2016). Other suggestions include pre-made response cards or the use of small whiteboards to share answers (Nagro et al., 2016). Any type of formative assessment should result in constructive feedback to students, whether it be correcting an equation or engaging in a direct conversation to clarify one's thinking. Constructive feedback should be aimed at moving student learning forward into success, not perseverating on failure (NCTM, 2007b).

Instructional Technology. While instructional technology continues to grow in popularity, the evidence is quite varied on its use in the classroom (USDE, 2008). Instructional technologies can include those that are content-specific, like a website that reviews multiplication facts, or content-neutral, like a learning platform such as Google Classroom (NCTM, 2011). When reviewing current studies, the NMAP found

inconclusive evidence to support the benefit, harm, or impact of instructional technology (USDE, 2008). However, the NCTM states that strategic use of instructional technology can strengthen math instruction and achievement (NCTM, 2011). When it comes to calculator use, the evidence is also varied. NCTM has stated that calculators can aid in student enjoyment of mathematics, provide access to more complex problems, and promote higher levels of thinking (NCTM, 2015b). However, they caution that calculators should not be used in place of practicing paper and pencil methods for computing (NCTM, 2015b). On the other hand, the 2008 NMAP report stated that there was no conclusive evidence that calculator use made any difference in student success (USDE, 2008).

Summary: Best Practices in Mathematics Education

Quality mathematics education consists of developmentally appropriate and research-based content and pedagogy. Ensuring that fourth-graders obtain a strong conceptual understanding of essential mathematics content, such as rational numbers and fractions, will set them up for success. Utilizing visual aids, engaging students in productive struggle alongside their peers, and providing constructive feedback all support student learning and growth. Students benefit from real-world and complex mathematical problems, and can find great success when given the opportunity to connect their prior knowledge to new learning. The following section of this literature review addresses the benefits of nature-based learning.

Benefits of Nature-Based Learning

In the past few years, our world has become increasingly digital due to the impacts of COVID-19. Specifically in the world of education, teachers and students were

forced to use screens in order to engage with one another. I have personally watched the average fourth-grade student's abilities with digital technology skyrocket: excelling in typing skills, digital presentations, and navigating social interactions via video calls. However, many skills have decreased since the pandemic began. My 10-year-old students need handwriting lessons, a skill that is typically solidified much earlier in the educational experience. They also have had to re-learn how to interact with one another in person, including seemingly simple skills like turn-taking and playing with peers. Even pre-pandemic, our elementary-aged children were spending more and more time indoors. According to a 2013 publication from the National Wildlife Foundation, only 25% of children in the U.S. play outside daily, compared to 75% a generation ago. Aside from the obvious factor of technology, other reasons why children spend more time indoors than they once did include limited access to natural areas, unreliable transportation, and safety concerns (Larson et al., 2011).

Bringing children and adolescents outdoors, whether simply for playtime or to facilitate educational experiences, is beneficial for their physical health, social and emotional wellness, and academic success. The move toward nature-based learning and outdoor education settings is not simply an aesthetic trend, but a research-based response to the growing needs of this generation of students. Nature Based Learning (NBL) is an educational approach that utilizes a natural environment, or natural elements, as both the context and content for learning (Chawla, 2018). This approach includes formal, non-formal, and informal learning experiences. Formal learning experiences are those that occur in a school or school-like setting, where students learn grade-level content from an instructor. Non-formal learning experiences include nature center programs,

summer camps, or outdoor retreats; while informal learning consists of free exploration and play, often in a park or local forest (Chawla, 2018).

The nature-based learning approach provides a timely answer to the dilemmas that families and educators are currently facing. Children not only benefit from extended time in nature, more physical movement, and a strong sense of place, but also from learning within the rich real-world context of a natural environment. This section of the literature review showcases the research endorsing nature-based learning as an effective and uniquely beneficial method for formal content-area instruction at the elementary level.

Physical Benefits of Nature-Based Learning

Time outdoors can benefit children and adults in a wide variety of ways. Spending a minimum of two hours per week outside can improve one's overall health and wellbeing (White et al., 2019). This time may be accumulated over the course of the week, or experienced all at once, and does not need to consist of strenuous physical activity to be beneficial (White et al., 2019).

Movement and time outdoors can also aid children and adults in their emotional regulation. In a 2004 study conducted by Kuo and Faber Taylor, it was found that in both non-ADHD and ADHD diagnosed individuals, time outdoors significantly decreased common ADHD symptoms like inattention, impulsivity, and attention fatigue. When focusing strictly on children ages 7-12 with a formal ADHD diagnosis, results indicated that common ADHD symptoms were less severe than usual after spending time in green settings such as neighborhood parks or local forests (Kuo & Faber Taylor, 2004). Even after the children went indoors, their symptoms stayed at a decreased level for some time.

The study found that the after-effects of outdoor activities in green settings were more noticeable in comparison to similar activities in indoor settings or less natural outdoor spaces (Kuo & Faber Taylor, 2004). The authors wrote, “the greener a child’s typical play settings, the less severe his or her general symptoms” (p. 1581).

Simply being in the sun can help children physically as well. Sunshine can help support children’s and adults’ mental health by stimulating serotonin, a mood-boosting neurotransmitter (Mead, 2008). Serotonin is eventually converted within the body to melatonin, a hormone that supports healthy sleeping patterns. Sleep is especially important in middle childhood, as children’s brains and bodies need significant, restful sleep to keep up with the rapid hormonal and physical changes that occur during these years (CDC, 2021b). Sunshine may also support bone strength and development and increase endorphin levels (Mead, 2008). Studies have shown that sunlight may help to prevent autoimmune disease by strengthening the immune system (Mead, 2008).

Another way that time outside can strengthen the immune system is via exposure to dirt (National Wildlife Federation [NWF], 2012). The microbes found in dirt can trigger children’s immune response, preparing them for more significant exposures. These microbes can also support the skin’s healing process and have the potential to increase serotonin levels as well (NWF, 2012).

Academic Benefits of Nature-Based Learning

While the physical benefits of time outdoors are significant, nature-based learning also supports children in their academic pursuits. In comparing classroom-based instruction with nature-based instruction, a 2022 study found that both methods were equally effective in content instruction (Faber Taylor et al.). This study confirms that the

nature-based approach is able to hold its own in regards to academic content instruction, along with providing students and educators with myriad additional benefits, as outlined below.

One way that nature-based learning can benefit students is by increasing their capacity for content retention. In an observational study conducted on third graders, Eick found that almost all students performed very well in standardized testing after engaging in learning in an outdoor classroom (2012). In a study in Bangladesh, when comparing students who learned in a newly renovated outdoor space with various diverse learning areas, students who learned in an indoor space at the same school, and students who learned in an indoor space at an unrenovated school, the children in the outdoor space showed markedly higher levels of academic attainment (Khan et al., 2020). In a similar U. S. study, children who engaged in science education outdoors scored better on their post-tests than their peers from the same school who engaged in the same science unit while indoors (Cronin-Jones, 2000). In Norway, a study found that students learning mathematics and biology content outdoors retained their learning more than students who learned the same content while indoors (Fägerstam & Blom, 2013). However, in another method of evaluation of the same students, no difference in retention was found between the indoor and outdoor groups (Fägerstam & Blom, 2013).

Students may find more joy in their learning experiences while outdoors. David Sobel suggests that children can enjoy their learning more when it is contextualized (2020). Context can provide meaning for the learning being done. For example, a teacher could ask their students to measure the distance of their morning hike, then convert that distance into feet, kilometers, inches, and so on. They may also be asked to find the

halfway point, one-third, four-fifths, or five-eighths of the distance traveled. Children can engage in division equations while sharing a snack with their classmates, or explore angle measurement by finding geometric shapes in nearby trees. Sobel encourages educators to show their students that math, science, and reading actually matter in real life, outside of their school walls (2020).

Students and educators may also find their overall educational experience to be of a higher quality when outdoors. In a 2004 study by Kuo and Faber Taylor, children with ADHD, as well as their peers, were likely to experience less inattention, impulsivity, and attention fatigue when learning outdoors. This same phenomenon appears to apply to children diagnosed with Oppositional Defiant Disorder (ODD) (Kuo & Faber Taylor, 2004). The American Institutes for Research (AIR) found that students showed an increase in problem-solving skills and motivation to learn when compared to their peers learning indoors (2005). These skills were retained by students even after they had transitioned back to indoor learning (AIR, 2005).

In a study performed on 13-14 students in Australia, students who learned outdoors spent more time on task, requiring less re-direction by their teachers (Francis Norwood et al., 2021). This change did not result in better grades but did boost their engagement and enjoyment of the content being taught. A similar study, conducted in the United States, showed that teachers reported longer attention spans and less disruptive behavior from their students when teaching in an outdoor setting (Szczytko et al., 2018).

Social/Emotional Benefits

Finally, students may experience social and emotional benefits from outdoor learning experiences. As previously mentioned, time outdoors in the sunlight can boost

one's mood by stimulating serotonin production and may increase endorphins (Mead, 2008). Exposure to dirt also has the potential to increase serotonin levels (NWF, 2012). Finding purpose and enjoyment in education can lead to lifelong curiosity and learning satisfaction (Sobel, 2020). According to David Sobel, happiness is a worthwhile goal of education (2020).

Learning in a natural environment has been shown to coincide with a decrease in cortisol levels, which are measured to indicate an individual's level of stress (Dettweiler et al., 2017). In a 2017 study, children who were taught academic content in a forest environment experienced a steady decline of cortisol levels throughout their day, in accordance with a healthy child's diurnal rhythm. Their counterparts who learned the same academic content in an indoor classroom setting, however, did not experience the same dip in cortisol levels, instead experiencing heightened cortisol levels throughout the day. These effects were constant over the course of a full school year, and indicate that time spent learning outdoors allows children to maintain a more natural emotional rhythm (Dettweiler et al., 2017).

Outdoor learning environments can provide students with an opportunity to take ownership of their learning environment. If students are involved in envisioning and creating their outdoor space, it allows them to engage in a real-world educational experience (Haines, 2006). They must plan and measure their space, determine what materials are needed to build and stock their outdoor classroom, acquire said materials, and follow through on the creation of their vision. I myself have walked students through this process, and it is a valuable learning experience and memory that they will hold on to for years to come.

In AIR's 2005 study, students who learned in an outdoor classroom setting experienced gains in their self-esteem, conflict resolution skills, and relationships with peers simply from learning in an alternative environment. Students' interest in nature and the environment can also be improved with time spent outdoors (Rios & Brewer, 2014). Exploring their natural surroundings and engaging in unstructured outdoor play/experiences can significantly impact a child's perspective on the natural world. Parents and teachers also influence children's environmental attitudes, which can affect their perception of time spent outdoors, educational or not (Rios & Brewer, 2014).

Summary: Benefits of Nature-Based Learning

Learning while outdoors, in any subject matter, can benefit students *and* educators in a variety of ways. Students may discover a new love of nature or experience relief from attention fatigue. They may also develop greater peer relationships and conflict resolution skills, while taking ownership of their learning. Educators may find that their instruction is more effective and better retained by students simply as a result of teaching outdoors. Physically, anyone who spends more time outdoors is likely to experience health benefits such as decreased stress, a greater ability to focus, a sunshine-fueled serotonin boost, or even a stronger immune system due to dirt exposure. Nature-based learning environments do not solely consist of extravagant outdoor classrooms, but instead include any and all outdoor spaces in which teaching and learning can occur, as well as indoor spaces where natural aspects have been introduced. A patch of grass near a parking lot, a nearby playground or playing field, a local wooded space, or a classroom full of houseplants can provide students and educators with the benefits of nature-based learning.

Summary

Children in fourth-grade are in a unique stage of life. They experience significant physical, cognitive, and social-emotional development over a short period of time. Not only must they keep up with these changes, but they are also expected to accomplish a great deal of learning, specifically in the area of mathematics. Considering that children in fourth-grade are capable of longer spans of time outdoors and have developed more physical stamina, they are well suited to engage in hands-on learning outdoors (TCCY, 2018c). Research indicates that fourth-graders would benefit from less screen time (TCCY, 2018b), and studies performed by the National Council of Teachers of Mathematics (2011) and the US Department of Education (2008) suggest that children do not need to engage with technology in order to engage in quality math instruction.

Outdoor learning settings have been proven to benefit both neurotypical and neurodivergent students with diagnoses such as ADHD (Kuo & Faber Taylor, 2004). Content retention, academic engagement, and social skills have all been seen to improve when content learning occurs outdoors (Eick, 2012; Khan et al., 2020; Cronin-Jones, 2000; Fägerstam & Blom, 2013). Additionally, time in nature can decrease cortisol and increase serotonin, resulting in less stress and a better overall mood (Dettweiler et al., 2017; Mead, 2008).

Research has shown that fourth-grade students benefit from instructional strategies that encourage metacognition, which aligns with the middle childhood stage of cognitive development (NCTM, 2015a; Lazarra, 2020). Hands-on and real-world learning are not only indicated by mathematics research, but also developmental research, and can be easily executed via nature-based learning (USDE, 2008; TCCY, 2018a).

In light of the information reviewed above, the following chapter outlines the details of my capstone project: a digital toolkit that will equip and empower educators to teach fourth-grade mathematics with both a standards- and nature-based approach. Chapter Four reviews my experience of writing this capstone and creating the accompanying toolkit.

CHAPTER THREE

Project Description

Overview

Students in fourth-grade need movement, time outdoors, opportunities for social skill development, and pathways to connect their new learning to prior knowledge and experiences (Lally & Valentine-French, 2019; Lazarra, 2020). Academically, they are expected to build on their previous understanding of whole numbers, fractions, decimals, base-ten, and measurement. They are also expected to complete more complex multiplication, division, addition, and subtraction equations than in previous years (CCSS, 2022; MDE, 2007). Many of the difficulties that children face in fourth-grade can be addressed through nature-based instruction. Additionally, exposure to sunlight can support children's immune systems, improve their sleep quality, and brighten their moods (Mead, 2008). Movement and exploration allow children to strengthen their bodies and minds. Children with ADHD experience a respite from common symptoms during and following their time outdoors (Kuo & Faber Taylor, 2004). Nature-based learning not only addresses the physical needs of fourth-graders, but also their academic and social-emotional needs.

Educators who teach fourth-graders and want to teach with a nature-based approach face a significant obstacle: how to provide effective and quality education to their students while fully utilizing the benefits and freedom that both nature-based learning and an outdoor learning space can offer. This led me to ask the question, *How can fourth-grade mathematics instruction expand student knowledge by utilizing a nature-based approach?* In light of the research available, I have created a digital toolkit

that will equip and empower educators to teach fourth-grade mathematics with both a standards- and nature-based approach. This toolkit is accessible and adaptable for all educators who have access to any natural space, not exclusively for those who teach at an explicitly outdoor-focused or nature-based school.

In this chapter I will describe the digital toolkit and its contents. I will also outline my intended usage for the toolkit, as well as its intended audience. Finally, this chapter will include an overview of the creation of this capstone project and my plan for its implementation and evaluation.

Project Description

When I began my journey into nature-based learning, I had no idea where to start. The internet is full of nature crafts and narrative blog posts loosely related to nature-based learning activities, but not many concrete academic ideas. While there are many hidden gems out there that are written and published by excellent educators, they are hard to find. I am still discovering new resources myself! When I began my capstone writing process, I knew I wanted to create a one-stop-shop for educators on a similar journey.

This digital toolkit is centered around the newest draft of Minnesota's K-12 Academic Standards in Mathematics, which was most recently updated in May of 2022. Minnesota reviews and revises academic standards on a 10 year cycle, and these standards will be fully implemented within the next five years. I have chosen to use this set of standards because it expands upon the current standards with much clearer expectations and language. The new standards are also slowly being introduced at smaller schools, such as my own, and more and more teachers will be looking for ways to teach

these new standards in the coming years while waiting for curriculum publishers to catch up. My hope is that this toolkit will inspire teachers to approach these new standards with fresh eyes and implement nature-based learning from the very start, regardless of their school or district's curriculum.

Each page of this toolkit highlights one of the eleven anchor standards from the 2022 standards draft, which I have titled: Number Sense, Procedural Fluency, Number Relationships, Expressions and Equations, Patterns, Measurement, Geometry, Spatial Reasoning, Data Sciences, Probability, and Financial Literacy. This edition of the standards is structured quite differently than the currently implemented version, so every page includes an overview of what is included within each anchor standard, as well as the specific benchmarks.

Most importantly, each anchor standard page includes two to four nature-based learning activities that teachers can implement or modify to their teaching context. These activities are aligned with specific benchmarks and have been collected from a wide variety of sources, including my own teaching practice. Some learning activities are simple, like using natural items such as leaves or sticks to represent multiplication equations.. Other ideas are more involved - like creating a variety of graphs to display bird species observed visiting a feeder within a given timeframe, where students are shown the merits of various graphing methods.

My hope is that these learning activities will be grab-and-go, so to speak, so that educators can seamlessly plug a nature-based activity into their regular math instruction. These activities are designed to be supplementary, providing the benefits of nature-based learning to students while allowing educators to follow their provided curriculum.

Implementing nature-based learning is a process, and it can be quite a slow journey. Bringing children outdoors can require a lot of transition time (especially in the winter), and will undoubtedly require an expansion of an educator's comfort zone. Learning outside is messy, chaotic, and full of distractions. Just this year, a well planned and engaging math lesson with my class was derailed by a pair of squirrels dropping acorns onto our heads, which was clearly more exciting than manipulating fractions. Aside from unruly wildlife, the weather can be fickle- especially in Minnesota. High winds, precipitation, and cold temperatures can all hinder one's outdoor learning attempts. In light of these potential roadblocks, a resources page is also included in this digital toolkit. This page includes book recommendations, teacher and parent blogs, and helpful websites with further nature-based learning lesson ideas.

Setting and Audience

This project was designed with fourth-grade classroom teachers in mind. As an upper elementary classroom teacher myself, I have an intimate understanding of the ins and outs of this role. Teaching a room full of bright and diverse minds, all from different backgrounds and with differing needs, is a monumental task. Adding a new aspect to one's teaching can be daunting, regardless of how motivated a teacher may be. I have been in this place myself: I knew that I wanted to integrate nature-based learning into my daily teaching practice, but I didn't know where to start, and I definitely didn't know where to look for support. In developing this digital toolkit, I am creating the resource I wish I had when beginning my nature-based journey.

Time is a precious resource, especially for busy classroom teachers. It is time consuming and frustrating to spend hours weeding through pages of google search returns

and teacher blogs to find nature-based learning ideas, only to spend even more time tailoring those ideas to fit grade-level standards. This toolkit will hopefully provide teachers with an easy starting point while also honoring their time. These easy lesson ideas have been created while considering the number of constraints that may be in place for classroom teachers: lack of outdoor space, limited time and materials, and strict curriculum scope and sequences.

Timeline

I began writing this capstone in February of 2022, and initially planned to create a place-based mathematics curriculum for fourth-graders. At the time, I was midway through my first year teaching at an environmentally-focused school, and was struggling to teach math to my fourth-graders in a meaningful and enriching manner. As time progressed, I began to learn more about nature-based learning as a concept, and was able to practice implementing it in various areas of my teaching practice. This experience shifted my focus to creating a toolkit of nature-based learning ideas for other teachers who may be in a similar situation as myself. During the summer of 2022, I continued to research and develop this capstone project, but was required to take a break due to familial obligations. In September of 2022, I returned to my capstone project. I revised and completed this project during the Fall of 2022.

In addition to being publicly available on the web, this digital toolkit will be utilized by myself and my fourth-grade co-teaching team during the spring of 2023, and will be assessed and reviewed during the subsequent summer months. Following the reviewal process, this toolkit will be revised and updated for future educator use.

Assessment

This toolkit will be assessed in two ways: through personal reflection and a formal feedback form. As my co-teachers and I utilize the toolkit and implement the nature-based learning activities, I will take notes for revision purposes. Additionally, a feedback form embedded within the digital toolkit will be available for public response collection. This form asks for the user's location and educational context. It also prompts users to rate how likely they are to use the learning activities included in the toolkit and how helpful they found the resources and learning activities. Any feedback collected via this form will be considered during the reflection and revision process during the summer of 2023.

Summary

My goal in creating this capstone project was to serve classroom teachers who want to integrate nature-based learning into their mathematics education. Teachers are busy, and have limited time to research and prepare lessons, especially those that are not included in their district or school mandated curriculum. Nature-based learning is beneficial to students and educators in a number of ways, and should be made accessible for as many classroom teachers as possible. This toolkit offers nature-based learning activities aligned with the May 2022 draft of Minnesota's K-12 Academic Mathematics Standards that classroom teachers can utilize to supplement their fourth-grade math instruction. The first version of this toolkit was published in December of 2022 and will be reviewed, revised, and republished in the summer of 2023.

The final chapter of this capstone will reflect upon my writing experience and major learnings found in the capstone creation process. I will return to relevant sources

from the literature review and suggest possible future research opportunities. Finally, I will outline the benefit that this capstone and toolkit provide to the field of education.

CHAPTER FOUR

Conclusion

Overview

My capstone writing process has been one of significant growth. Over the course of the past year, I have encountered a number of hurdles: both academically and personally. I have learned not only the value of perseverance, but also of rest. Caring for myself in the midst of meeting rigorous academic standards was often easier said than done. I experienced the sudden loss of my grandfather in the summer of 2022, and was not sure that I would ever return to this capstone project following such unexpected grief. However, my family rallied around me and continued to support my goal of completing not only this capstone, but my master's program as a whole. My grandfather was an avid environmentalist who cared deeply about educating the next generation, and this capstone has been written in honor of his memory.

This capstone project answers the research question: *How can fourth-grade mathematics instruction expand student knowledge by utilizing a nature-based approach?* I have answered this question by reviewing the literature and applying my personal experience to create a digital toolkit for classroom teachers. I am excited to share this toolkit, and hope that it will equip fourth-grade classroom teachers to bring their math instruction outdoors. Incorporating nature-based learning into content area instruction benefits both teachers and students in a number of ways: physically, socially, emotionally, and academically.

In this chapter, I will describe my major learnings throughout the writing process. I will revisit the literature and reflect on its impact on this project, and will identify the

possible limitations and implications of this project. Finally, I will discuss potential future expansions on this work and its benefit to the education profession as a whole.

Major Learnings

Throughout this process, I have grown in a number of ways. As a writer, I experienced the ever-frustrating writer's block time and time again. I often became stuck while trying to pick the perfect wording, but eventually found a rhythm of taking frequent breaks while writing. Perhaps the most important lesson I've learned during this writing process has been the power of revision. As a classroom teacher, I stress the importance of both the revising and editing processes, but did not truly understand their power until working on this capstone. It can be painful to re-read my own writing, but I have found the value of revisiting my own work. Through revision, I have created a piece of writing that I am truly proud of.

This capstone process not only led to my growth as a writer, but also as a researcher. Over the course of the past year, I spent countless hours reading through studies from across the globe, looking for relevant information. Through this research, I learned to track down original sources and discovered the value of learning from both my peers and those who have come before. Perhaps most importantly, I found that the literature confirms my theory: that children learn better while in nature.

Revisiting the Literature Review

In revisiting the literature review, a few key points have emerged as key to the core of this capstone project. First, the physical benefits of spending time in nature, especially for children. Studies have shown that being outdoors coincides with a decrease in cortisol levels, translating to less stress (Dettweiler et al., 2017). Exposure to dirt and

sunlight boost one's mood by increasing serotonin production and leads to deeper, more restful sleep (NWF, 2012, Mead, 2008).

The second key takeaway from the literature is the academic benefits of nature-based learning. Learning outdoors has been found to decrease common ADHD symptoms in children ages 7-12 with a formal ADHD diagnosis (Kuo & Faber Taylor, 2004). Additionally, academic learning that occurs in a natural context provides students with real-world applications of their studies, showing that what they are learning truly matters (Sobel, 2020). Nature-based learning is also effective in academic retention. In comparing classroom-based instruction with nature-based instruction, a 2022 study found that both methods were equally effective in delivering content instruction (Faber Taylor et al.).

Finally, I noticed significant connections between the social-emotional, cognitive, and physical developmental stages of the common fourth-grader and Minnesota's fourth-grade academic standards in mathematics. Children at this age consider social relationships to be highly important, even above familial relationships (CDC, 2021b). Many benchmarks in Minnesota's fourth-grade math standards emphasize the importance of social interaction: discussing with one's peers and sharing their work with classmates. According to Jean Piaget's Theory of Cognitive Development, children ages 7-11 are in the Concrete Operational stage of development, which means that they excel in logical and concrete reasoning, but struggle with abstract thinking (Lazzara, 2020). The Minnesota fourth-grade math standards address this as well: Students are expected to represent their thinking using a variety of physical and visual models (MDE, 2007; MDE,

2002c). A significant portion of fourth-grade mathematics in Minnesota is spent studying geometry, arguably the most concrete and visual element of mathematics.

Implications and Limitations

I believe that the research presented and referenced in this capstone could lead to a beautiful transformation in the world of elementary education. My work will not be solely responsible for that change, but I do hope that it can be a nudge in the right direction for teachers and administration alike. My dream is to see growth in the use of nature-based teaching and learning in upper elementary grades, especially in mathematics education. Beyond that, a complete K-5 nature-based mathematics curriculum, aligned with the Minnesota standards and available to local schools and districts.

When considering possible limitations of this project, a few concerns come to mind. The first concern is regarding how effectively this website will reach my intended audience: fourth-grade classroom teachers across Minnesota. I chose to utilize Google Sites as my project platform, since it was easily accessible, free, and user-friendly. However, I'm not sure that my work will appear in internet searches, especially as a newly published site. I have already taken a few steps to circumvent this issue: sharing my toolkit link with colleagues in public school districts around the Twin Cities and choosing to publish this site's link along with my project materials in Hamline's Digital Commons. I will continue to look for ways to share this material, as I believe it will be highly beneficial for any Minnesota fourth-grade classroom teacher.

My second concern is the lasting relevancy of this project. I chose to build this toolkit around the most recent draft of the Minnesota K-12 Academic Standards, from May of 2022. This set of standards is certainly the most relevant, in addition to being

much more specific than the currently adopted standards from 2007. However, these drafted standards will likely undergo more changes before they are adopted in their final form. When the standards are updated, some details in my toolkit will become inaccurate, and may require some revision.

The literature reviewed in this capstone has enriched my experience as an educator. I am more intimately familiar with the science behind fourth-grade development and the health and academic benefits of time in nature. Not only has this research driven the creation of my capstone project, which will equip other teachers to teach in nature; it has empowered me to become a more confident nature-based educator to my current and future students.

Future Expansion

As the Minnesota standards are updated and implemented in the next few years, I would love to see an expansion of this toolkit to align more closely with the official edition of the standards. This expansion could include more lesson ideas, potentially covering every benchmark. Experts in the field could contribute to the toolkit by sharing learning activities or adding their own work to the resource list. Additionally, this toolkit could expand to include more grade levels, hopefully beginning with other upper elementary grades like third and fifth, then moving to primary grade levels.

Beyond the toolkit, there is great potential for a number of research studies to be conducted on nature-based mathematics instruction in Minnesota. There are many teachers in our state who have begun to integrate nature-based practices into their mathematics instruction, both formally or informally. These teachers and their students might be compared to peers who are not utilizing a nature-based approach to find which

strategies prove to be most effective. Another possible study could look at the implementation of nature-based learning activities in an outdoor setting versus the same activities adapted for an indoor setting with a number of added natural elements.

Benefits to the Profession

This capstone and toolkit will further the conversation about content area nature-based learning in an upper elementary context. For many teachers, their only exposure to nature-based learning is the unique learning that occurs at forest preschools or alternative high school programs. This work will allow classroom teachers to see nature-based learning as a tool that is accessible for themselves and their students, regardless of their teaching context. My hope is that this toolkit will equip teachers to incorporate bits and pieces of nature-based learning into their day-to-day lessons, supplementing their district-mandated curriculum and prewritten units with these hands-on activities.

Summary

In this capstone, I have addressed the question: *How can fourth-grade mathematics instruction expand student knowledge by utilizing a nature-based approach?* Ultimately, time spent outdoors increases students' ability to learn. It enhances children's information retention rates and allows them multiple connection points between their new learning and prior knowledge. Nature-based learning allows children to engage in their learning in a hands-on manner. Students learn academic content, in this case mathematics, in their local and natural context. Fourth-graders are at a prime stage of development to benefit from hands-on, social, and contextualized learning. This makes nature-based learning the perfect solution for frustrated fourth-grade teachers. This

accompanying toolkit will provide classroom teachers with the activities and resources they need to integrate nature-based learning into their mathematics instruction, expanding their students' knowledge of both mathematics and the natural world.

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