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The Impact of Early Math and Numeracy Skills
on Academic Achievement in Elementary School

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A Literature Review Presented
in Partial Fulfillment of the Requirements
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Abstract

The following literature review explores the impact of learning early math and numeracy skills prior to formal schooling on later academic success. Much of the current focus in early childhood is based around literacy. However, as this literature review shows, early math skills are a more powerful predictor of academic success through elementary school. Several studies have been performed to show the significance of these skills on future math success and were consulted for this review. Within this review is what early math and numeracy skills are, how they develop in young children, the importance of these skills, how they affect later math success, and best practices for teaching early math and literacy skills to young children. By analyzing the previous literature and research and combining it with my own experiences, it is obvious that early math has a strong impact on later academic achievement, especially math success. This information is pertinent to parents, early childhood educators, administrators, district officials and curriculum developers. Further research on the connection to higher level math classes in middle and high school, as well as the connection to other subjects is needed to strengthen this research.

Keywords: early childhood education, early math, early numeracy, best practices, play, preschool, kindergarten

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The Impact of Early Math and Numeracy Skills
on Academic Achievement in Elementary School

Poor achievement in math in U.S. schools is a major concern nationwide. Students in the United States are consistently performing below other countries in math achievement (Fisher, Dobbs-Oates, Doctoroff & Arnold, 2012). The United States is falling behind in math instruction which will impact the future in the global workplace. Students must be proficient in high school mathematics to be successful in college level math and science which are crucial for all STEM vocations (Jordan, Kaplan, Ramineni & Locuniak, 2009). Math is a subject that builds on itself starting in early childhood. A student who fails a sixth-grade math course has a 60% chance of dropping out prior to high school graduation (Ribner, Willoughby, Blair, & Family Life Project Key Investigators, 2017). In a study in Delaware, which is reflective of the nation as well, it was found that 25% of third graders failed to meet math state standards (Jordan et al., 2009). By the time the same group of students got to ninth grade, 49% of the students failed to meet math state standards (Jordan et al., 2009). Our schools are failing in math and intervention needs to start in early childhood with early math and numeracy skills. Students are not catching up in upper elementary and middle school. In fact, more are falling behind. They need a better math foundation in order to be able to succeed in higher level math classes and pass state tests.

This year, Nebraska passed the Nebraska Reading Improvement Act (LB1081) requiring schools to develop a reading intervention program for any kindergarten through third grade student identified as reading deficient through a reading assessment. The goal is for all students to be reading at or above grade level by the end of third grade (Nebraska Reading Improvement Act, 2018). Due to these new requirements, Nebraska schools are pressured to put even more of an emphasis on literacy skills and not necessarily numeracy skills. Schools are being forced to

spend more instruction and intervention time on literacy, taking away from other subjects such as math. However, research shows that literacy skills are not as much of a predictor of success than math skills are (Chesloff, 2013). There needs to be more of a focus on teaching math skills, especially early math and numeracy skills in early childhood. To help support young learners with early math and numeracy skills, parents and teachers need to know what early math skills are, why they are important, how they affect future academic success and strategies to create a strong math foundation in early childhood.

Early math and numeracy skills are crucial for later academic success. This includes math achievement as well as other subjects such as reading (Fuson, Sarama, & Clements, 2015). The main focus of this literature review, however, will be on the effect on future math classes. Several studies have shown the importance of early math (Aubrey & Godfrey, 2003; Aunio et al., 2015; Clerkin & Gilligan, 2018; Jordan et al., 2009). The learning that takes place during early childhood creates a foundation necessary for future math concepts and possible vocations. Teachers and parents play a crucial role in supporting and teaching these early math concepts. Without a strong foundation and proper teaching strategies and interventions, students will continue to struggle in math through elementary school. The purpose of the following literature review synthesis is to explore early math and numeracy skills and the correlation between early math skills and math achievement throughout elementary school. The literature will explore early math and numeracy skills in connection with math and literacy development, academic achievement, and school behavior. It is crucial for parents and educators to be aware of the importance of teaching math skills in early childhood as the push for literacy increases possibly taking away time from math learning. This research will look at research to find the impact of early math and numeracy skills on later academic achievement, especially math achievement.

Review of the Literature

Recently, there has been a nationwide recognition of the importance early childhood education makes on children's academic future (Aubrey & Godfrey, 2003; Clerkin & Gilligan, 2018). However, much of the early childhood academic push has been toward literacy, not numeracy. The original idea was that early literacy, specifically the number of letters a child can identify before age five, was the strongest predictor of later academic achievement (Aubrey & Godfrey, 2003). Now, there have been studies done to show how important early math is as well (Aunio, Heiskari, Van Luit & Vuorio, 2015; Aubrey & Godfrey, 2003; Clerkin & Gilligan, 2018; Harris & Petersen, 2019; Jordan, Kaplan, Kroesbergen et al., 2009; Ramineni & Locuniak, 2009). Early math can teach many valuable skills for future math classes, other academic classes and life in general. In fact, it may be the most powerful predictor of future academic success (Chesloff, 2013). If students have the chance to be exposed to and learn early math skills at a young age, they are more likely to succeed in school. Students who enter Kindergarten low in math skills tend to continue to perform below their peers in later grades (Harris & Petersen, 2019). Math learning and intervention needs to happen before Kindergarten. These students, especially at-risk students, need to opportunity to build a strong foundation at a young age. Young students' brains are naturally receptive to logic and math skills which makes the early childhood years the best time to begin teaching early math and numeracy skills (Chesloff, 2013). This solidifies the importance of early childhood education but shows the need for more numeracy opportunities in those environments.

Early math and numeracy is the general understanding of numbers and basic mathematical concepts (Harris & Petersen, 2019; Toll & Van Luit, 2014). These are skills such as counting, comparing and contrasting, describing shapes and positions and problem solving

(Aunio, Heiskari, Van Luit & Vuorio, 2015; Aubrey & Godfrey, 2003; Harris & Petersen, 2019; Ramani & Eason, 2015). Early math and numeracy skills are the building blocks of all future math classes. Without these skills, students will continue to struggle with higher math concepts. Students need to learn how to solve problems, one of the basic early math skills, for all areas of academics and life outside of school. Early math and numeracy also coincide with language and critical thinking development (Toll & Van Luit, 2014; Vilorio, 2014). More and more, students are entering kindergarten with language deficits and unable to think critically. Students need to be directly taught language skills and critical thinking skills and early math is the perfect way to teach those skills.

Teaching math skills in early childhood are important because it is during that time that children are the most open to learning. Early math and numeracy skills build on children's natural curiosity, inquiry and exploration of the world around them (Chesloff, 2013; Harris & Petersen, 2019). Math at all ages requires curiosity and inquiry. Young students are naturally curious and learn through experiencing their surroundings. They want to know how things work and ask questions about everything. This is what makes early childhood the best time to begin learning early math and numeracy skills. Along with math skills, teaching early math helps to support verbal, spatial and memory skills in young children which are crucial in all areas of life and academics (Jordan et al., 2009). It is important to build the foundation for future math learning early by maximizing skills young students already possess.

Early math ability is directly related to future math ability and has been proven in several longitudinal studies (Aubrey & Godfrey, 2003; Aunio et al., 2015; Jordan et al., 2009). A student's ability to perform early math skills before formal schooling can predict their math achievement in the future. By teaching students these skills before first grade, students enter

school with a foundation of skills to build on in order to do more advanced math. The Kindergarten Common Core skills, representing, relating and operating on whole numbers and describing shapes and space, which are early math skills, are essential for the skills students will learn up to third grade including operations, place value and geometry (Ramani & Eason, 2015). These skills do not stop being used in third grade either. Students will continue to use early math skills throughout the rest of their math education and life. Therefore, it is important to teach early math skills in early childhood.

In order to best prepare students for their future, teachers and parents need to explicitly teach early math concepts to children beginning as infants. Having a language rich environment where children can learn the academic language required for math, is extremely beneficial for young children to learn math concepts (Harris & Petersen, 2019). Children need to be able understand what they are being asked to do in order to be successful at math. If they do not know the language, they cannot perform the skills correctly. This can be done through daily interactions as well as purposeful play time (Harris & Petersen, 2019; Ramani & Eason, 2015; Toll & Van Luit, 2014). Young children can learn a significant amount of math language from playing with an adult or older child and hearing math words being used throughout such as sorting groups, number names and shape names. For students struggling with early math skills at any age, revisiting the academic language should be the first line of intervention (Toll & Van Luit, 2014). Solving math difficulties can be as easy as strengthening a student's academic language.

Early Math and Numeracy Skills

Early math and numeracy skills are skills that are already being used by most young children daily through play and everyday interactions (Help your child, n.d.). These are skills

that begin in early childhood and are the foundation for the rest of elementary math and into upper level math classes as well. These skills must be introduced at a young age so students are able to continue to build on those skills as they progress through the vertical math curriculum because higher level math classes, such as algebra and geometry, depend on a strong foundation of number sense and number skills (Jordan et al., 2009). Without the strong numeracy foundation, students will not have anything to build on when they learn more advanced skills and continue to struggle. The main early math and numeracy topics are counting, comparing and classifying, and geometry (Aunio, Heiskari, Van Luit & Vuorio, 2015; Aubrey & Godfrey, 2003; Harris & Petersen, 2019; Ramani & Eason, 2015). In addition, early math and numeracy skills include logical thinking, problem solving, and reasoning skills (Aunio et al., 2015). As simple as these skills may seem, they are arguably the most important skills a student will learn to aid in their future academic success.

Counting. Counting is one of the most basic skills in math. It starts with the basic ability to count verbally forward and progresses into more advanced skills such as being able to add and subtract (Help your child, n.d.). Some of the necessary early math skills related to counting are one-to-one correspondence, including seriation and cardinality, and number identification (Aubrey & Godfrey, 2003; Aunio et al., 2015; Ramani & Eason, 2015). One-to-one correspondence is the ability to accurately point to objects one-by-one, count in order (seriation) and say how many (cardinality). Students have to understand that each object can only be counted once and that each number can only be said for one object. Students who struggle with one-to-one correspondence tend to either count or move their finger too quickly over the objects. Number identification is the ability to see a numeral and say what it is called. Students who struggle with number identification cannot accurately and consistently say the correct number

name for a numeral. Mastering these skills leads to the ability to say number word sequences, counting in order forward or backward from any number, which are the basis for all future number awareness and a Nebraska State Standard for Kindergarten math (Aunio et al., 2015; Nebraska State Board of Education, 2015).

Comparing and classifying. Comparing and classifying numbers and groups are fundamental skills to mathematical reasoning (Aunio et al., 2015). Students need to be able to look at two groups and identify how they are different or the same and eventually be able to compare numerals and say which is greater or less. They also need to be able to sort objects by attributes into groups including color, size and shape. A more advanced version of this skill is sorting by more than one attribute at the same time such as color and shape. By understanding how numbers and items are related, through comparing and classifying, children are creating numerical relationships (Aunio et al., 2015). These relational skills are not only essential for early numeracy development, but also critical for future math learning (Aunio et al., 2015). Students will always need to be able to know how numbers are related to one another throughout their math career.

Geometry. In early childhood, geometry mostly refers to spatial relationships, shapes and measurement in a way to describe the real world (Jacobs & Rak, 1999). Students are learning vocabulary such as left, right, over, and under as well as colors and shape names. Geometry concepts begin basic with identifying and creating shapes, using positional words and using measurement words to describe and compare objects in Preschool and Kindergarten and expand on those same skills all the way through elementary school (Nebraska State Board of Education, 2015). By the end of elementary school, students use their geometry skills to do higher level

geometry such as identifying vertices, graphing on a coordinate plane and making conversions between metric and standard units of measurement.

Thinking skills. Being able to count, compare, classify and do geometry are necessary skills for elementary school math and beyond but are meaningless unless students can apply their learning outside of a rote math problem. Children also need to learn logical thinking, problem solving and reasoning skills alongside early math instruction. In fact, researchers have suggested that logical thinking is the most important skill for early math and numeracy learning (Aunio et al., 2015). Students need to be able to understand mathematical concepts at a deeper level and understand the logic behind what they are doing. Logical thinking is also present in everyday situations such as what to do if something gets spilled or what to do if there are missing supplies. English professors, Aubrey and Godfrey (2003), during their research on the development of early numeracy, found that early childhood education is at need of a conceptual curriculum. The curriculum needs to focus on deeper understanding of concepts and creating a better foundation of problem-solving skills. Children must be able to make their learning meaningful and be able to understand the reasoning behind the math skills beyond surface, rote level (Aunio et al., 2015). Without logical thinking, problem solving and reasoning skills, students will not only struggle in the classroom, but also outside the classroom in daily life.

Development of Early Math and Numeracy Skills

The development of early math skills happens mostly before first grade, which in school is considered the start of formal schooling and happens hand-in-hand with language and physical development (Harris & Petersen, 2019; Toll & Van Luit, 2013; Toll & Van Luit, 2014). Most young children learn these skills at home as a part of their daily life (Toll & Van Luit, 2013). As children learn to physically manipulate objects in the world around them, they begin developing

basic math skills and vocabulary (Harris & Petersen, 2019). This can be as simple as sorting a set of toy dinosaurs by meat-eaters and plant-eaters or seeing how many steps it takes to get from the car into the living room. By talking about different attributes of dinosaurs or verbally counting steps one at a time, children are developing math skills. Toll and Van Luit's (2014) research shows that math and language skills and growth rate are interrelated and are an influence on each other. They found that language skills, specifically math academic language skills, are a prerequisite for early math skills (Toll & Van Luit, 2014). Children must be able to understand math vocabulary in order to complete basic math tasks. Math vocabulary starts simply with number names and positional words but later transitions into harder academic language such as addition, subtraction, multiplication, and division. Children do not learn math language without adult interaction. In fact, Harris and Petersen (2019) found that children with more parent interactions related to math in early childhood are more likely to succeed in school overall. Children will not learn math vocabulary on their own. They need adults to introduce the words and connect the meaning to a physical interaction. For example, a young child can sort by color on their own but will not understand the words "sort" or "attributes" until they hear them from an adult and the words are used in connection with what they child is already doing.

Similarly, to early literacy and language development, early math development begins with academic vocabulary, extends to using that language in daily life and then translates into the ability to learn more complex skills (Harris & Petersen, 2019). As babies, children can distinguish two small groups by noticing quantity, color and size. By the toddler years, they enter the primary understanding stage and can count by pointing or touching and use number words to refer to quantities. The toddler years also include the acoustic counting and asynchrony stages where they can say number words as they count but may or may not say the numbers correctly in

order. As children reach the preschool years around age four or five, they can quickly subitize groups to say how many and can count in order correctly, the synchronic stage. By Kindergarten age, children are in the resultative counting stage and can accurately count objects by only counting each object once, begin to add and subtract small quantities and understand that the last number said when counting is the total amount. Soon after, they enter the shortened counting stage and can identify numerals and count on from any given number (Aunio et al., 2015; Harris & Petersen, 2019).

Reading and early math development. Reading and math can be taught hand in hand as they develop in a similar way and use the same cognitive skills. Both math and literacy use recognizing and memorizing symbols, visual spatial skills and vocabulary (Davidse, De Jong & Bus, 2014). Students have to learn how to distinguish between letters and numbers and remember the difference between literacy and numeracy. They learn to use visual spatial skills through letter and word shapes in literacy and using manipulatives and visualization in math. Math and literacy build on, not take away from, each other and should be taught hand-in-hand to promote stronger skills in both areas.

The way students learn reading skills is the same way they learn math skills (Harris & Petersen, 2019). They begin by learning the basics and build to more advanced skills. In reading, students begin by learning words and their meanings, vocabulary, then they begin adding more and more words together to make longer and more complex sentences (Harris & Petersen, 2019). Without learning the words and vocabulary at a young age, children will continue to have difficulties with more advanced literacy skills. Similarly, students begin learning math concepts by first learning the vocabulary and recognizing math in their world then they are able to perform more advanced math such as measurement, geometry and reasoning (Harris & Petersen, 2019).

Math skills are important for literacy development as literacy skills are important for math development. For example, there is a medium to large correlation between phonological skills and numeracy skills (Davidse, De Jong & Bus, 2014). Students need to have phonological skills in order to learn number names and verbal codes in math tasks. They need to have numeracy skills to be able to count phonemes, syllables, letters and words in reading.

Without the basic early math skills being taught in early childhood with literacy skills, students will struggle in both math and reading (Davidse, De Jong & Bus, 2014). Literacy and numeracy build on each other and are necessary for the development of the other. When math is taught hand-in-hand with reading and other subjects, it does not take away from those subjects, in fact, more learning happens (Harris & Petersen, 2019). Math can be taught through books and literacy can be taught through verbal math tasks in early childhood. Integrating the subjects with each other is beneficial for student learning.

Early math development and school behavior. Two of the reasons to teach math at an early age are to begin fostering a positive attitude toward math and to help children learn executive functioning skills. Both of these are crucial to start in early childhood. It is proven that students who have a positive attitude and high interest in math activities at a young age do better with math in school throughout elementary school (Fisher et al., 2012). Students also need to have strong executive functioning skills to succeed, not only in math, but also in other areas in school and beyond. Attitude and executive functioning skills are crucial to student success in school.

Attitude. Student attitude toward math includes liking or disliking, level of engagement and thoughts about usefulness of the topic (Clerkin & Gilligan, 2018). It is also reciprocal to achievement. Students who enjoy math tend to spend more time doing activities that strengthen

math abilities (Fisher et al., 2012). These are the students who may not necessarily be the best in math to begin with but enjoy the challenges and logic behind math, so they spend more time in math-based activities. Students may enjoy sorting objects in different ways or seeing how high they can count. Because of the extra time they spend with math activities, their ability increases with their rate of growth. In the same way, students who excel at math tend to enjoy being successful, so they have a high interest in math (Fisher et al., 2012). These students love the feeling of success that comes with a natural high ability in math. They may lean more toward math activities than literacy or other activities when given the chance because of their natural ability in math. Because of their high ability, their interest in math increases. This idea of reciprocity between attitude and ability in math has been proven as young as preschoolers (Fisher et al., 2012). Negative attitudes toward math tend to come from social influences, negative parent or teacher attitudes toward math, pressure to succeed or embarrassment from struggling (Clerkin & Gilligan, 2018). The earlier teachers and parents can foster an interest in and positive attitude toward math, the better off the child will be as their interest and attitude increases their ability.

Executive functioning. Executive functions are higher level abilities such as planning, goal setting, impulse controlling, shifting, and updating (Kroesbergen, Van Luit, Van Lieshout, Van Loosbroek & Van de Riit, 2009). These are skills that are necessary to persevere through math activities and other academic tasks. Planning and goal setting are crucial for students to be able to figure out what the goal is and the steps they need to accomplish that goal. This could be as simple as seeing a group of counters and knowing that in order to find out how many, they need to touch and count each one only one time. Or, it can be as advanced as multi-step problems and the ability to understand the order of the steps and what comes next in order to get to the solution. Impulse control and shifting are when students are in control of their responses and able

to go between tasks and strategies to get to a solution (Kroesbergen et al., 2009). Updating refers to the ability to sift through information and know what is important and being able to change strategies to reach a goal. Kroesbergen et al. (2009) and Ribner et al. (2014) performed studies looking at the connection between executive functioning skills and early math and numeracy.

Kroesbergen et al.'s (2009) research found that executive functioning skills are crucial for counting skills and are more closely correlated to early math success than math intelligence. Students who have stronger executive functioning skills perform better in early math skills than students with a higher IQ. Executive functioning ability could be used as an indicator for identifying at-risk students for math (Kroesbergen et al., 2009). By teaching students executive functioning skills alongside early math skills, students will be more prepared to learn advanced math skills throughout their school career. Similarly, Ribner et al.'s (2014) research showed that higher executive functioning skills can compensate for lack of exposure prior to formal schooling. This study shows that strengthening executive functioning skills can be used as an intervention to help students who start out behind, catch up with their peers.

Executive functioning skills are crucial to early math and numeracy development. These skills develop between three and five years old and are extremely important for the development of working memory which is the short-term memory component that holds information for storing and processing information (Kroesbergen et al., 2009). Early childhood is the time to teach these skills alongside early math. It is especially important for at-risk students who may have limited prior knowledge before school to be explicitly taught these skills so that they do not remain behind their peers in math throughout their school career. Students not only need a foundation of early math skills, but they also need to build a foundation of executive functioning skills to have a successful academic future.

The Importance of Learning Early Math and Numeracy Skills

Our current economy needs STEM workers and there is more demand than there are qualified workers. The best way to create a stable local future for the STEM jobs is by fostering math skills in young children (Chesloff, 2013). Early math skills are already a natural part of a young child's world. Children are naturally curious and interacting with their environment daily. Just by building with blocks, children are practicing spatial, sorting, and reasoning skills to make the best tower (Harris & Petersen, 2019). They want to figure out which shapes can stack on each other to make the strongest and tallest tower and they want to know how tall it is. Math requires that type of curiosity to create stamina to figure out word problems or strive to understand why a math formula works.

Curiosity, creativity, collaboration, critical thinking, inquiry and exploration are skills that are foundational parts of math learning and they are innate skills in young children and the early childhood learning process (Chesloff, 2013). Children ask questions about everything in their life. They want to know how things work, how they can make things, why things happen and so much more. In the workforce, workers need the capability to use mathematical relationships to solve daily problems such as using formulas and making improvements throughout the industries (Vilorio, 2014). The ability to work with numbers and make connections begins with early math and numeracy instruction. These skills learned in preschool and Kindergarten, or even earlier, can have a major impact on the student's future job opportunities.

Along with natural skills aligning with early math skills, early childhood is a time when children are eager to learn, free of peer pressure and free of the pressure of grades (Fisher, et al., 2012). They are more open to becoming interested in math even if their friends are not interested

than they will be when peer pressure begins. They are not concerned about not getting a good grade but instead are focused on learning new skills and enjoying school. This makes early childhood the best time to introduce and teach early math and numeracy skills. By building on skills that children already naturally possess, adults can foster a love of learning and create a solid foundation for future math learning and success.

Early Math and Numeracy as Predictor of Future Math Skills

The greatest reason for teaching early math and numeracy skills is that it is a proven predictor of future math skills. There are several studies previously performed by researchers around the impact of early math and numeracy on later math success. Studies by Jordan et al. (2009), Aubrey and Godfrey (2003), Aunio et al. (2015) and Clerkin and Gilligan (2018) all show significant correlation between early math and later mathematical achievement. Students who were exposed to math skills before first grade, continued to succeed in math through elementary school (Aubrey & Godfrey, 2003; Aunio et al., 2015; Jordan et al., 2009, Kroesbergen et al., 2009). Unfortunately, the opposite is also proven true. Without early math and numeracy skills, students continue to struggle throughout elementary school (Aubrey & Godfrey, 2003; Aunio et al., 2015; Jordan et al., 2009). These results stress the importance of early childhood math education.

Jordan et al. (2009) performed a study beginning at the start of Kindergarten and ending at the end of third grade testing number competence. The researchers used activities for counting and number recognition, number comparisons, nonverbal calculation, story problems and number combinations to test early math skills (Jordan et al., 2009). The activities had to be developmentally appropriate for Kindergarten students but still useful with third grade students. They found that Kindergarten number ability is directly related to first grade math ability and

early number competence in Kindergarten is a strong predictor of math achievement at the end of third grade (Jordan et al., 2009). Students who struggled in math in Kindergarten continued to struggle in third grade. The early math skills were a foundation for the skills learned throughout first, second and third grade. Without that foundation, math was much more difficult.

Aubrey and Godfrey (2003) performed a similar study with five to seven-year-old students. In the United States, most students are five in Kindergarten and seven through some of second grade, which is a very similar age range as Jordan et al. (2009). Aubrey and Godfrey (2003) tested students on comparison, classification, correspondence, seriation, counting, calculation and real-life problem solving. These skills are early math and numeracy skills and very similar to the skills tested by Jordan et al (2009). The researchers found that the scores when a student is five were strongly correlated to that student's scores at age seven (Aubrey & Godfrey, 2003). Just as Jordan et al. (2009) found, these results show how Kindergarten math achievement is predictive of later math achievement.

Aunio et al. (2015) performed a yet another related but shorter study testing early math skills at the beginning of Kindergarten to the end of Kindergarten. This study shows the importance of preschool early math learning. The researchers found that they students who were low-performing at the beginning of Kindergarten were still low-performing at the end of the year (Aunio et al., 2015). The students who had access to early math skills before Kindergarten did much better at Kindergarten math the entire year than those who were just beginning their math instruction in Kindergarten. This shows how important it is to begin introducing math skills to students at a young age prior to Kindergarten. Even though this study only lasted from the beginning to the end of Kindergarten, it is very likely that these students continued to be low-performing as they could not catch up on the foundational skills which are essential for more

advanced skills (Help your child, n.d.). Parents and preschool teachers are the first educators in a child's life that can help prepare them for their future. From the previous two studies by Jordan et al. (2009) and Aubrey and Godfrey (2003), it is proven how important Kindergarten math achievement is to second and third grade math success. This study by Aunio et al. (2015), adds how important early math skills prior to Kindergarten are for Kindergarten math achievement, therefore second and third grade math success. Math learning must start prior to Kindergarten at home or in early childhood classrooms.

Clerkin and Gilligan (2018) performed a study connecting numeracy activities at home with young children and attitudes toward math with math achievement in fourth grade. They found that early numeracy play in early childhood was significantly and positively related to math attitude in fourth grade (Clerkin & Gilligan, 2018). The students with early exposure to math activities, formed a more positive attitude toward math in general. The positive attitude remained through at least fourth grade. Furthermore, they found that students with a negative attitude toward math in fourth grade also were achieving at a lower level (Clerkin & Gilligan, 2018). This shows that early numeracy play is directly linked to positive attitudes toward math which leads to higher achievement in upper elementary math classes. Parents are the first teachers in a child's life and their time devoted to introducing numeracy activities at a young age is shown to pave the way for their child's math future.

All four studies found compelling evidence of the importance of early math instruction before first grade, or even Kindergarten as in the case of Aunio et al. and Clerkin & Gilligan's studies (Aubrey & Godfrey, 2003; Aunio et al., 2015; Clerkin & Gilligan, 2018; Jordan et al., 2009). Parents and early childhood educators must begin to shift some of the focus on literacy to early math and numeracy. Math difficulties do not go away easily in elementary school as it

continues to create negative attitudes toward math leading to lower achievement (Clerkin & Gilligan, 2018). A child who struggles with number sense early on will struggle with fractions and then algebra in future math classes (Jordan et al., 2009). Number sense is a topic included on state standardized tests and is directly related to the amount of informal math instruction students receive prior to formal schooling (Hanley, 2005). In a culture where standardized test scores mean so much for students, schools and districts, parents and early childhood educators must begin teaching early math and numeracy skills to young students. Math skills build on these foundational early math and numeracy skills and students deserve to have a strong foundation so that they don't have to struggle for the rest of their math education.

Teaching Early Math Skills

Early math skills must be a part of all early childhood classrooms. Teachers and parents must be intentional about including activities that expose children to math concepts. Math skills must be explicitly taught through formal numeracy activities but can also be a part of daily routines and play in the classroom or home environment, informal numeracy activities (Clerkin & Gilligan, 2018; Ramani & Eason, 2015; Toll & Van Luit, 2014). Children are naturally going to explore the world around them and ask questions about what they discover. Children can learn basic math concepts through exploration and experimentation with the world around them on their own, but they need adults to support their learning as well (Fuson, Sarama, & Clements, 2015). Formal numeracy activities improve number identification and naming as well as counting (Clerkin & Gilligan, 2018). Informal numeracy activities improve non-symbolic skills, number sense and more general math achievement (Clerkin & Gilligan, 2018; Hanley, 2005). Both formal and informal numeracy activities are necessary for early math development.

Early childhood learning should be language rich throughout daily tasks, especially with math language (Harris & Petersen, 2019; Toll & Van Luit, 2014). Adults should be intentional about explaining math concepts and using academic language as children are involved in play, activities and games. For example, while a child is sorting toys, they need an adult to explain that they are sorting and use words such as “sorting,” “groups,” and various attribute names like color words and size words. Games can be created by teachers or parents to target specific math skills or existing games can be used or modified as well (Ramani & Eason, 2015). This allows students to have fun and play while learning, making the math more meaningful in their life. The more repetition and practice a student has for a skill, the more in-depth they will understand that skill (Fuson, Sarama, & Clements, 2015). It is perfectly fine for students to play the same game over and over because every time, they will learn something new at a deeper level. For example, parents or teachers can play Simon Says or I Spy with young children and include finding shapes, making shapes with their hands, or finding colors around the room (Jacobs & Rak, 1999). Games require little to no preparation or materials but are excellent at reinforcing skills in a fun way.

Parents and teachers also must have numeracy-related activities and visual-spatial activities available for children to play with (Clerkin & Gilligan, 2018; Weisberg, Kittredge, Hirsh-Pasek, Golinkoff & Klahr, 2015). These are toys such as dice, toys with numerals, puzzles, Legos, and blocks. In fact, children who play with blocks develop spatial skills and math language better and quicker than their peers (Clerkin & Gilligan, 2018). Young children learn best through play as they are given opportunities to practice their new skills and it is related to future math success (Clerkin & Gilligan, 2018; Ramani & Eason, 2015). The more chances they have to use their new skills, the more they learn and understand about that skill. Play not only

gives the chance to practice their skills but also incorporate it in into the real world and make their learning meaningful.

Other ways to introduce children to math language is by reading books that include math concepts, pointing out numbers, color and sizes in the environment, and participating in calendar time (Harris & Petersen, 2019; Ramani & Eason, 2015). Young children are quick learners, especially when it is relevant to their daily life. Early math skills can also be taught without any materials such as counting everyday objects, verbally counting together or singing counting songs (Clerkin & Gilligan, 2018). This is especially important for at-risk students who come from low-income houses and do not have access to early numeracy toys such as puzzles and blocks. All children deserve to have the chance to learn early math skills and develop a positive attitude toward math at a young age to set them up for success in the future.

Since math academic language is a crucial first step in early math development, researchers recommend focusing on the language in early childhood (Toll & Van Luit, 2014). Academic language includes math vocabulary, concepts, colors, shapes, numbers and much more. Toll & Van Luit (2014) recommend focusing on the math specific language with young children or any age children who are struggling with early math skills. Children need to be able to use and understand the language related to skills they are asked to perform. Without the knowledge of what they are being asked to do, they will continue to struggle. The focus on the language will provide a more in-depth knowledge of the word and thus the concept or skill. This is especially crucial for minority, low-income or English Language Learner students who tend to have fewer math language experiences prior to formal schooling (Harris & Petersen, 2019). Exposing these at-risk students to math language in early childhood can have a lasting impact on their academic performance (Aunio, Hautamäki, Sajaniemi & Van Luit, 2009).

By incorporating informal and formal early math and numeracy activities into daily life at home and at school, children can be prepared for math in elementary school. Parents and educators should use play, games, books, songs and daily conversations to boost learning. By creating a language rich environment and being intentional about using academic language, adults can create an ideal learning environment to help create a foundation for elementary math. Introducing and revisiting math academic language can both be used in instruction and intervention for children, especially at-risk students. Both parents and educators have a responsibility to provide formal and informal numeracy learning activities for children.

Analysis

Early math and numeracy skills are a crucial part to early childhood education and may be the most powerful predictor of future academic success, especially in higher level elementary math classes (Chesloff, 2013). Students need to build a foundation early on, to allow them to build on those skills in the future. Without the basic early math and numeracy skills: counting, comparing and classifying, geometry and thinking skills, studies show students will continue to struggle throughout their math education if they enter school lacking these basic math skills (Aubrey & Godfrey, 2003; Aunio et al., 2015; Jordan et al., 2009, Kroesbergen et al., 2009). While analyzing these studies, it is obvious how important teaching early math and numeracy skills is in early childhood. In order to begin creating a stronger foundation for students, teachers need to know the best practices for teaching early math and numeracy skills and how to create successful early intervention programs for students with limited experience prior to school (Clerkin & Gilligan, 2018; Toll & Van Luit, 2014). By knowing what early math and numeracy skills are, how they develop and affect future math skills, and how to teach them, educators and parents can create a more successful math future for students.

Early math and numeracy skills are the basic skills behind all future math success. These are skills that students are exposed to on a daily basis through exploration and play. Educators and parents must work together to expose young children to early math and numeracy skills to create a strong foundation. Several studies found a significant and strong correlation between early math ability prior to formal schooling, around first grade, and later math achievement (Aubrey & Godfrey, 2003; Aunio et al., 2015; Jordan et al., 2009, Kroesbergen et al., 2009). Students who entered school with a strong foundation in early math skills tend to continue to succeed and enjoy math throughout elementary school. Studies also show that students who create a positive attitude toward math at a young age continue to have a positive attitude by the end of elementary school (Clerkin & Gilligan, 2018). This is also crucial because having a positive attitude is linked to greater success due to additional time spent with math activities (Fisher et al., 2012). By using early childhood to create a strong math foundation and positive attitude, students are set up to be successful in school and enjoy math. Educators and parents must know how these early math and numeracy skills develop through interactions with adults while playing and engaging with the world around them (Harris & Petersen, 2019). By harnessing the natural curiosity and explorative tendencies of young children, adults can introduce and teach, formally and informally, the basic math and numeracy skills necessary for academic success. Early childhood teachers and parents must be knowledgeable about how to incorporate math language throughout the day and integrate math with other subjects. Students need adult guidance to learn academic language and connect what they are already capable of doing through games and play to the vocabulary necessary for formal math (Harris & Petersen, 2019; Toll & Van Luit, 2014). Educators and parents must intentionally use play to introduce and strengthen early math skills as it is the best way children learn and retain new skills (Clerkin

& Gilligan, 2018). It is especially important to intentionally expose at-risk students, English Language Learners and low-income families, to early math skills. By intervening early and intentionally in preschool, kindergarten or first grade, schools can catch up some students and avoid later math difficulties and possible special education referrals (Hanley, 2005; Toll & Van Luit, 2013).

Based on the research found in this literature review, early math and numeracy skills are indeed an important part of early childhood education as they determine a student's later academic success. Students need to have a strong foundation of math skills in order to succeed in future, higher level math classes. These skills develop prior to formal school so it is the responsibility of parents and early childhood educators to teach and remediate these skills before students enter Kindergarten or First Grade. When teachers and parents work together to create a math academic language rich environment for young children, it creates a strong foundation for math learning and sets students up for a successful academic future.

Application

Early math and numeracy skills are a crucial beginning to academic success. The studies previously discussed show that young students who gain a strong foundation in math are significantly more likely to be successful in math throughout elementary school ((Aubrey & Godfrey, 2003; Aunio et al., 2015; Jordan et al., 2009, Kroesbergen et al., 2009). Students must be able to count, compare and classify, do geometry and think critically in order to succeed in higher level math classes and perform higher level tasks such as fractions and algebra (Jordan et al., 2009). Since early childhood learning takes place both at home and school, both educators and parents can benefit from knowing the importance of early math and numeracy skills and how to best teach young learners.

After teaching Kindergarten for three years, I am currently staying home with my daughter and subbing so I do not have an immediate classroom to apply my research in with students. However, I do have access to a network of local moms. Through future playdates and conversations, I will be able to share my research with moms across Omaha. This will help establish a culture of change and a push toward more math with young students beginning at home. By providing parents with this research and early numeracy activities, I will be able to support and teach parents of young children the importance of their role in their child's math development. Additionally, I am planning on substitute teaching in several different school buildings and districts this coming school year. This will give me the perfect opportunity to share my findings with many early childhood educators and administrators through daily interactions and conversations. Another way I may be able to use my research is through small group or one on one tutoring in math. Since math is not a subject that is widely taught in early childhood, I would focus my tutoring on preschool age students. By also incorporating literacy activities into my tutoring sessions, my students will be able to learn more in both numeracy and literacy (Harris & Petersen, 2019). This would also give me another avenue to share ideas and activities with parents for continued support at home.

As a stay at home mom, other moms will be my main target group for now. I plan on sharing my ideas with moms at places such as MOPS meeting, mom support groups, the park and play dates. My focus will be on how to incorporate academic language into the daily routine and learn through play (Clerkin & Gilligan, 2018; Harris & Petersen, 2019; Toll & Van Luit, 2014). I will provide simple activities and ideas such as playing with blocks, counting toys, sorting silverware and playing games. These are activities that most families could do without any additional materials or preparation. Additionally, I will model using academic language

throughout my interactions with my daughter by discussing colors at the park, different sizes of objects and counting. Parents are the first place children learn their early numeracy skills so the movement toward early childhood math must start at home.

Early childhood teachers are the next biggest influences in a child's early math development. Teachers need to be instructed on how to integrate math into a literacy-focused curriculum and the importance of early math skills for future math success. They need to know how to create a language rich environment and incorporate academic language into the everyday preschool discussions (Toll & Van Luit, 2014). However, just integrating math is not enough. There needs to be a dedicated time for math instruction toward specific math goals or standards (Fuson, Sarama, & Clements, 2015). The easiest way for teachers to begin this change is through calendar time. Most early childhood classrooms already begin their day with calendar time so it would be simple to begin to add early numeracy skills into that time. It could be as simple as reading a book with numeracy concepts, counting the days of school every day, taking extra time to talk about the date or having a shape and number of the day to focus on. Clerkin and Gilligan (2018), explain how formal teaching of numeracy skills is an important part of math development. Calendar time is a simple way to add formal math instruction in an early childhood classroom. Informal teaching through play is also a valuable part of math development as well. By having numeracy and visual-spatial activities and games available for students to explore, students are able to apply and practice their math skills from calendar each day (Ramani & Eason, 2015).

In order for early childhood teachers to be able to make the necessary changes to support early math development, they will need support and accommodations from administrators, such as principals. Many schools, such as the one I taught in for three years, have strict curriculum

and time requirements for each subject. Typically, math has a significantly lower number of required minutes per day. Since the research in this literature review shows that early math skills are the most powerful predictor of future academic success, administrators will need to be willing to give math more time during the day even if it means taking away time from literacy (Aubrey & Godfrey, 2003; Aunio et al., 2015; Chesloff, 2013; Jordan et al., 2009; Kroesbergen et al., 2009). Early childhood teachers, along with administrators, will need professional development to learn how to better incorporate and teach early math and numeracy skills in preschool and Kindergarten. There will be a cost to hire a speaker to run a professional development course as well as the cost of substitute teachers for teachers to be able to attend during contract hours. Additionally, in a culture that pushes academic rigor, it will be important for administrators to see the benefit of play and games in the early childhood classroom and allow time in the schedule for this hands-on learning to take place (Weisberg, et al., 2015).

School districts can aid in the implementation of early math and numeracy in early childhood by providing schools with math interventionists in addition to reading interventionists. At the school I previously taught at, a Kindergartener could qualify for reading assistance as early as the second week of school but had to wait for math assistance until February. By providing math interventionists for each building and allowing them to work with early childhood students, at least Kindergarteners, immediately if a skills deficit is noticed, students can receive intentional help right away and not continue to struggle in math (Toll & Van Luit, 2013). This early intervention process can reduce the number of students who qualify for Specific Learning Disability in Math and help identify the students who truly have a learning disability, not lack of exposure, thus saving the district's special education resources (Clerkin & Gilligan, 2018). Students who are from low-income or non-English speaking home, need to

especially be targeted for early intervention based on academic language to ensure they begin their academic career strong (Aunio et al., 2009). School districts will need to allocate more resources toward early childhood math but the hope is that with early intervention, students will not need the resources later on in elementary school.

This research also calls for a change in curriculum development for early childhood programs. Traditionally, the curriculum is based on literacy skills with math skills added in. However, from research by Jordan et al. (2009), Aubrey and Godfrey (2003), Aunio et al. (2015) and Clerkin and Gilligan (2018), it is now known that math needs to be a priority in early childhood learning. Literacy and math do not need to be exclusive when taught in early childhood, in fact, it is better if they are taught together as they use similar cognitive skills (Davidse, De Jong & Bus, 2014). However, early math skills cannot be an afterthought in curriculum planning, they must be a priority of equal or greater value as literacy. Early childhood educators need access to quality early childhood curriculum in order to be able to properly teach students early math skills and begin creating a strong foundation.

Although there are quite a few strong studies on the effect of early math and numeracy on future math success, there is very limited information or action research studies to show the correlation between early math skill and future general academic success. There needs to be more research on how early math success translates to other areas such as reading, social studies and science. Additionally, it would be very interesting to see longer studies that show how early math skills continue to affect math success through middle school, high school and college or occupations. We know early math skills create a necessary foundation for future math skills but the studies only test the correlation up to upper elementary school. It would be interesting to see how those same students continued to succeed or struggle in math classes for years to come. Do

students every catch up? Does a student's math ability in preschool or Kindergarten accurately predict their math ability in high school? These are questions that would need to be answered with an in-depth longitudinal study.

With parents, early childhood educators, administrators, school districts and curriculum developers working together to create a more math-focused early childhood experience, students will be able to begin a strong foundation of math skills early on. A strong foundation will lead to less students needing assistance later in elementary school and more enjoyment and success in future math classes. Children do not acquire early math skills on their own, they need a support system that works together in the best interest of the student. All parties play a role in early math education and are equally responsible for a student's math success.

Conclusion

In the current early childhood realm, literacy is the main focus. However, based on the research outlined above, math needs to be a priority as well. Proficiency in early math skills such as counting, comparing and classifying, geometry and thinking skills create a necessary foundation for future math skills and success later in school. These skills are a crucial step in math development and cannot be skipped. Students must know how to do the basic skills before they can learn more advanced skills. This also includes the ability to use and understand academic language in association with skills and abilities. Parents and early childhood educators are both responsible for introducing and teaching early math academic language along with skills both formally and informally. Learning can take place through daily interactions with numeracy activities and games, casual conversations about math concepts, and formal instruction time. Play is a necessary part of early math learning as it gives students opportunities to use and practice their academic language alongside a skill. Based on the research found, integrating math

into early childhood curriculum would be a beneficial change for future math courses and STEM occupations. Early math and numeracy skills not only pave the way for success in future math classes but also help students form a positive attitude toward math and learn basic executive functioning and problem solving skills. The knowledge of early numeracy skills, the development of math skills and the best practices for teaching these skills will help parents, early childhood educators and administrators best prepare young students for a strong academic career. Early math and numeracy skills indeed have a strong impact on academic achievement throughout elementary school and therefore should be a main component of early childhood education.

References

- Aubrey, C., & Godfrey, R. (2003). The development of children's early numeracy through key stage 1. *British Educational Research Journal*, 29(6), 821-840.
- Aunio, P., Hautamäki, J., Sajaniemi, N., & Van Luit, J. (2009). Early numeracy in low-performing young children. *British Educational Research Journal*, 35(1), 25-46.
- Aunio, P., Heiskari, P., Van Luit, J., & Vuorio, J. (2015). The development of early numeracy skills in kindergarten in low-, average- and high-performance groups. *Journal of Early Childhood Research*, 13(1), 3-16.
- Chesloff, J. (2013, March 5). STEM education must start in early childhood. Retrieved February 27, 2019, from <https://www.edweek.org/ew/articles/2013/03/06/23chesloff.h32.html>
- Clerkin, A., & Gilligan, K. (2018). Pre-school numeracy play as a predictor of children's attitudes towards mathematics at age 10. *Journal of Early Childhood Research*, 16(3), 319-334. doi:10.1177/1476718X18762238
- Davidse, N., De Jong, M., & Bus, A. (2014). Explaining common variance shared by early numeracy and literacy. *Reading and Writing: An Interdisciplinary Journal*, 27(4), 631-648.
- Fisher, P., Dobbs-Oates, J., Doctoroff, G., & Arnold, D. (2012). Early math interest and the development of math skills. *Journal of Educational Psychology*, 104(3), 673-681.
- Fuson, K., Sarama, J., & Clements, D. (2015). Making early math education work for all children making early math education. *Phi Delta Kappan*, 97(3), 63-68.
doi:10.1177/0031721715614831

- Hanley, T. (2005). Commentary on early identification and interventions for students with mathematical difficulties: Make sense--do the math. *Journal of Learning Disabilities*, 38(4), 346-9.
- Harris, B., & Petersen, D. (2019). Developing math skills in early childhood [PDF]. *Mathematica*. Retrieved from <https://www.edimpactlab.com/download-media?MediaItemId=%7B3360C48F-576D-44A8-AB63-EA259BABC359%7D>
- Help your child develop early math skills. (n.d.). Retrieved June 6, 2019, from <https://www.zerotothree.org/resources/299-help-your-child-develop-early-math-skills>
- Jordan, N., Kaplan, D., Ramineni, C., & Locuniak, M. (2009). Early math matters: Kindergarten number competence and later mathematics outcomes. *Developmental Psychology*, 45(3), 850-67. doi:10.1037/a0014939
- Kroesbergen, E., Van Luit, J., Van Lieshout, E., Van Loosbroek, E., & Van de Rijt, B. (2009). Individual differences in early numeracy. *Journal of Psychoeducational Assessment*, 27(3), 226-236.
- Nebraska Reading Improvement Act, A. LB1081, 105th Leg., 2d Sess. §§ 79-2601 - 79-2607 (Neb. July 19, 2018). Retrieved from https://nebraskalegislature.gov/laws/display_html.php?begin_section=79-2601&end_section=79-2607
- Nebraska State Board of Education. (2015, September 4). *Nebraska mathematics standards*. Retrieved June 8, 2019, from https://www.education.ne.gov/wp-content/uploads/2017/07/2015_Nebraska_College_and_Career_Standards_for_Mathematics_Vertical.pdf

- Ramani, G., & Eason, S. (2015). It all adds up: Learning early math through play and games. *Phi Delta Kappan*, 96(8), 27-32.
- Ribner, A., Willoughby, M., Blair, C., & Family Life Project Key Investigators. (2017). Executive function buffers the association between early math and later academic skills. *Frontiers in Psychology*, 8, 869-869. doi:10.3389/fpsyg.2017.00869
- Toll, S., & Van Luit, J. (2013). Early numeracy intervention for low-performing kindergartners. *Journal of Early Intervention*, 34(4), 243-264.
- Toll, S., & Van Luit, J. (2014). The developmental relationship between language and low early numeracy skills throughout kindergarten. *Exceptional Children*, 81(1), 64-78.
doi:10.1007/s11145-013-9465-0
- Vilorio, D. (2014). STEM 101: Intro to tomorrow's jobs. *Occupational Outlook Quarterly*, 2-12.
Retrieved from <http://www.stemedcoalition.org/wp-content/uploads/2010/05/BLS-STEM-Jobs-report-spring-2014.pdf>
- Weisberg, D. S., Kittredge, A. K., Hirsh-Pasek, K., Golinkoff, R. M., & Klahr, D. (2015). Making play work for education: Research demonstrates that guided play can help preschool children prepare for reading and math better than free play and direct instruction. *Phi Delta Kappan*, 96(8). Retrieved from Gale OneFile database.