INTERVENING ON EARLY NUMERACY FOR CURRICULUM APPLICATION AND ADVANCED MATH SKILL ACQUISITION

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Abstract: At the present time the field of school psychology lacks tools to offer supplementation and remediation in early mathematics for struggling students. Although research clearly demonstrates valid and efficient models of instruction for beginning learners, practitioner implementation remains inadequate. While the current early numeracy assessments and interventions available to school psychologists are robust screeners, they may lack a connection to the classroom curriculum and may not aid in shaping behavior through mathematical vocabulary to encourage the acquisition of advanced math skills. This is important as early numeracy builds a foundation for a student's acquisition of future math skills. Teaching and mastery of arithmetic pre-skills in a systematic fashion can create a base for comprehending strategies and algorithms introduced in later grades (Gersten, Darch, & Gleason, 1988). The purpose of the current study was to determine if implementing early numeracy interventions that align with a standardized scope and sequence of early numeracy skills assisted students in acquiring accurate and fluent responding with basic math facts and assisted them in performing at a higher level on advanced mathematical skills. The current study found that exposure to the MIND: EN interventions increased student's accurate responding on the Dot-Number, Dot-Number-Total and Number-Total assessments. Visual analysis of the data indicated that baseline data across participants were stable and flat with no clear trend for the measure of Number-Total across all participants for data of DCPM. Data demonstrated, across 4 participants, that exposure to the MIND: EN interventions increased student's accurate responding on the Dot-Number, Dot-Number-Total and Number-Total assessments.

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CHAPTER I

INTRODUCTION

The value and importance of early exposure to foundational academic skills is critical to preparing children to be successful in school. This has been repeatedly demonstrated in regard to early literacy skills and also in the area of mathematics (Codding, Volpe, & Poncy, 2017). Specifically, it has been shown that early numeracy skills such as ordinality and number knowledge are robust predictors of student's future achievement (Duncan et al., 2007). Unfortunately, in kindergarten student exposure to early numeracy skills is less than desirable as teachers spend about half as much time teaching math as they do reading (Codding, Volpe, & Poncy, 2017). This lack of exposure may result in unnecessary skill deficits that will lead to compromised levels of future math achievement. This may have lasting implications as increased levels of math achievement are associated with better outcomes across a variety of areas, including post-secondary education, career, and future income (U.S. Department of Education, 2008). Additionally, Science, Technology, Engineering and Mathematics (STEM) careers are expected to grow rapidly compared to other jobs, and wages for STEM occupations, on average, are 26% more compared to individuals in other non-STEM jobs (U.S. Department of Commerce, 2011). In order to equip graduates with the skills to obtain these opportunities schools need to ensure that students are exposed to high quality mathematics instruction.

Mathematical Achievement in Schools

The National Assessment of Educational Progress (NAEP) (2017) standards provide three target levels of achievement: basic, proficient, and advanced. Basic is defined by students showing partial mastery of prerequisite knowledge and skills fundamental to grade level proficiency. Proficient is defined as students demonstrating competency over challenging grade level subject matter where students have grade level skills, can use these skills to solve real world problems, and can analyze commensurate mathematical data. Advanced is defined as superior performance. Using these standards NAEP (2017) reported that in 4^{th} grade 80% of students met the basic achievement level, 40% met the proficient achievement level, and 8% met the advanced achievement level. In 8^{th} grade 70% of students met the basic achievement level, 34% met the proficient achievement level, and 10% met the advanced achievement level. These scores are concerning as 60% of 4^{th} graders and 66% of 8^{th} graders are not meeting the standard of proficient, a number that has not improved over the last decade (NAEP, 2017).

When compared internationally, American students are achieving in the average range. Specifically, the data from the Trends in International Mathematics and Science Study (TIMSS) (National Center for Education Statistics, 2015) report placed the United States (U.S.) in the average range ranking 14^{th} out of 49 countries in 4^{th} grade and 11^{th} out of 39 countries in 8^{th} grade. With that said, the U.S. and the rest of the world are increasingly falling behind East Asian countries (e.g., Singapore, Korea, Japan). Data did show that between 1995 and 2015 U.S. scores in 4^{th} grade math achievement increased, however, scores did not increase between 2011 and 2015 (National Center for Education Statistics, 2015). To achieve the goal of continued improvement it is imperative that educators focus research on validating improvements in assessment, curriculum, and instruction that can be used to maximize student achievement in mathematics.

Current Recommendations Regarding Mathematics Instruction

Educators have debated how to best increase math achievement for decades. In the literature there are a variety of viewpoints and philosophies of what, how, and why mathematics should be taught. This political push and pull has seen different iterations of traditionalist and reformist arguments about mathematics curricula and instruction for the last decade (Schoenfeld, 2004). These “math wars” have proponents of traditional approaches who emphasize explicit instruction, computational automaticity, and procedural fluency while the reformist emphasize implicit instruction, process based learning, and rich conceptual knowledge (Ansari, 2016). Similar to the whole language vs. phonics debate it is likely that when the dust settles research will support a hybrid approach where aspects of both approaches, traditionalist and reformist, are used to meet learning goals (Schoenfeld, 2004). Specifically, teaching foundational skills and procedures will require explicit instruction to increase accurate and fluent responding, which will be faded and replaced with opportunities for problem-based and experiential methods as students are scaffolded to apply these skills across contexts. Although the debate will continue, experimental data converges to suggest that pedagogical approaches that incorporate guidance result in the strongest and most consistent outcome effects (Kirschner, Sweller, & Clark, 2006; Mayer, 2004).

The National Council of Teachers of Mathematics (NCTM) consists of more than 60,000 members and advocates for high-quality instruction and learning for students. To outline recommendations, they have published The Principles and Standards for School Mathematics (NCTM, 2000). This comprehensive document outlines skills that need to be taught in a grade by grade sequence. Their recommendations overlap findings by the NMAP (U.S. Department of Education, 2008) as both also report that it is important for students to learn facts, procedures, and develop conceptual understandings. That being said, many contributors to NCTM question the validity of automaticity and argue that student learning can be adversely affected by interventions that focus on automatic responding (Boaler, 2015). Although NCTM recommendations support the development of fluent responding to basic facts, consensus among members appears to be inconsistent. In regard to recommendations of procedural and conceptual skill development, NCTM strongly advocates that this be an emphasis of teachers as future learning becomes easier when a student has learned with comprehension.

Although the dispute regarding procedural versus conceptual learning frequently frames each as being separate and against the other, research indicates a strong relationship between the two (Ansari, 2016). However, when administering initial instruction to beginning learners research advocates for explicit instruction paired with substantial guidance (Kirschner, Sweller, & Clark, 2006). An instructional program, referred to as Direct Instruction, has long been supported by research to advance student's academic growth utilizing fast, energetic instruction with choral responding and corrective feedback (Baumann, 1984; Becker & Gersten, 1982). Research supported guidelines of effective instruction are the foundation of Direct Instruction (Marchand-Martella, Slocum, & Martella, 2004, p.16-17). These include a focus on structured academics, with teachers as firm leaders, utilizing demonstration-practice-feedback procedures. The Direct Instruction program includes 1) Identification of main ideas with strategies for generalization, 2) Explicit communication with clear meanings, 3) Structured dialogues with support fading, 4) Carefully sequenced skills and 5) Skill development allowing for application and aggregated review (Marchand-Martella, Slocum, & Martella, 2004, p. 29-37). The primary principles of Direct Instruction include enforcing academic learning time with engaged student participation, quickly paced instruction with mastery-criteria and corrective procedures and implementing continuous assessment of student progress (Marchand-Martella, Slocum, & Martella, 2004, p.41-50).

Originally, Direct Instruction was developed with a specialized interest in achievement for disadvantaged populations. After initial success utilizing Direct Instruction at a preschool, the instructional model was elected to participate in a government research study called Project

Follow Through (Marchand-Martella, Slocum, & Martella, 2004, p.19-20). Project Follow Through compared the effectiveness of various educational approaches on three outcomes: basic and cognitive-conceptual skills and affect. Basic skills included recognizing words, language, spelling and math computations. Cognitive-conceptual skills included math concepts, problem solving and reading comprehension. Affect was defined as student's self-concept. When compared to other educational models only Direct Instruction produced positive results on all three outcomes (Marchand-Martella, Slocum, & Martella, 2004, p.57-58). Additionally, students receiving three years of the Direct Instruction Follow Through program performed higher on instances of spelling, language, total reading and total math when compared to a national group (Becker & Gersten, 1982). When future effects of the Direct Instruction Follow Through program were examined students continued to perform better on measures of academic achievement six years after termination of the program (Gersten, Darch, & Gleason, 1988).

To review, organize, and summarize empirical findings concerning math instruction and achievement the U.S. government commissioned the National Mathematics Advisory Panel (NMAP) (U.S. Department of Education, 2008). Their findings stated that mathematics curricula in schools should incorporate a progression of skills where advancements are focused, logical, and emphasize topic proficiency as well as skill automaticity. It was also reported that students develop skills across three types of knowledge: 1) Facts, 2) Procedures, and 3) Concepts and that all three of these are important, have "mutually reinforcing benefits", and need to be included and systematically programmed when delivering math instruction. The report highlights the importance of teaching to mastery which can be observed in children that automatically recall facts (e.g., addition problem, signs, vocabulary), employ procedures with proficiency (e.g., algorithms, word problem strategies), and explain when and why they use learned math skills (i.e., conceptual understanding). To best meet these goals early exposure to a well-defined and sequenced curriculum that supports numeracy development is of vital importance. Although most kindergartners enter the classroom with number knowledge, a majority of students in low-income homes begin their schooling with less knowledge than their middle-income peers, which results in early discrepancies in math achievement (U.S. Department of Education, 2008). Prevention and/or early remediation is critical as this achievement disparity generally continues across the entirety of low-income student's education (U.S. Department of Education, 2008).

Importance of Early Numeracy

Early numeracy builds a foundation for a student's acquisition of math skills. Teaching and mastery of arithmetic pre-skills in a systematic fashion can create a base for comprehending strategies and algorithms introduced in later grades (Gersten, Darch, & Gleason, 1988). Inadequate math performance during Kindergarten can impact a student's later achievements in math. Students classified as low performers on "numbers and operations" during the spring of their Kindergarten year displayed an increased risk for performing low in third grade math (Missall, Mercer, Martinez, & Casebeer, 2012). According to the Standards for Number and Operations, during their early years in school students should develop an understanding of numbers, number sense and number operations, acquiring accuracy and fluency with computation (NCTM, 2000). Students' development of number sense was tracked during their initial years in school, finding their development of number sense (defined as counting skills, knowledge of numbers and set transformations) was strongly related to their math achievement at the conclusion of first grade (Jordan, Kaplan, Locuniak, & Ramineni, 2007). Students require the foundational skills built through early numeracy to transition from their early years of schooling through graduation. For students to successfully transition from early numeracy skills to more complicated mathematical instruction, computational fluency, with proportion and whole number operations, development of conceptual understandings and mathematical vocabulary must be focused upon (VanDerHeyden et al., 2011).

While the current early numeracy assessments and interventions available to school psychologists are robust screeners, they may lack a connection to the classroom curriculum and may not aid in shaping behavior through mathematical vocabulary to encourage the acquisition of advanced math skills. Aside from the benefits to a student's math abilities, early numeracy is a valuable component to building language in young students, introducing words and symbols with corresponding meanings and definitions. The Communication standards in the Principles and Standards for School Mathematics (NCTM, 2000) concur, stating that students should be able to communicate their mathematical thought processes and should utilize the mathematical language to express ideas. Teaching techniques including explicit instruction and repeated exposure can assist students in learning and retaining necessary math vocabulary (Riccomini, Smith, Hughes, & Fries, 2015). The relationship between early numeracy, early literacy and future achievement outcomes for students has been corroborated through research, in fact the domains of early numeracy and early literacy were found to be highly correlated (Betts, Pickart, & Heistad, 2009). This suggests that these skill areas overlap. While there remains a deficit in the literature regarding incorporating mathematical language into early numeracy interventions, it may behoove a student to acquire mathematical vocabulary along with early literacy skills. There remain many unknowns in measuring young student's mathematical capacities including the value of skills related to number sense, instructional practices and when number sense skills can be measured with reliability (VanDerHeyden, 2010), further encouraging advancements with empirical support in this area.

At the present time the field of school psychology lacks tools to offer evidence-based remediation in early mathematics for struggling students. Although research clearly demonstrates valid and efficient models of instruction for beginning learners, practitioner implementation remains inadequate. Research has demonstrated the importance of mathematical instruction for students, beginning at an early age, however outcome data indicates students are not achieving at expected levels in mathematics. To reach the educational goals outlined by the NMAP (U.S. Department of Education, 2008) and to align with the principles of the NCTM (2000) it is imperative to develop and implement effective early numeracy assessments and interventions. One step toward realizing these goals is the development and distribution of assessment and intervention resources validated to prevent and remediate math achievement deficits.

CHAPTER II

REVIEW OF LITERATURE

Defining Early Numeracy

Overall, number sense is conceptualized as obtaining counting skills, demonstrating proficiency with magnitude approximations of objects, being able to determine the numeral value of a small quantity and developing an ability to complete basic operations. Advanced development of number sense includes an understanding of how to compose and decompose whole numbers, place value and the meaning of number operations (U.S. Department of Education, 2008). According to the Principles and Standards for School Mathematics (NCTM, 2000), an indication of number sense in children is flexibility in thought regarding numbers. However, in experimental research there lacks a consensus of what constitutes the necessary competencies of early numeracy. Although a consensus has not been explicitly agreed upon, there are commonly included skills across the early numeracy research that are highlighted as instrumental for the adequate development of a student's numeracy in their early years of formal schooling (see Table 1 for a summarization).

Table 1. General Skills Comprising Early Numeracy

General Skills Comprising Early Numeracy						
	Purpura, Reid, Eiland and Baroody (2015)	Purpura and Lonigan (2015)	Lee, Lembke, Moore, Ginsburg and Pappas (2012)	Jordan, Kaplan, Oláh and Locuniak (2006)	Lago and DiPerna (2010)	Clarke and Shinn (2002)
Counting Skills						
Oral Counting	X	X	X	X	X	X
Number Identification	X	X	X		X	X
One-to-One Relationships	X	X		X	X	
Cardinality	X	X		X		
Subitizing	X	X				
Counting a Subset	X	X				
Number Combinations						
Addition	X	X	X	X	X	
Subtraction	X	X	X	X	X	
Numeral Comparisons						
Comparing Sets	X	X				
Comparing Numbers	X	X		X		
Number Skills						
Quantity Discrimination	X	X	X	X	X	X
Order/ Sequencing	X	X	X	X		X
Numeral Fluency					X	X
Mathematical Applications						
Estimation	X			X	X	
Shapes					X	
Measurement					X	
Story Problems	X	X		X		

General Skills Comprising Early Numeracy (Continued)						
	VanDerHeyden et al. (2011)	Jordan, Kaplan, Locuniak, & Ramineni (2007)	Floyd, Hojnoski, & Key (2006)	Lembke & Foegen (2009)	Methe, Hintze, & Floyd (2008)	VanDer-Heyden et al. (2004)
Counting Skills						
Oral Counting		X	X		X	X
Number Identification		X	X	X	X	X
One-to-One Relationships	X		X	X	X	X
Cardinality	X					
Subitizing	X					
Counting a Subset						
Number Combinations						
Addition	X	X				
Subtraction	X	X				
Numeral Comparisons						
Comparing Sets	X					
Comparing Numbers		X				
Number Skills						
Quantity Discrimination		X	X	X		
Order/ Sequencing	X	X		X	X	
Numeral Fluency			X			X
Mathematical Applications						
Estimation						
Shapes	X					X
Measurement						
Story Problems		X				

A majority of studies investigating early numeracy have incorporated measures of oral counting, number identification, one-to-one relationships, quantity discrimination and order/sequencing, with only half addressing number combinations. Few early numeracy studies examined numeral comparisons, mathematical applications and emphasized the development of fluency. Although the literature lacks a consensus on the necessary skills that compose early numeracy, the overarching theme of current research is to establish the foundational requirements a student must meet to be considered competent in informal mathematics and capable of transitioning, and being successful, in formal mathematics. Informal mathematics can include counting skills, numeral comparisons and number skills. Formal mathematics relates more to the demonstration of number combinations and mathematical applications. However, the relationship between informal math knowledge and formal math knowledge has been found to be accounted for by numeral knowledge (Purpura, Baroody, & Lonigan, 2013). Numeral knowledge requires a student to both identify a number and link the number to a quantity. A lack of numeral knowledge could act as a barrier to a student's formal math development (Purpura et al., 2013), emphasizing the importance of developing a student's numeracy skills.

Given the importance of early numeracy for educational success, the field lacks sufficient research on early numeracy assessments geared towards identifying a student's skill deficit with interventions that target a student's knowledge gap. Additionally, school psychologists require materials that will prepare a student to engage in their classroom curriculum. The general education curriculum for early numeracy often lacks differentiation for struggling students. Early numeracy assessments with corresponding interventions are needed that can be utilized for intensive intervention and build a foundation for students to later acquire mathematical concepts, problem-solving skills and conceptual knowledge.

Early Numeracy Assessments

There is a strong research base supporting assessment measures of early numeracy and their technical adequacy for the purposes of screening, however these assessments do not necessarily provide a measure of student progress on outcomes that are important to the student's engagement in the classroom and their acquisition of advanced math skills. Early numeracy assessments in the current literature include measures of mathematical tasks that represent the construct of early numeracy. While there is a strong research base supporting the reliability and validity of early numeracy assessments (Floyd, Hojnoski, & Key, 2006; Lee, Lembke, Moore, Ginsburg, & Pappas, 2012; Lembke & Foegen, 2009; Methe, Hintze, & Floyd, 2008; Purpura & Lonigan, 2015; VanDerHeyden et al., 2004), very few studies exist that show how these assessments link to instructional decision making and increased student math achievement.

The Tests of Early Numeracy (TEN) (Clarke & Shinn, 2002) are a widely used, standardized assessment protocol. The TEN includes measures of Oral Counting (counting orally from 1-100), Number Identification (identifying numbers 1-10 for kindergartners and identifying numbers 1-20 for first grade students), Quantity Discrimination (selecting between larger and smaller quantities) and Missing Number (completing a three-number sequence) (Clarke & Shinn, 2002). Current research supports the TEN to screen students and to measure student progress. Specifically, studies have been conducted demonstrating that Quantity Discrimination, Missing Number and Number Identification (TEN) are assessments can be used to screen students in kindergarten and first grade (Lembke & Foegen, 2009). Number Identification, Quantity Discrimination and Missing Number (TEN) were also shown to effectively monitor student's progress in mathematics over the course of seven months, with significant growth observed on all three measures (Lembke, Foegen, Whittaker, & Hampton, 2008). The Tests of Early

Numeracy Curriculum-Based Measurement (TEN-CBM) measures of Quantity Discrimination and Missing Number displayed the most predictive power of student's future math performance on a statewide third grade assessment (Missall, Mercer, Martinez, & Casebeer, 2012). Although research provides evidence that the TEN could assist in mathematical prevention, it is important to ensure growth on the TEN is depicting acquisition of math skills and knowledge. Growth on these measures of early numeracy, and subsequent assumptions about student learning, could be misleading if it lacks relation to the domain of mathematics (Clarke, Baker, Smolkowski & Chard, 2008); especially since the accuracy in classifying a student as having a math disability was found to be primarily driven by the math screening measures of CBM Computation and CBM Concepts/Applications (Fuchs et al., 2007).

Current early numeracy assessments display technical adequacy. However, many relationships remain correlational, without adequately assessing the outcomes relevant to a student's classroom curriculum and the acquisition of higher order math skills that require abstract thinking, conceptualization and application. If the goal of building a strong foundation of early numeracy skills is to assist a student in engaging in the classroom, promote their acquisition of advanced math skills and to build accurate and fluent responding, early numeracy assessments with corresponding interventions should mirror these goals.

Early Numeracy Interventions

The field of academic interventions targeting mathematics demands the construction of early numeracy interventions that build gateway and numeracy skills. The current research examining early numeracy interventions is limited, and since academic assessments are intended to guide academic interventions this area needs to be further developed.

Current research indicates early numeracy interventions have the potential to prevent and remediate mathematical difficulties (Bryant et al., 2011; Clarke et al., 2014; Codding, George, Ferreira, Chan-Iannetta, & Volpe, 2011). First grade students who received a preventative intervention targeting early numeracy performed better on measures of mathematical progress monitoring and measures concentrated on whole number computation, with 45% of the students no longer being classified as at-risk in math (Bryant et al., 2011). Specifically, the intervention included tasks of counting (principles of counting and counting sequences), tasks of number knowledge (comparisons between numbers, ordering numbers and placing numbers in a sequence), tasks requiring partitioning out numbers (composing numbers, decomposing numbers and part-whole relationships), and number combinations (completing fact families, part-part-whole relationships and facts). However, the intervention failed to result in differences on student's problem-solving, a more advanced mathematical skill (Bryant et al., 2011).

Further supporting the potential benefits of early numeracy interventions, the Kindergarten Peer-Assisted Learning Strategies in Mathematics (KPALS) intervention, targeting number knowledge through number concepts, number combinations and quantity comparisons, improved student performance on a standardized assessment and on the measures Number Identification and Missing Number from the Tests of Early Numeracy (Clarke & Shinn, 2002) (Codding, George, Ferreira, Chan-Iannetta, & Volpe, 2011). However, it failed to improve student performance on the measure Quantity Discrimination from the Tests of Early Numeracy (Clarke & Shinn, 2002) (Codding, George, Ferreira, Chan-Iannetta, & Volpe, 2011). A remediation intervention, called ProFusion, targeted whole-number skills for at-risk first-grade students. ProFusion utilized models, examples, and academic feedback to teach small groups for a 30-min duration. Students displayed significantly higher gains on a measure of whole-number conceptual understanding when compared to students who did not receive the ProFusion intervention (Clarke et al., 2014).

The acquisition and mastery of early numeracy concepts is valuable for student progress and success through their formal education. However, to adequately and accurately address student's skill deficits the field requires materials that build gateway and numeracy skills connected to the classroom curriculum and encourage the acquisition of advanced mathematical skills. Additionally, to improve transparency regarding math expectations for young learners empirically valid assessments and interventions should align with a standardized early numeracy skill hierarchy.

A Skill Hierarchy for Early Numeracy

The instructional hierarchy has frequently been discussed in the context of reading. Traditionally, it is understood that for a learner to acquire a novel skill they must 1) acquire the skill, 2) demonstrate fluency, 3) engage in skill generalization across contexts and finally, and 4) modify, or adapt, the skill as necessary to new demands (Daly, Lentz & Boyer, 1996). The literature suggests for a learner to reach the stage of generalization they must first demonstrate accurate and fluent responding on the desired skill, with automaticity of responding being the main antecedent to generalization (Daly et al., 1996). Accuracy training through modeling of responding and prompting tends to occur separate from the context, while it is argued that fluency building needs to occur in context to encourage generalization. When targeting early literacy skills, research found that generalization required programming to ensure it occurred (Duhon et al., 2010). Additionally, Duhon et al. (2010) examined the implementation of cued responding and response training through examples, finding that generalization techniques for early literacy skills were student dependent. Research indicates that for generalization to occur it may be necessary for the trained behavior to be highly similar in topography to the behavior desired through generalization (Poncy, Duhon, Lee & Key, 2010). A common stimuli used to cue students was found to be an effective generalization technique for student's building accurate word reading (Mesmer et al., 2010).

Formal mathematics includes a hierarchy of skills that build upon each other and culminate, although prior research has been inconclusive regarding skill generalization. Schutte (2015) found following implementation of practice and procedural instruction, students fluent (40 DCPM) in addition generalized their skills to subtraction problems; however other research also found that fluent responding on addition problems did not generalize to acquiring fluent responding on subtraction problems, even after conceptual lessons were implemented (Poncy et al., 2010). According to the Principles and Standards for School Mathematics (NCTM, 2000) mathematical learning requires a curriculum where accumulated ideas are communicated and revisited. There lacks a similar established skill hierarchy for early numeracy and research regarding early numeracy skills generalizing to formal mathematics remains under researched. It is debated what skills are necessary, at what age and in what order for early mathematics, however there is a deficiency of applied data regarding sub-skills that most adequately display number sense and a recommended skill sequence (Methe, Hintze, & Floyd, 2008). Further emphasizing the importance of a skill hierarchy, 2nd through 5th graders who received a fluency intervention targeting math computations progressed, after obtaining mastery, through a pre-determined scope and sequence of computational math skills. Across grade levels, student's achieving mastery for a computation skill that occurred previously in the skill hierarchy had a positive relationship with the mastery of connected, more complex future computation skills (VanDerHeyden & Burns, 2009). This research indicates it is important that students acquire, build fluency and achieve mastery in a prerequisite skill to have a foundation for future development of higher order math skills.

For an Early Numeracy skill hierarchy, some gateway skills have previously been identified (Baglici, Codding, & Tryon, 2010) including measures of Oral Counting and Number Identification (TEN). The measure of Missing Number (TEN) appeared to evaluate the main components of number sense, significantly predicting student's performance on computation in first grade (Baglici, Codding, & Tryon, 2010). A scope and sequence of skills for early numeracy should clearly define and delineate gateway and numeracy skills that gradually culminate to assist students in transitioning from informal mathematics to formal mathematics.

Operating under a skill hierarchy is important to aid in the problem-solving process teachers and professionals encounter when addressing a student's academic deficits. When a student is unable to perform a skill, it can be the result of multiple factors, one being the lack of a previous skill that is necessary to complete the task (Skinner, Pappas & Davis, 2005). When a student is missing a prerequisite skill, they may know what they should be doing but they are unable to complete the presented task (Skinner et al., 2005). Although the value is evident, there is a deficit in the literature establishing an efficient and comprehensive skill hierarchy for early numeracy with assessments and interventions that can be utilized by school personnel.

Measures & Interventions for Numeracy Development

The Measures & Interventions for Numeracy Development (MIND) are a collection of empirically validated mathematical resources that can be utilized by school psychologists and general school personnel to supplement a student's mathematical curriculum or provide remediation for struggling students. Researchers, specializing in academic interventions and instruction, developed and constructed the Measures & Interventions for Numeracy

Development (Poncy & Duhon, 2017). The MIND utilizes scripted intervention protocols and empirically-validated interventions to provide math instruction in a tiered system of academic supports. The MIND can supplement a student's main instruction, provide skill remediation for mathematical computational deficits or aid in intensive skill acquisition. The foundational principles of the MIND program include short duration yet highly intense empirically-validated interventions operating within a skill sequence framework and informing decisions through assessment data to ensure student mastery. The MIND: EN has proposed a recommended skill hierarchy (Table 2) for students to obtain mastery on for effective and efficient acquisition of early numeracy skills.

Table 2. MIND: EN Skill Hierarchy

MIND: EN Skill Hierarchy	Mastery Criteria
Gateway Skills	
Oral Counting Fluency	Kindergarten: Accurately verbalizing numbers 1-10 in 10 seconds 1st Grade: Accurately verbalizing numbers 1-100 in 100 seconds
Number Identification Fluency	Kindergarten: Automatically identifying randomly administered numerals of 1-10 1st Grade: Automatically identifying randomly administered numerals of 1-100
Number Writing Accuracy	Writing numbers 1-10 with 100% accuracy
Number Writing Fluency	Kindergarten: Writing numbers 1-10 with 30 written DCPM 1st Grade: Writing numbers 1-10 with 60 written DCPM
Numeracy Skills	
Dot-Number	Responding with 100% accuracy and 10 DCPM
Dot-Number-Total Set A	Responding with 100% accuracy and 10 DCPM
Dot-Number-Total Set B	Responding with 100% accuracy and 10 DCPM
Dot-Number-Total Set C	Responding with 100% accuracy and 10 DCPM
Number Combinations	
Addition to 10: Cover, Copy and Compare with Sprint and Self-Graphing	Responding with 100% accuracy
Addition to 10: Explicit Timing	Kindergarten: Responding with 100% accuracy and 20 DCPM 1st Grade: Responding with 100% accuracy and 40 DCPM

In correspondence with the MIND, the development of the MIND: EN Assessments and Interventions were created with the guidelines and instructional recommendations consistent with those used in Direct Instruction. Trademark components of explicit instruction in mathematics include, teacher modeling with consistent language, guided practice with examples and cumulative review, and academic feedback (Doabler & Fien, 2013). The MIND:EN scripted protocols, including student trainings and measures of treatment integrity, were developed to align with evidence-based practices (Doabler & Fien, 2013) including stating clear expectations, beginning with an appropriate number of instructional examples, using consistent phrases across activities, offering straightforward demonstrations, explaining each step of the activity, and allowing the student to frequently practice with corrective and positive feedback. During intervention sessions utilizing the MIND: EN Interventions, students complete task demands while the interventionists provide verbal praise for adherence to the presented tasks and feedback regarding student's accuracy after each 1 min session (Skinner, Fletcher, & Henington, 1996).

Current Study

The purpose of the current study was to determine if implementing early numeracy interventions that align with a standardized scope and sequence of early numeracy skills assisted students in acquiring accurate and fluent responding with basic math facts and assisted them in performing at a higher level on advanced mathematical skills. The Measures & Interventions for Numeracy Development: Early Numeracy (MIND: EN) proposed an early numeracy skill hierarchy, which includes gateway skills followed by numeracy skills and finally number combinations, with skills that gradually build upon each other. Gateway skills include the measures of Oral Counting Fluency, Number Identification Fluency and Number Writing Accuracy and Fluency. Numeracy skills include the measures of Dot-Number and Dot-Number-

Total (Set A, B and C). Number combinations include the measures of accuracy and fluency on Addition to 10. The MIND: EN Interventions will target each student's skill deficit, as determined by the MIND: EN Assessment (see Table 3).

Table 3. MIND: EN Assessments and Interventions

MIND: EN Assessments	MIND: EN Interventions
Gateway Skills	Gateway Skills
Oral Counting Fluency	Oral Counting Fluency
Number Identification Fluency	Number Identification Fluency
Number Writing Accuracy	Number Writing Accuracy
Number Writing Fluency	Number Writing Fluency
Numeracy Skills	Numeracy Skills
Dot-Number	Dot-Number
Dot-Number-Total [Set A]	Dot-Number-Total Set A
	Dot-Number-Total Set B
	Dot-Number-Total Set C
Number Combinations	Number Combinations
Addition to 10 Accuracy	Addition to 10: Cover, Copy and Compare with Sprint and Self-Graphing
Addition to 10 Fluency	Addition to 10: Explicit Timing

Intervention sessions were distributed, frequent, short sessions, as displayed by research to be most effective (Codding et al., 2016). As students obtained mastery on skills, they progressed through the skill hierarchy. In addition to their skill specific intervention, students were administered the MIND: EN Assessment measures of Number Writing Fluency, Dot-Number, Dot-Number-Total and Number-Total daily to assess generalization.

Research Questions

1. Will exposure to the MIND: EN Interventions result in increases in accurate and fluent responding in Dot-Number-Total assessment?
2. Will increases in accurate and fluent responding in the Dot-Number-Total assessment generalize to student scores on addition to 10 problems?

CHAPTER III

METHODOLOGY

Participants & Setting

Participants included four kindergarten students ages 5-6 years old who attended an elementary school in the Midwest. two males, Student H and Student L, and two females, Student B and Student I, composed the participant group. Student I was retained the year before and was completing her second year of Kindergarten.

Study Environment

These students were selected by their teacher as students able to perform gateway skills (Oral Counting, Number Identification and Number Writing Accuracy). Prior to the study students were assessed using the MIND: EN Assessment to determine performance on assessment measures of Oral Counting Fluency (OC), Number Identification Fluency (NI), and Number Writing Accuracy (NW). All four participants met instructional level standards. All assessment data were collected daily in the school's library and daily intervention occurred during the same session also in the school's library. The interventionist was one-on-one with the student participants. When procedural integrity data were collected, a second researcher was present.

General Education Environment

All four participants were in the same Kindergarten class. The classes' main curriculum was Everyday Math by McGraw Hill, a new math curriculum for the Kindergarten teachers that year. Broadly, the core math curriculum targeted numbers and counting with application (birthdays, age), shapes, sorting, use of ten frames, comparisons, dot number correspondence, math symbols (addition, equal, subtraction) and estimation. The classroom teacher also supplemented instruction with KinderMath (West, 2017). This math curriculum teaches number knowledge in chunks through reading, writing then comparing and ordering them (i.e. Numbers

1, 2, 3 then Number 4, the Number 5, then Numbers 0-5). KinderMath also includes units on measurement, shapes, addition and subtraction, graphing, time and money values.

The participant's classroom teacher received a Bachelor of Science in Family Relations and Child Development Specializing in Early Childhood Education and a Master of Science in Child Development. The classroom teacher had been teaching for 22 years, with 16 of those spent as a Kindergarten teacher.

Materials

Each session the participants were provided with a pencil, an assessment packet and the appropriate intervention. The researcher used a timer to monitor the 1-minute timings across administration and when applicable an integrity checklist was completed by a second observer. The interventionist spent the first session explicitly modeling for students how to complete the assessments and intervention, following a scripted protocol across students and sessions. Each time a student transitioned to a new skill in the sequence the interventionist modeled the new intervention. After the initial session the interventionist modeled the intervention procedure one time before each session and complete the example with the student. After the student demonstrated visible understanding with the expectations and procedures, verbal instructions were faded. The students independently completed the intervention with goal setting and performance feedback being provided by the interventionist. In addition, student adherence was monitored and corrective feedback and reinforcement through behavior specific praise and stickers for demonstrating appropriate behavior was provided.

Dependent Measures & Scoring Procedures

Measures & Interventions for Numeracy Development: Early Numeracy (MIND: EN) Assessment (see Appendix A for more information on the MIND: EN Assessment)

Each student was evaluated on the MIND: EN Assessment before MIND: EN Interventions were implemented. Skills assessed and measured by the MIND: EN Assessment included Number Writing Fluency, Dot-Number, Dot-Number-Total and Number-Total. Assessment packets were obtained using the MIND website for each individual student.

Measures & Interventions for Numeracy Development: Early Numeracy (MIND: EN) Interventions (see Appendix B for more information on the MIND: EN Interventions)

After students were evaluated on the MIND: EN Assessment students completed the prescribed skill sequence beginning with the intervention measure Dot-Number. Intervention probes were obtained using the MIND website for each individual student. Skills trained and practiced using the MIND: EN Interventions included Dot-Number, Dot-Number-Total Set A, Set B, Set C and Number-Total. As students achieved mastery they progressed through the MIND: EN skill hierarchy. Mastery criteria were completed once the student met one of the following:

- 3 consecutive days of at least 10 DCPM and 100% accuracy on the intervention measure
- 10 non-consecutive days of 100% accuracy on the intervention measure

Dependent Variable

Once it was verified that all students had the necessary prerequisite skills the Number Writing Fluency, Dot-Number, Dot-Number-Total, and Number-Total assessments were administered to each student to collect baseline data. The dependent variables were student's Digits Correct per Minute performance on the MIND: EN Assessment measures of Dot Number, Dot-Number-Total and Number-Total (Appendix A).

Independent Variable

The independent variables were the MIND: EN Interventions of Dot Number and Dot-Number-Total Set A, Set B, Set C and Number-Total (see Appendix B and Table 4). Each student received intervention an average of four times per week for a total intervention duration of 15 min per session. Daily, skill probes were administered for 3 1-min timings, with the median DCPM score being recorded. Initially, students received the MIND: EN intervention for Number Writing Fluency as well; however, due to time constraints the Number Writing Fluency intervention was not implemented for the duration of data collection. All participants began intervention at the beginning of the skill sequence with the Dot-Number intervention. Treatment sessions concluded when a student met mastery criteria on the final skill in the sequence, which was the Number-Total intervention.

Table 4. MIND: EN Interventions

Intervention	Skill Focus	Intervention Procedure
Number Writing Fluency	▪ Increasing student's fluency on digits written correctly per minute	▪ Student is instructed to look at a numeral and write the same numeral below 0-9 for a one-minute timing.
Dot-Number	▪ 1-to-1 Correspondence ▪ Matching quantities to the associate numbers	▪ Student is instructed to count the dots and write the number in the box that shows how many dots they counted.
Dot-Number-Total Set A	▪ 1-to-1 Correspondence ▪ Matching quantities to the associated number ▪ First criteria in shaping the behavior of composing a number through a number combination	▪ Student counts the number of dots in the top box and writes the corresponding numeral to the right. ▪ Student repeats with the set of dots in the bottom box. ▪ Student circles the addition sign and solves the problem by writing the total.
Dot-Number-Total Set B	▪ 1-to-1 Correspondence ▪ Matching quantities to the associated number ▪ Second criteria in shaping the behavior of composing a number through a number combination	▪ Student circles the addition sign and says what it means. ▪ Student looks at the problem and identifies the numeral. ▪ Student counts dots, writes numeral, and identifies which numeral is bigger. ▪ Student solves problem by counting up from the larger numeral and writing total.
Dot-Number-Total Set C	▪ 1-to-1 Correspondence ▪ Matching quantities to the associated number ▪ Final criteria in shaping the behavior of composing a number through a number combination	▪ Student circles the addition sign and says what it means. ▪ Student looks at the problem and identifies the larger numeral and counts up. ▪ Student solves the problem and writes the total.
Number-Total	▪ Composing numbers through a number combination	▪ Student circles the addition sign and says what it means. ▪ Student looks at the problem and identifies the larger numeral. Counts up to solve. ▪ Student solves the problem and writes the total.

Experimental Design & Analysis

A multiple baseline across participant design was used to evaluate the effect of the MIND: EN Dot Number, Dot-Number-Total and Number-Total interventions on student's DCPM. Data were examined using visual analysis. Baseline data were collected using the MIND: EN Assessment measures of Dot-Number, Dot-Number-Total and Number-Total. Student DCPM data were then collected using the MIND: EN Intervention measures of Dot-Number, Dot-Number-Total Set A, Set B and Set C and Number-Total.

Procedures

Data-Collection

Baseline data (MIND: EN assessments of Number Writing Fluency, Dot-Number, Dot-Number-Total and Number-Total) were collected until a stable level and trend were demonstrated. During treatment sessions, students were first administered the MIND: EN assessments, with skill probes being presented in a counterbalanced order. From the outset, the Number-Total assessment was probed every day; however, due to students learning incorrect and incompatible responses administration of the Number-Total assessment was discontinued until students entered the Dot-Number-Total Set A intervention phase. Upon conclusion of administering the MIND: EN assessments, students completed the intervention aligning with their status in the skill hierarchy. MIND: EN assessment data was collected at the beginning of each intervention session until the interventionist terminated services.

Intervention

Each session was on average 25 min in duration due to the administration of both the MIND: EN assessments and interventions. Each student received intervention an average of four times per week for a total intervention duration of 15 min per session. Initially, students received the MIND: EN intervention for Number Writing Fluency as well; however, due to time constraints the Number Writing Fluency intervention was not implemented for the duration of data collection. All participants began intervention at the beginning of the skill sequence with the Dot-Number intervention. During the Dot-Number intervention students were instructed 1) to count the dots in the box and 2) write the numeral that shows how many dots they counted. Students completed problems as quickly as they could for 3 1-min timings. Students were given verbal praise and the median DCPM score was recorded. After mastery criteria were met students transitioned to the Dot-Number-Total Set A intervention. During the Dot-Number-Total Set A intervention students were instructed to 1) count the number of dots in the top box and write the corresponding numeral to the right, and 2) repeat with the set of dots in the bottom box. Finally, students were instructed to 3) circle the addition sign and 4) solve the problem by writing the total under the equal bar. At this point in the skill sequence students were taught the math vocabulary matching the symbols and their meaning. For example, the interventionist told the student "the plus sign means we are doing addition and when we do addition, we put 3 and 5 together to make a total". The interventionist then counted the dots in both sets of boxes and prompted the student to respond with the total. Then, students completed problems as quickly as they could for 3 1-min timings. Students were given verbal praise and the median DCPM score was recorded. After mastery criteria were met students transitioned to the Dot-Number-Total Set B intervention. During the Dot-Number-Total Set B intervention students were instructed to 1) circle the addition sign and 2) say what it means. Next, students 3) identified the numeral, 4) counted the set of dots and wrote the corresponding numeral. Then students, 5) identified which quantity was larger. Finally, students 6) solved the problem by counting up from the larger numeral and 7) wrote the total under the equal bar. Students completed problems as quickly as they could for 3 1-min timings. Students were given verbal praise and the median DCPM score was recorded. After mastery criteria were met students transitioned to the Dot-Number-Total Set C intervention. During the Dot-Number-Total Set C intervention students were instructed to 1) circle the addition sign and 2) say what it means. Next, students 3) identified which quantity was larger. Finally, students 4) solved the problem by counting up from the larger numeral and 5) wrote the total under the equal bar. Students completed problems as quickly as they could for 3 1-min timings. Students were given verbal praise and the median DCPM score was recorded. Lastly, after mastery criteria were met, students transitioned to the Number-Total intervention. During the Number-Total intervention students were instructed to solve the problem by finding the total. Students completed problems as quickly as they could for 3 1-min timings. Students were given verbal praise and the median DCPM score was recorded. Treatment sessions concluded when a student met mastery criteria on the final skill in the sequence, which was the Number-Total intervention.

Procedural Integrity & Interscorer Agreement

A second observer collected procedural integrity data for 25% of the intervention sessions and for 30% of the assessment sessions. To calculate interscorer agreement (IA), 33% of the assessments were scored by the principal investigator and scored independently by a research assistant trained on the scoring procedures. All disagreements were scored by a third research assistant to determine the correct score. To calculate interscorer agreement (IA), 33% of the interventions were scored by the principal investigator and scored independently by a research assistant trained on the scoring procedures. All disagreements were scored by a third research assistant to determine the correct score.

Procedural Integrity for Intervention Sessions

Procedural integrity was collected for 25% of intervention sessions by a second observer. During intervention administration, the researcher followed a scripted instruction protocol. Once instructions became familiar and comfortable for the students, the scripted instructions were unnecessary, however the math vocabulary was consistently implemented. For the sessions where integrity was collected the researcher demonstrated 100% adherence to the pre-determined procedures.

Procedural Integrity for Assessment Sessions

Procedural integrity was collected for 30% of assessment sessions by a second observer. During assessment administration, the researcher followed a scripted instruction protocol. Once instructions became familiar and comfortable for the students, the scripted instructions were unnecessary. For the sessions where integrity was collected the researcher demonstrated 100% adherence to the pre-determined procedures.

Interscorer Agreement for Intervention Probes

Interscorer agreement was collected for 33% of the intervention probes. From the total intervention probes, 33% of the probes were randomly selected, and a second scorer independently scored them. The second scorer was instructed on the scoring procedures. There was 88% agreement (45 Agreement/ 51 Agreement + Disagreement) on scoring between the principal investigator and the second scorer. When a third scorer examined the probes that demonstrated a disagreement, the agreement remained at 88% (45 Agreement/ 51 Agreement + Disagreement). For intervention sessions across participants inter-scorer agreement ranged from 50% to 100% on intervention probes.

Interscorer Agreement for Assessment Probes

Interscorer agreement was collected for 33% of the assessment probes. Since each assessment packet included three different skills (Dot-Number, Dot-Number-Total and Number-Total) there were 188 total assessment probes administered across participants. From the total intervention probes, 33% of the probes were randomly selected, and a second scorer independently scored them. The second scorer was instructed on the scoring procedures. There was 95% agreement (182 Agreement/ 188 Agreement + Disagreement) on scoring between the principal investigator and the second scorer on individual assessment measures. There was 89% agreement (59 Agreement/ 66 Agreement + Disagreement) on scoring between the principal investigator and the second scorer on assessment packets. When a third scorer examined the probes that demonstrated a disagreement, agreement increased to 94% (62 Agreement/66 Agreement + Disagreement) across the assessment packets and 97% (182 Agreement/188 Agreement + Disagreement) across the individual assessment probes. For assessment sessions across participants inter-scorer agreement ranged from 75% agreement to 100% agreement on assessment packets.

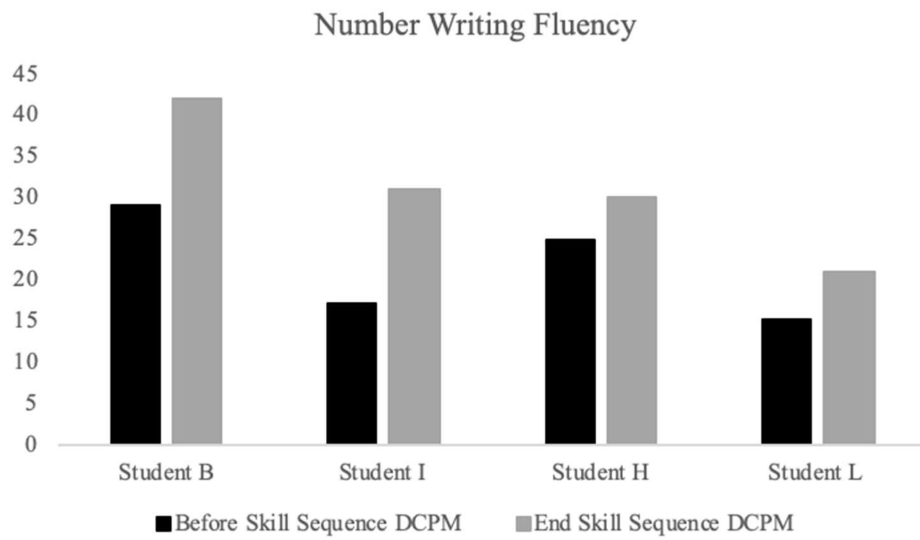
CHAPTER IV

RESULTS

Number Writing Fluency

All students were administered the Number Writing Fluency assessment daily. Initially, students received a Number Writing Fluency intervention along with their specific skill intervention daily to ensure writing skills would not hinder DCPM growth, however due to time constraints the intervention was not administered after Session 27 for Student B, Session 30 for Student I, Session 32 for Student H and Session 30 for Student L. Figure 1 indicates student's digits written correctly in 1 min. (DWCPM) before the student received any intervention. These data were calculated by averaging each student's first three scores on the Number Writing Fluency assessment. Figure 1 demonstrates student's DWPCM near the end of the skill sequence after receiving all interventions. These data were calculated by averaging each student's last three scores on the Number Writing Fluency assessment while they were in the final intervention phase (Number-Total). All students demonstrated growth on their DWCPM, however Student H and Student L did not build their number writing fluency as dramatically as Student B and Student I, based on the results of this aggregated data.

Figure 1. Pre-Intervention versus Post-Intervention Numbers CPM



Dot-Number, Dot-Number-Total and Number Total

A multiple baseline design was implemented across participants (Student H, Student I, Student L and Student B) to evaluate the effect of the MIND: EN interventions (Dot-Number, Dot-Number-Total Set A, Set B and Set C and Number-Total) on student's Digits Correct per Minute (DCPM) and accuracy on the MIND:EN assessments of Dot-Number, Dot-Number-Total and Number-Total. Table 5 displays the participants DCPM averages across the last three sessions of each intervention phase. These data were collected from experimenter developed probes using CBM procedures across assessments of Dot-Number, Dot-Number-Total and Number-Total and interventions of Dot-Number, Dot-Number-Total and Number-Total. Student's DCPM for each skill was used as the dependent variable. Figure 2 displays the participants' accuracy data across sessions and intervention phases. These data were collected from experimenter developed probes across assessments measuring Dot-Number, Dot-Number-Total and Number-Total and interventions targeting Dot-Number, Dot-Number-Total Set A, B and C and Number-Total. Student's percent of accuracy for each skill was used as the dependent variable.

Phase changes occurred after the student reached mastery criteria on the intervention measure. Mastery criteria was defined as student demonstrating 3 consecutive days of 10 DCPM with 100% accuracy on the intervention or demonstrating 10 consecutive days of 100% accuracy on the intervention.

Table 5. Fluency averages on assessments across phases

Fluency Averages on Dot-Number Assessment Across Phases						
	Baseline	Dot-Number	Dot-Number-Total Set A	Dot-Number-Total Set B	Dot-Number-Total Set C	Number-Total
Student B	16	22.3	29.3	36	38.3	37.3
Student I	10	14	16.7	15.3	16.7	22.7
Student H	11	20	6.7	15.3	21	20
Student L	4.7	16.3	20.3	15.7	18	23

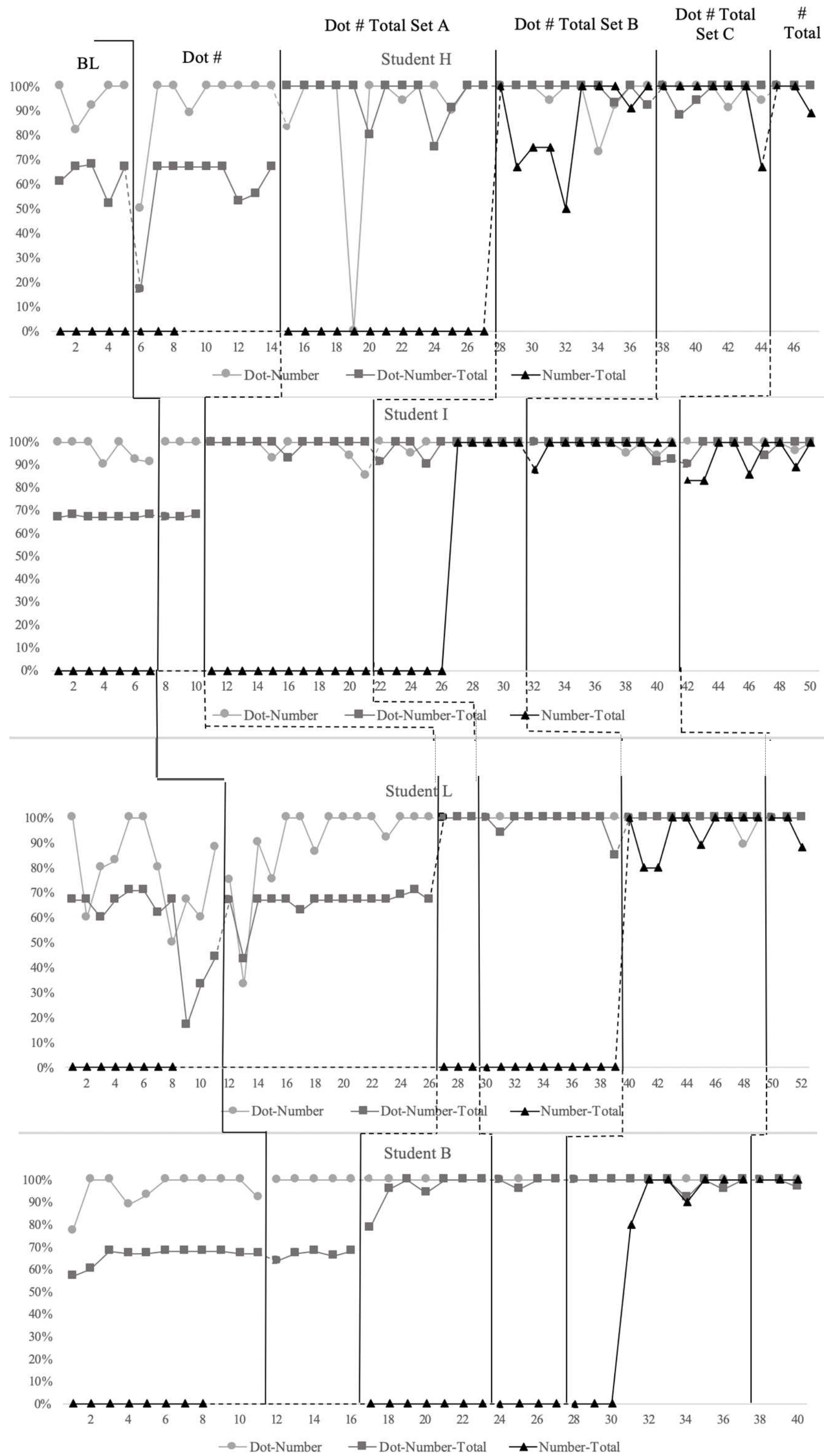
Fluency Averages on Dot-Number-Total Assessment Across Phases						
	Baseline	Dot-Number	Dot-Number-Total Set A	Dot-Number-Total Set B	Dot-Number-Total Set C	Number-Total
Student B	19.7	21.7	20.3	25	21.7	26.3
Student I	13.7	15.7	11.7	10.3	11	16.3
Student H	12.7	11	9	12.3	18.7	14
Student L	2.7	11	12	13	18.7	34.3

Fluency Averages on Number-Total Assessment Across Phases						
	Baseline	Dot-Number	Dot-Number-Total Set A	Dot-Number-Total Set B	Dot-Number-Total Set C	Number-Total
Student B	X	X	0	0	9.3	13.7
Student I	0	X	0	7	6	10.7
Student H	0	X	0	6.7	5	6
Student L	X	X	0	0	7	9.3

X= Number-Total Assessment was not administered

An average of the last three sessions of the Dot-Number intervention phase indicated all students demonstrated growth in their DCPM. Before being instructed on how to accurately complete the Dot-Number-Total problems most students were building fluency but not accuracy. Once the Dot-Number-Total Set A intervention was introduced most participants demonstrated stagnate fluency growth as a result of the procedural skills that were taught as part of the intervention phase. Slow fluency growth on the Dot-Number-Total assessment maintained throughout Dot-Number-Total Set A, Set B and Set C intervention phases as procedural instructions increased. An average of the last three sessions of the Number-Total intervention phase indicated all students demonstrated growth in their DCPM.

Figure 2. Accuracy percentage on assessment measures across participants



Assessment Interpretation: Student H

Baseline: Student H's accuracy baseline data were flat with no clear trend for the measure Number-Total and stable for Dot-Number, whereas the data for the measure Dot-Number-Total exhibited a slight upward trend when baseline concluded.

Dot-Number: Upon introduction of the Dot-Number intervention, Student H's accuracy data for the measure Dot-Number demonstrated a negative change in level, however the data trended upward for a majority of the remaining sessions in the intervention phase, exhibiting stability at the phase change. Student H's accuracy data demonstrated a downward trend for the measure Dot-Number-Total, however the data trended upward for a majority of the remaining sessions in the intervention phase and were trending upward at the phase change. During Session 9, administration of the measure Number-Total was discontinued until the phase change.

Dot-Number-Total Set A: Upon introduction of the Dot-Number-Total Set A intervention, Student H's demonstrated a positive change in level for accuracy on the measure Dot-Number-Total, with slight variability through the intervention phase but demonstrating stability at the phase change. Student H's accuracy data for the measure Dot-Number decreased upon the introduction of the Dot-Number-Total intervention, with variability through the intervention phase. Student H's Number-Total accuracy data were flat with no clear trend throughout the intervention phase.

Dot-Number-Total Set B: Upon introduction of the Dot-Number-Total Set B intervention, Student H's accuracy data demonstrated a trend upward for Number-Total, while other measures (Dot-Number and Dot-Number-Total) maintained. Student H's accuracy data for the measure Number-Total demonstrated variability throughout the intervention phase.

Dot-Number-Total Set C: Upon introduction of the Dot-Number-Total Set C intervention, Student H's accuracy data maintained for all measures. For the measure Number-Total Student H's accuracy data exhibited variability throughout the intervention phase.

Number-Total: Upon introduction of the Number-Total intervention, Student H's accuracy data maintained at the phase change, with the measure Number-Total demonstrating a decreasing trend at the end of the phase.

Assessment Interpretation: Student I

Baseline: Student I's accuracy baseline data were flat with no clear trend for measures of Dot-Number-Total and Number-Total. Student I's accuracy baseline data were trending slightly downward for the measure Dot-Number when baseline concluded.

Dot-Number: Upon introduction of the Dot-Number intervention, Student I's accuracy data exhibited an immediate change in level for the measure Dot-Number. Student I's accuracy data maintained for the measure Dot-Number-Total. All data were stable at the phase change. During Session 8, administration of the measure Number-Total was discontinued until the phase change.

Dot-Number-Total Set A: Upon introduction of the Dot-Number-Total Set A intervention, Student I's accuracy data demonstrated a positive change in level for the measure Dot-Number-Total, with slight variability through the intervention phase but demonstrating stability at the phase change. Student I's accuracy data for the measure Dot-Number maintained upon the introduction of the Dot-Number-Total Set A intervention. Student I's Number-Total accuracy data were flat with no clear trend throughout the intervention phase.

Dot-Number-Total Set B: Upon introduction of the Dot-Number-Total Set B intervention, Student I's accuracy data demonstrated an increase for Dot-Number, while they decreased for the measure Dot-Number-Total. Student I's Number-Total accuracy data were flat until Session 27. During Session 27, Student I's accuracy data demonstrated an upward trend and maintained stability until the phase change.

Dot-Number-Total Set C: Upon introduction of the Dot-Number-Total Set C intervention, Student I's accuracy data maintained for all measures, except Number-Total which exhibited a negative level change.

Number-Total: Upon introduction of the Number-Total intervention, Student I's accuracy data decreased for the measures Number-Total and Dot-Number-Total. However, Student I's accuracy data were trending upward on all measures at the end of the phase.

Assessment Interpretation: Student L

Baseline: Student L's baseline accuracy data were flat with no clear trend for Number-Total, whereas baseline accuracy data for the measures of Dot-Number and Dot-Number-Total were trending upward when baseline concluded.

Dot-Number: Upon introduction of the Dot-Number intervention, Student L's accuracy data displayed a negative change in level for the measure Dot-Number, however data trended upward for a majority of remaining sessions in the intervention phase, with stability at the phase change. Student L's accuracy data trended upward for the measure Dot-Number-Total with stability through the intervention phase and at the phase change. During Session 9, administration of the measure Number-Total was discontinued until the phase change.

Dot-Number-Total Set A: Upon introduction of the Dot-Number-Total Set A intervention, Student L's accuracy data changed in level for the measure Dot-Number-Total, while the measure Dot-Number increased, with both demonstrating stability throughout the phase. Student L's Number-Total accuracy data were flat throughout the intervention phase.

Dot-Number-Total Set B: Upon introduction of the Dot-Number-Total Set B intervention, Student L's accuracy data maintained for all measures, except on the measure Number-Total which were flat throughout the intervention phase.

Dot-Number-Total Set C: Upon introduction of the Dot-Number-Total Set C intervention, Student L's accuracy data maintained at the phase change, however Student L's accuracy data demonstrated variability throughout the intervention phase.

Number-Total: Upon introduction of the Number-Total intervention, Student L's accuracy data maintained at the phase change across all measures, however the measure Number-Total demonstrated a decreasing trend at the end of the phase.

Assessment Interpretation: Student B

Baseline: Student B's baseline accuracy data were flat with no clear trend for the measures of Number-Total and Dot-Number-Total, while the measure Dot-Number was trending downward.

Dot-Number: Upon introduction of the Dot-Number intervention, Student B's accuracy data for the measure Dot-Number demonstrated a slight change in level, with stability through the intervention phase and at the phase change. Student B's accuracy data demonstrated stability, without a significant change in trend, for Dot-Number-Total. During Session 9, administration of the measure Number-Total was discontinued until the phase change.

Dot-Number-Total Set A: Upon introduction of the Dot-Number-Total Set A intervention, Student B's accuracy data changed in level for Dot-Number-Total, trending upward throughout the intervention phase. Student B's accuracy data for the measure Dot-Number maintained upon introduction of the Dot-Number-Total intervention, while Number-Total's accuracy data were flat throughout the intervention phase.

Dot-Number-Total Set B: Upon introduction of the Dot-Number-Total Set B intervention, Student B's accuracy data maintained for all measures.

Dot-Number-Total Set C: Upon introduction of the Dot-Number-Total Set C intervention, Student B's accuracy data maintained for measures Dot-Number and Dot-Number-Total at the phase change. Student B's accuracy data for the measure Number-Total demonstrated an upward trend on Session 31 and maintained throughout the intervention phase.

Number-Total: Upon introduction of the Number-Total intervention, Student B's accuracy data maintained for all measures (Dot-Number, Dot-Number-Total, Number-Total).

CHAPTER V

DISCUSSION/CONCLUSIONS

Discussion

The current study found that exposure to the MIND: EN interventions increased student's accurate responding on the Dot-Number, Dot-Number-Total and Number-Total assessments. Visual analysis of the data indicated that baseline data across participants were stable and flat with no clear trend for the measure of Number-Total across all participants for data of DCPM. The accuracy data for the measure Number-Total were flat with no clear trend across the Dot-Number phase, where daily probing was discontinued due to student's learning incorrect procedures. At the Dot-Number-Total Set A intervention phase, Number-Total was re-introduced across all participants, however it remained flat with no clear trend. For the measure Number-Total each student demonstrated generalization of procedural skills at different points in the intervention sequence. At the Dot-Number-Total Set B phase change, Student H's accuracy data changed in level. Mid-way through Student I's Dot-Number-Total Set B intervention phase, generalization occurred as seen through Number-Total's accuracy data trending upward. At the Dot-Number-Total Set C phase, Student L's accuracy data changed in level at the phase change, while Student B's data trended upward mid-way through the intervention phase. All students demonstrated a stable increase in accuracy throughout the Dot-Number-Total Set C and Number-Total phases.

Each participant generalized their number combination skills at a point in the intervention sequence, although generalization points were student dependent. Student's fluency responses were highly variable. The findings from the present study suggest that it is not necessary for a student to demonstrate fluent responding before generalization can occur if they build accurate responding through common procedural skills.

All students began the study not being able to accurately respond to the Number-Total measure (i.e. sums to 10). The Number-Total measure assessed a student's ability to compose a number through an additive number combination. The probe included a plus sign and equal bar, cues that became familiar to the students through intervention sessions. The Dot-Number-Total Set A, Set B and Set C interventions were designed to shape student behavior to performing traditional number combinations, while training necessary vocabulary (e.g. plus sign, equal sign). These common stimuli programmed generalization, although individual student responding was variable within the skill sequence.

Currently there lacks coherence in the definition of early numeracy, however the literature demonstrates two broad categories: informal and formal mathematics. Previous research has indicated that numeral knowledge is required for a student to bridge between the two (Purpura, Baroody, & Lonigan, 2013). The results from this study support that a student's ability to assign visual numerals to quantities is an important part of their development of number combination skills. Additionally, the results from this study contributes to the current literature base because it suggests that a student learning the meaning of mathematical symbols with associated vocabulary may contribute to their generalization of number combination skills to novel problems.

Implications for Practice

Given the importance of early numeracy for future educational success, the field of school psychology lacks sufficient research on early numeracy assessments with corresponding interventions that target a student's skill deficits. Unfortunately, the general education curriculum for early numeracy often lacks differentiation for struggling students. As educational environments move toward working within a framework of multi-tiered systems of support, school psychologists will require materials that will prepare a student to engage in their classroom curriculum. The proposed early numeracy assessments with corresponding interventions demonstrated improvement in accuracy on measures of early numeracy for a student requiring remediation and students requiring instruction. If these foundational skills aid students in later acquisition of mathematical concepts, problem-solving skills and conceptual knowledge, practitioners and educators would have a sequence of early numeracy skills to transition students through, much like that widely accepted for early literacy skills.

Limitations

This study has a variety of limitations. Data were collected using a small sample size from one public school in the Midwest. Additionally, the proposed early numeracy measures require replication across populations, settings (individual, small group, class-wide) and grades (1^{st} and 2^{nd}). Although data showed clear increases in accurate responding across intervention phases for each of the students, there is a lack of formal data on the reliability and validity of the MIND: EN materials. Furthermore, the interventions were time intensive and inefficient due to strict adherence to the scripted protocol, which anecdotally appeared to interfere with student attentiveness. While a standard protocol approach allows standardization across sessions and interventionists, which ensured each participant received the same instructions in the same format, it can hinder student engagement due to the repetition. Behavioral observations were not formally collected during treatment sessions; however, student's observed problem behaviors (i.e. non-compliance with directions, work refusal) appeared to increase as sessions continued and correlate with decreased DCPM and Accuracy on assessments and interventions.

Future research will need to examine the feasibility of implementation in applied settings. While the presented data are encouraging, procedures require refinement (i.e. streamline scripts) and external validity of the MIND: EN measures needs to be investigated.

Conclusion

At the present time the field of school psychology lacks tools to offer supplementation and remediation in early mathematics for struggling students. Although research clearly demonstrates valid and efficient models of instruction for beginning learners, practitioner implementation remains inadequate. The current study called for the exploration of early numeracy assessments and interventions including what and how to target skill deficits at the Tier 1, Tier 2 and Tier 3 levels of tiered interventions. Data demonstrated across 4 participants that exposure to the MIND: EN interventions increased student's accurate responding on the Dot-Number, Dot-Number-Total and Number-Total assessments.

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APPENDIX A

Measures & Interventions for Numeracy Development: Early Numeracy Assessments

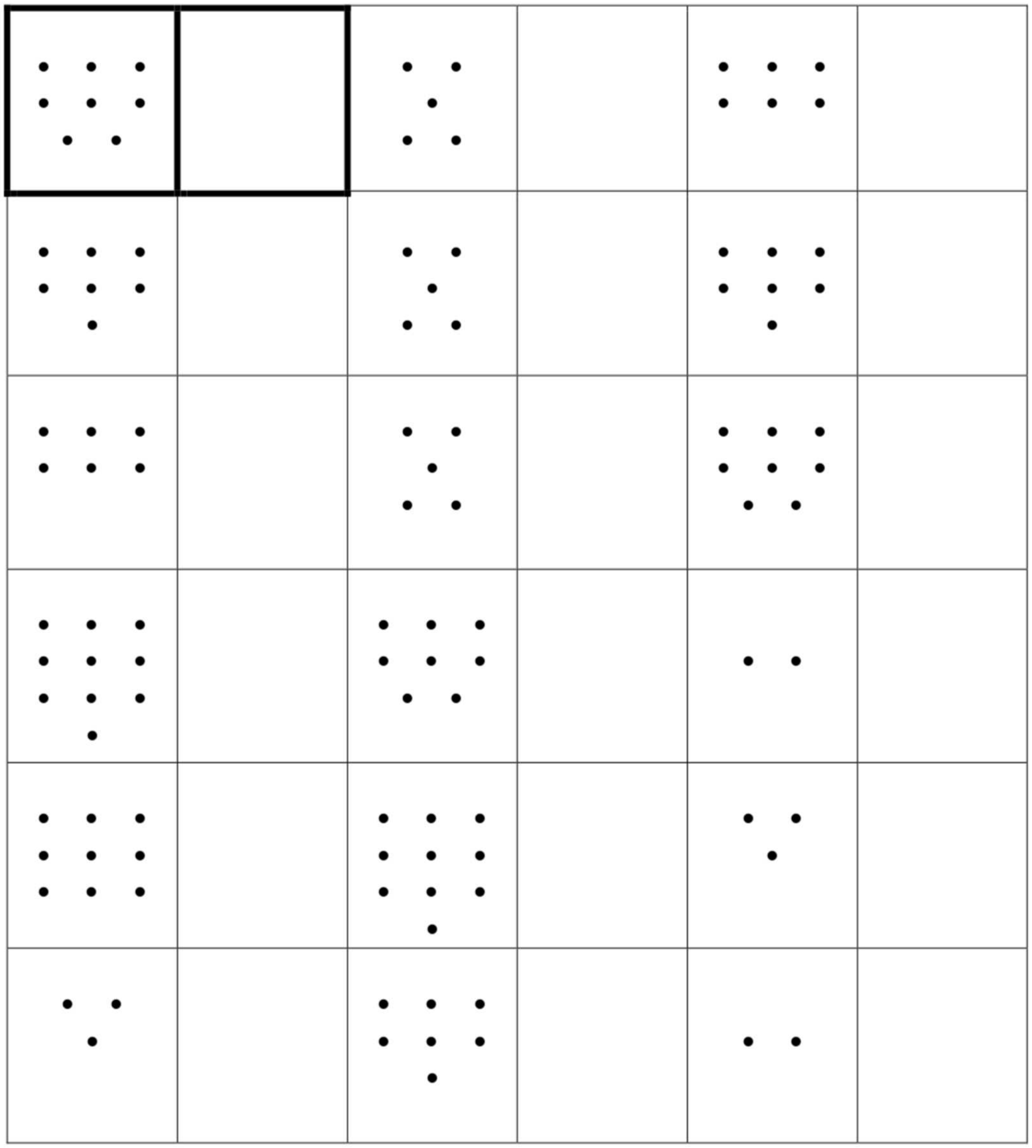
Number Writing Fluency Assessment **Page 1**

Name: ______________________________ Date: ________________________________

0	1	2	3	4	5	6	7	8	9

Dot-Number Assessment **Page 1**

Name: ____________________________ Date: _____________________________



Dot-Number-Total Assessment **Page 2**

Name: ________________________ Date: __________________________

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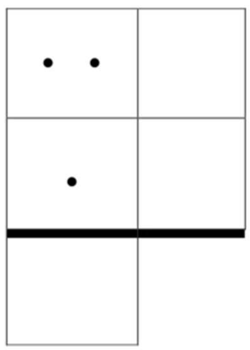

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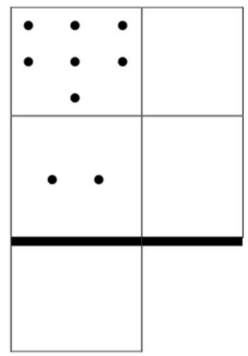

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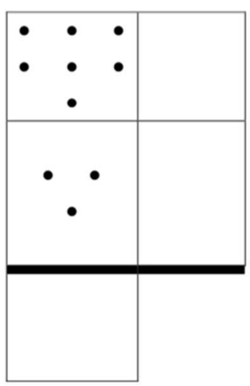

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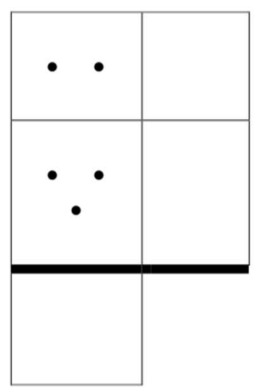
4.



+

Number-Total: Addition to 10 Assessment **Page 1**

Name: ________________________________ Date: ____________________________

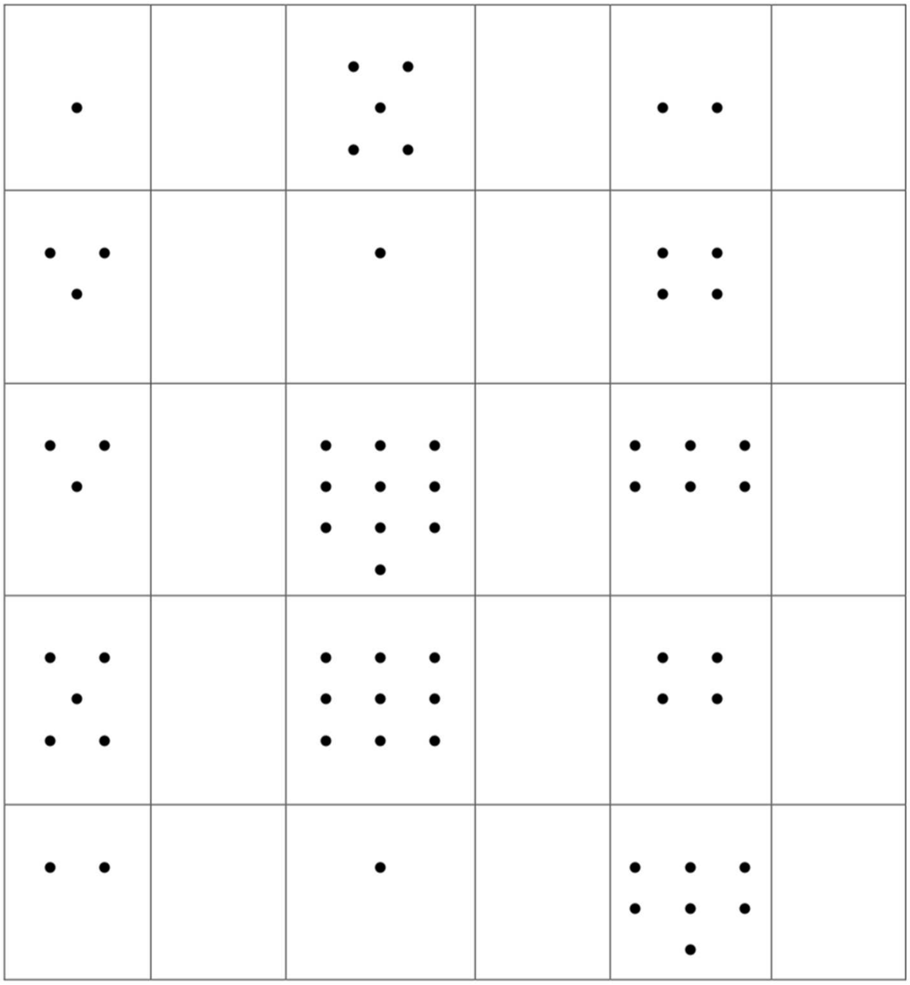
2	4	4	6	2
+ 5	+ 4	+ 3	+ 4	+ 4
____	____	____	____	____
2	3	5	2	2
+ 8	+ 2	+ 2	+ 2	+ 7
____	____	____	____	____
3	7	5	6	3
+ 6	+ 2	+ 5	+ 3	+ 3
____	____	____	____	____
4	5	2	3	4
+ 6	+ 3	+ 2	+ 3	+ 5
____	____	____	____	____
2	3	4	4	5
+ 6	+ 4	+ 2	+ 4	+ 5
____	____	____	____	____

APPENDIX B

Measures & Interventions for Numeracy Development: Early Numeracy Interventions

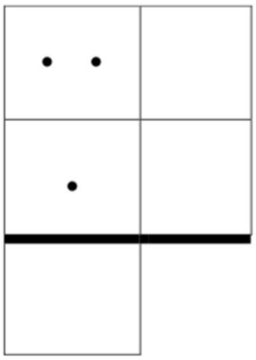
Dot-Number **Set 1 Probe 1**

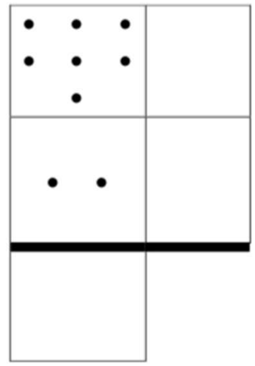
Name: ______________________ Date: ______________________



Dot-Number-Total: Set A **Set 1 Probe 1**

Name: ________________________ Date: __________________________

1.
+


2.
+


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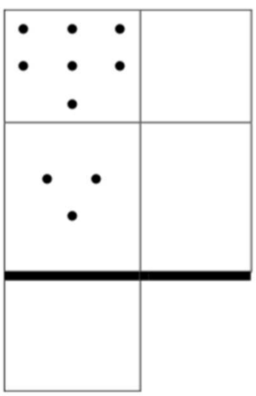
+


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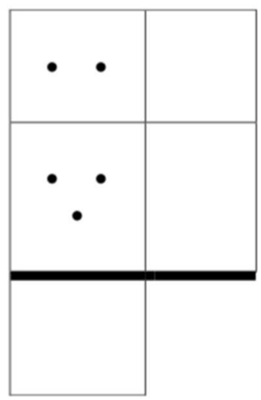
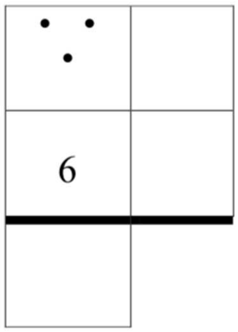
+


Dot-Number-Total: Set B **Set 1 Probe 1**

Name: ____________________ Date: ____________________

1. +


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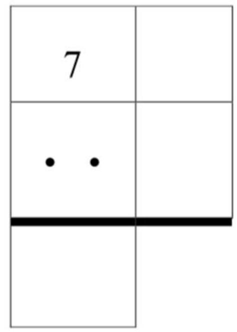

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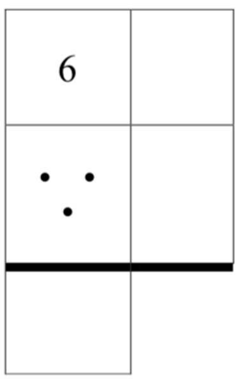

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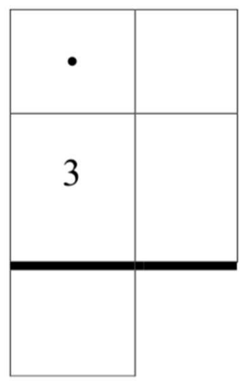

Dot-Number-Total: Set C **Set 1 Probe 1**

Name: ________________________ Date: __________________________

1.

2	
+ 2	

2.

7	
+ 2	

3.

7	
+ 3	

4.

2	
+ 3	

Number-Total: Addition to 10 — Set 1 Probe 1

Name: ________________________________ Date: ____________________________

1.

7
+ 2

2.

5
+ 0

3.

6
+ 2

4.

4
+ 1

5.

3
+ 3

6.

5
+ 4

Oklahoma State University Institutional Review Board

Date:	09/11/2018
Application Number:	ED-18-113
Proposal Title:	Intervening on Early Numeracy for Curriculum Application and Advanced Math Skill Acquisition
Principal Investigator:	Janna Sanders
Co-Investigator(s):	
Faculty Adviser:	Brian Poncy
Project Coordinator:	
Research Assistant(s):	
Processed as:	Exempt

Status Recommended by Reviewer(s): Approved

The IRB application referenced above has been approved. It is the judgment of the reviewers that the rights and welfare of individuals who may be asked to participate in this study will be respected, and that the research will be conducted in a manner consistent with the IRB requirements as outlined in section 45 CFR 46.

The final versions of any recruitment, consent and assent documents bearing the IRB approval stamp are available for download from IRBManager. These are the versions that must be used during the study.

As Principal Investigator, it is your responsibility to do the following:

1. Conduct this study exactly as it has been approved. Any modifications to the research protocol must be approved by the IRB. Protocol modifications requiring approval may include changes to the title, PI, adviser, other research personnel, funding status or sponsor, subject population composition or size, recruitment, inclusion/exclusion criteria, research site, research procedures and consent/assent process or forms.
2. Submit a request for continuation if the study extends beyond the approval period. This continuation must receive IRB review and approval before the research can continue.
3. Report any unanticipated and/or adverse events to the IRB Office promptly.
4. Notify the IRB office when your research project is complete or when you are no longer affiliated with Oklahoma State University.

Please note that approved protocols are subject to monitoring by the IRB and that the IRB office has the authority to inspect research records associated with this protocol at any time. If you have questions about the IRB procedures or need any assistance from the Board, please contact the IRB Office at 223 Scott Hall (phone: 405-744-3377, irb@okstate.edu).

Sincerely,

Hugh Crethar, Chair Institutional
Review Board

VITA

Janna M. Sanders

Candidate for the Degree of

Doctorate of Philosophy

Thesis: Examining the relationship between medical adherence strategies and intervention implementation with high treatment integrity in educational environments

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Professional Memberships

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School Psychology Graduate Organization