THE EFFECTS OF INDIVIDUALIZING AN EARLY NUMERACY INTERVENTION FOR KINDERGARTENERS STRUGGLING WITH EARLY MATHEMATICS

by

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B.A, (Hons)., University of British Columbia, 2014

A THESIS SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR

THE DEGREE OF

MASTER OF ARTS

in

THE FACULTY OF GRADUATE AND POSTDOCTORAL STUDIES

(School Psychology)

THE UNIVERSITY OF BRITISH COLUMBIA

(Vancouver)

June 2019

The following individuals certify that they have read, and recommend the Faculty of Graduate and Postdoctoral Studies for acceptance, the thesis entitled:

The effects of individualizing an early numeracy intervention for kindergarteners struggling with early mathematics

submitted by Jovanka Durica in partial fulfillment of the requirements for

the degree of Master of Arts

in School Psychology

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Abstract

Numerous longitudinal studies demonstrate that students who perform poorly in mathematics at the end of kindergarten continue to perform poorly throughout elementary school. This finding is critical as early mathematics knowledge is not only vital for later success in mathematics, it is the greatest predictor of overall academic success. Hence, a compelling starting point for intervention is kindergarten; effective intervention in early numeracy would lead to success with later mathematics, and consequently academics in general. The current study employed a multiple baseline design (multiple probe technique) to determine if individualization of a standard protocol early numeracy intervention is effective in improving early numeracy skills of struggling kindergarteners. A functional relationship (3 demonstrations of a basic effect) was found for number identification. Two of the three participants required extensive individualization before this effect was demonstrated. The fourth participant's lack of effect was due to improving performance in baseline, which complicated analysis. Additionally, there was an increase in broad early numeracy skills from pre-baseline to post-intervention for all participants. Implications and future directions for research are discussed.

Lay Summary

Early mathematics knowledge is not only important for later success in mathematics, it is also the greatest predictor of overall academic success. Taking this into account, a logical starting point for intervention in mathematics is kindergarten. The current study examined whether a tailored version of an early mathematics program is effective in improving early mathematics skills of struggling kindergarteners. It was found that students' abilities to recognize numbers was improved.

Preface

The research conducted was approved by the University of British Columbia Behavioral Research Ethics Board (BREB) under certificate H16-03224 and the Catholic Independent Schools Vancouver Archdioceses Research Committee. The present study was conducted by Jovanka Durica (primary research graduate) under the supervision of her research supervisor, Dr. Sterett Mercer. The primary research graduate collected and analyzed the data. A secondary research graduate conducted inter-observer agreement.

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Acknowledgements

First, I would first like to thank my thesis supervisor, Dr. Sterett Mercer who was always available and willing to help whenever I ran into a trouble spot or had a question about my research or writing. Next, I would like to thank the participants of the current study; it was a pleasure working with each participant, and I am forever grateful that I was able to help improve their early math skills. Finally, I must express my very profound gratitude to my spouse, my son, and my parents for providing me with unfailing support and continuous encouragement throughout my years of study and through the process of researching and writing this thesis. This accomplishment would not have been possible without them. Thank you!

Chapter 1: Introduction

Much like struggles with reading, poor mathematics skills are associated with a myriad of serious and life-long problems (National Mathematics Advisory Panel, 2008). A number of longitudinal studies have shown that students who perform poorly in mathematics at the end of kindergarten are likely to continue to perform poorly throughout elementary school (Bodovski & Farkas, 2007; Duncan et al., 2007; Hanich, Jordan, Kaplan, & Dick, 2001; Morgan, Farkas, &Wu, 2009). For example, using a U.S. nationally representative sample of students from the Early Childhood Longitudinal Study–Kindergarten Cohort, Morgan et al. (2009) found that students who entered and exited kindergarten below the 10th percentile were 70% more likely to remain in the lowest 10th percentile five years later.

The prevalence of mathematics difficulty ranges from 3-10%, and although the occurrence of these difficulties is analogous to difficulties in reading, problems with mathematics have received significantly less empirical investigation than problems with reading (Barbaresi, Katusic, Colligan, Weaver, & Jacobsen, 2005; Fuchs, Fuchs, & Malone, 2016; Shalev, Auerbach, Manor, & Gross-Tsur, 2000). Moreover, the lack of attentiveness to difficulties with mathematics, compared to difficulties with reading has not only been evident in research, but also in school settings. Schools are much more likely to provide small-group intervention in reading than in mathematics (Fuchs et al., 2016).

The fact that mathematics difficulties receive significantly less attention than those is reading is astonishing when one considers the importance of mathematics for everyday functioning. Mathematics is embedded into a multitude of everyday tasks such as cooking, grocery shopping, paying taxes, and budgeting household expenses. Furthermore, knowledge of early mathematics concepts is not only a predictor of later math success, it has also been shown

to be one of the most powerful predictors of future academic success in general (Duncan, Dowsett, & Classens, 2008).

If early mathematics knowledge is essential for later mathematics concept development, and if it predicts overall academic success, then it is imperative that there be more research into effective, evidence-based intervention strategies for those who are struggling with these early concepts. Without targeted efforts in kindergarten, the learning gap is likely to persist or even widen. The gap will also become more difficult to remediate over time as students leave kindergarten without a solid foundation from which understanding of increasingly complex mathematics concepts stems (Geary, 1993; Jordan, Kaplan, & Hanich, 2002; Morgan et al., 2009). Effective targeted interventions in early numeracy would ensure success with later math concepts, and thus in the long run, success in everyday functioning.

Chapter 2: Literature Review

Early Numeracy

There are a number of skills that comprise early numeracy, and these skills are either a precursor or critical part of an individual's number sense. Gersten and Chard (1999) describe number sense as "a child's fluidity and flexibility with numbers, the sense of what numbers mean, and an ability to perform mental mathematics and to look at the world and make comparisons" (p. 19). The National Council of Teachers of Mathematics (2000) states that number sense entails "moving from the initial development of basic counting techniques to more sophisticated understandings of the size of numbers, number relationships, patterns, operations, and place value" (p. 79). Thus, early numeracy skills and the development of number sense allow an individual to effectively use early numeracy skills to perform conceptual and procedural mathematics in the real world.

Subitizing is one of the first skills that develops. It is defined as the ability to instantly perceive the quantity of a group, without counting. Young children have an innate ability to subitize, which they may use spontaneously (Klein & Starkey, 1988). Moreover, subitizing is a necessary precursor to counting (Fitzhugh, 1978; Klein & Starkey, 1988). The next skill early numeracy is composed of is magnitude perception and comparison. Magnitude is the size of a number in comparison to other numbers, e.g., as being bigger or smaller. Symbol representation is another element of early numeracy, and it is defined as the knowledge that numerals represent quantities. Counting is also a vital skill composing number sense. Gelman and Gallistel (1978) describe the five implicit principles that represent the inherent constraints of counting. The first of these principles is one-to-one correspondence, which is the principle that each object to be counted must be given one and only one number name. The next principle is stable order,

meaning that the order of the word tags must remain unchanged across all counted sets ("one" is always followed by "two", which is always followed by "three," etc.). Cardinality, the next principle, is that the value of the final word tag stands for the number of items in the counted set. The notion that one can apply counting to anything, or abstraction, is the next principle. Order-irrelevance, or the fact that one can count in any order, is the last principle. These early numeracy skills have been taught within a Response to Intervention (RTI) model, which will be discussed in detail below.

Response to Intervention (RTI)

RTI can be conceptualized in two ways: a process that can be used to identify students with learning disabilities, or a system of multi-tiered instructional supports for all students (Clarke, Smolkowski, Doabler, Baker & Chard, 2011). The multitiered RTI approach allows for early identification of learning difficulties and timely intervention for students at risk for long term challenges. The three tiers of RTI are viewed as three levels of prevention, which represent a continuum of supports for struggling students. The three tiers will be discussed in greater detail below.

Tier 1. At the heart of Tier 1 is high quality, research-based instruction that is culturally and linguistically responsive and aligned to grade level curricular achievement standards (National Center on Intensive Intervention, 2010). Culturally and linguistically responsive instruction means that educators take purposeful consideration of the "cultural, linguistic, and socio-economic factors that may have an impact on students' success or failure in the classroom" (National Center on Intensive Intervention, 2010, p. 9). Taking these factors into account allows teachers to provide differentiated instruction according to the unique way each student learns.

In a well-designed RTI system, primary prevention is effective for about 80% of the student population (National Center on Intensive Intervention, 2010). Using high quality, universal, research-based instruction allows educators to conclude that the remaining 20% of students are not struggling due to ineffective classroom instruction. It permits educators to confidently recommend that these students receive more intensive support at subsequent tiers.

Tier 2. Tier 2 is composed of evidence-based interventions of moderate intensity that address the academic needs of those who are not meeting expectations at Tier 1. These more intensive, secondary interventions are based on adult-led small group instruction, and are very specific in their procedures, duration, and frequency (National Center on Intensive Intervention, 2010). The duration of such interventions is typically 10 to 15 weeks, 3 to 4 times per week, and each session is 20 to 40 minutes (National Center on Intensive Intervention, 2010). Secondary interventions do not occur in isolation, rather they happen in addition to the core curriculum the students are receiving.

Tier 3. At the core of Tier 3 of the RTI process is intensive, data-based, individualized intervention intended to meet the needs of those students who have not responded to evidence-based secondary intervention or other standardized remediation programs (National Center on Intensive Intervention, 2013). First described by Deno and Mirkin (1977), data-based individualization (DBI), the core principle of Tier 3 intervention, is a systematic approach for using assessment data to determine when and how to intervene at the individual level. DBI is based on collecting systematic and frequent student-level data that is analyzed in order to determine which intervention components must be modified when those data indicate inadequate response (National Center on Intensive Intervention, 2013). DBI does not occur in isolation,

rather it is used in conjunction with interventions the student is receiving at the universal and secondary tiers.

Using the DBI framework, an interventionist selects an intervention program, which serves as a "platform" that he or she will change to meet the student's specific needs (National Center on Intensive Intervention, 2013). Once the intervention is implemented, the interventionist uses ongoing progress monitoring data and diagnostic assessment data to evaluate the student's response to the intervention, and determine whether adjustments must be made (National Center on Intensive Intervention, 2013). This process allows for individualized instruction as data are collected for each struggling student which in turn reveals his or her unique academic needs.

Fidelity at each tier of RTI. The quality and fidelity with which interventions at all tiers of RTI are implemented are of crucial importance. Fidelity means that the instruction is delivered as it was intended by the creator, "all elements of content are covered, and session frequency, duration, and group size are consistent with what is recommended" (National Center on Intensive Intervention, 2013). At Tier 1, fidelity of intervention means that all students are taught the same core, research-based curriculum. At Tiers 2 and 3 fidelity of intervention is ensured by the use of standardized, evidence-based academic interventions.

Utility of RTI. Many experts within special education disagree on the utility of RTI as a vehicle for identification of students with learning disabilities, thus using RTI for this purpose has remained somewhat controversial (Clarke et al., 2011; Fuchs, Mock, Morgan, & Young, 2003; Reynolds & Shaywitz, 2009). Research on the use of RTI as a multi-tiered system as a whole lacks support (Baker, Fien, & Baker, 2010; Kovaleski & Black, 2010); however, individual components of the system have been empirically validated. The use of research-based

interventions, as well as research-based instructional practices, has been shown to be effective (Gersten, Chard et al., 2009; Newman-Gonchar, Clarke, & Gersten, 2009). Additionally, using RTI for screening, assessment, and progress monitoring has been supported through scientific research (Fuchs et al., 2007; Foegen, Jiban, & Deno, 2007; Gersten, Beckmann et al., 2009). The use of the RTI model in mathematics research will be discussed below.

RTI Mathematics Research

Tier 1 standard protocol interventions in early numeracy. Evidence-based, Tier 1, or class-wide early numeracy interventions will now be discussed. Early Numeracy in Mathematics (ELM; Chard et al., 2008) is an early numeracy program that has been evaluated as successful in improving earl numeracy skills, engaging the students who partake in it, and appealing to the teachers that implement it. ELM employs research-based instruction design principles that have been shown to be effective with those struggling with mathematics. These principles are utilized in an effort to teach the most essential mathematics knowledge kindergarteners need to develop (Chard et al., 2008)). The instructional design principles, paired with essential math knowledge are key components of the ELM intervention, and are believed to specifically target the learning needs of those students most at-risk (Chard et al., 2008). Because number sense is a crucial component for subsequent learning in mathematics, the intervention targets this skill.

ELM introduces content in a systematic way; it uses a scope and sequence that builds the learning process from initial understanding to mastery (Clarke et al., 2011). To help guide the student through the learning process, scaffolding and explicit, scripted instruction are utilized. Interventionists begin instruction by providing extensive modeling and different representations of the mathematics concepts to be learned (Clarke et al., 2011). These diverse representations are taught using a “concrete-representation-abstract” sequence (Clarke et al., 2011). The

interventionists first work with concrete manipulatives to demonstrate the mathematical concept, then they move to visual representations, and conclude with working with abstract symbols (Clarke et al., 2011).

As the student progresses through the learning process, the instructional supports are gradually removed, and the student gets moved from interventionist modelling to interventionist guided practice, and later from interventionist guided practice to student independent practice (Clarke et al., 2011). The students are also taught to verbalize their thinking as they solve math problems. Verbalization allow for immediate intervention on the part of the instructor if there is an error in the student's comprehension of the mathematical concept. Moreover, in order to ensure mastery of the mathematical content, ELM employs frequent and cumulative review both within and across lessons; repetition and review is essential to mathematics skill retention (Clarke et al., 2011). The effectiveness of the ELM program will be discussed below.

Effectiveness of ELM at Tier 1. In one study exploring the effectiveness of ELM, Clarke et al. (2011) assessed the impact of ELM on the achievement of students at risk for mathematics difficulties. In their study, kindergarten classrooms were randomly assigned to treatment (ELM intervention; $n = 34$) or control (no ELM intervention; $n = 30$) conditions. The study sample was composed of two groups: kindergarten classroom teachers ($n = 65$) and the students in the participating kindergarten classrooms ($n = 64$). In an attempt to minimize any treatment diffusion, only the treatment group of teachers participated in ELM curriculum training, and were asked not to share ELM ideas with the control group teachers (Clarke et al., 2011). Treatment condition teachers received 4-hour ELM curriculum trainings in the fall, winter, and spring of the school year. Fidelity of implementation was measured three times throughout the year.

Five student measures were administered at pretest and posttest to assess the effectiveness of the intervention. The Test of Early Numeracy (TEN, Clarke and Shinn, 2002) was administered. The AIMSweb TEN is composed of four subtests: Oral Counting, Number Identification, Quantity Discrimination, and Missing Number. Each of these subtests is a 1-minute fluency measure that assesses knowledge of key mathematical concepts. Validity and reliability information from Clarke, Baker, Chard, Braun, and Otterstedt (2006), and Clarke and Shinn (2004) indicates that these measures have excellent psychometric properties. In addition to the AIMSweb TEN, the Test of Early Mathematics Ability, Third Edition (TEMA-3, Ginsburg & Baroody, 2003) was administered. The TEMA-3 is a norm-referenced, individually administered measure of early mathematics for children ages 3 years to 8 years, 11 months. It has excellent psychometric properties, and provides information on student strengths and weaknesses in specific areas of mathematics.

Results of the study revealed that those students not at risk for mathematics difficulties in ELM classrooms did not make gains over those in control classrooms (Clarke et al., 2011). When examining the subgroup of children at risk for mathematics difficulties, Clarke et al. (2011) found statistically significant improvements for those classrooms in the ELM program on TEMA-3 raw scores and AIMSweb TEN total score. Hedges's *g* effect sizes were .24 on the TEMA-3 and .22 on the AIMSweb TEN, both of which are small effects.

Chard et al. (2008) evaluated the feasibility of using the ELM program by assessing the program's general effect, the usability of the program, and teacher satisfaction with the program. The researchers utilized 14 elementary schools in a medium-sized district of about 11,000 students. In Year 1 of the study, five schools implemented the initial version of ELM, while 4 schools served as comparison schools. During Year 1 based on teacher feedback and student data

in experimental and comparison schools, ELM was revised during implementation and at the end of the school year. In Year 2, all Year 1 schools implemented the revised curriculum, and 5 new schools served as comparison schools. Only Year 2 data were analyzed, and participants were 254 kindergarten students. The impact of the ELM curriculum was measured by student performance on the Stanford Early School Achievement Test-Fourth Edition (SESAT-2), which was administered at pretest and posttest to all students. Research staff observed ELM classrooms three times across the school year to determine the extent to which teachers were implementing the program as intended. Additionally, teacher interviews were conducted prior to program training and at the end of the year to further assess the feasibility and teacher satisfaction with the ELM curriculum.

Results indicated that students in Year 2 ELM classrooms exceeded the performance of students in Year 2 control classrooms on the SESAT-2, and the different between the groups was statistically significant (Chard et al., 2008). When it comes to fidelity of implementation, using a random sample of fidelity observations, the researchers found that that teachers completed over 80% of the activities in the lesson and that activities not completed were due to time constraints. Teachers also expressed positive views when it came to the overall quality of the curriculum, their knowledge of the curriculum, and the likeliness of using the curriculum again the following year (Chard et al., 2008). In conclusion, ELM seems to be a viable option for improving early numeracy skills, while keeping the student participants engaged, and the teachers to implement it satisfied.

Tier 2 standard protocol interventions in early numeracy. Evidence-based, Tier 2, or small-group early numeracy interventions will now be discussed. ROOTS Foundations for Early Learning in Mathematics is a Tier 2 early numeracy program that has been successful in

improving early numeracy scores, while being simple and engaging to implement. It was co-developed and intended to be used in conjunction with the ELM program discussed previously. The published version of the ROOTS Foundations for Early Learning in Mathematics intervention is called Whole Number Foundations Level K, and this name will be used in the remainder of this document. The Whole Number Foundations Level K is an early numeracy intervention that is designed for children in kindergarten who are struggling with core mathematics content (Clarke et al., 2015). The program teaches children essential foundational knowledge and conceptual understanding of early mathematical concepts including number sense, numbers and operations, and vocabulary (Clarke et al., 2015). The intervention is made up of fifty 20-minute lessons designed for small-group delivery, and is administered three to five times per week in addition to regular classroom math instruction (Clarke et al., 2015).

An additional Tier 2 program that has been evaluated is the Booster Lesson intervention by Bryant, Bryant, Gersten, Scammacca, and Chavez (2008). Booster Lessons occur in small groups using scripted lessons consisting of number, operation, and quantitative reasoning skills (Bryant et al., 2008). The tutoring lessons occur four days per week per session across 23 weeks. Each subskill is designed to be taught over a two-week period, and emphasis is placed on number concepts that are known to be especially difficult for students who struggle with mathematics (Bryant et al., 2008). The effectiveness of each program will be discussed below.

Effectiveness of Tier 2 standard protocol early numeracy interventions. Clarke et al. (2016) examined the effectiveness of using the Whole Number Foundations Level K intervention with small groups of students at risk for mathematics difficulties. In their study, teachers with 1 year of ELM experience and teachers with no ELM experience were randomly assigned to experimental (ELM+ Whole Number Foundations Level K; n = 15) or control (ELM only; n =

14) conditions. The teachers were blocked or stratified based on ELM experience in order to control for biases that may come from systematic differences between the conditions (Clarke et al., 2016). Teachers were then asked to nominate students that they thought would benefit most from small-group math intervention: 140 students were nominated, 67 students from intervention classrooms and 73 students from control classrooms. In the ELM+ Whole Number Foundations Level K classrooms, those students receiving Whole Number Foundations Level K received all of the whole-class ELM instruction. On day 3 of the ELM curriculum, these students did the Whole Number Foundations Level K intervention instead of participating in that day's ELM topics independently at the end of the lesson (Clarke et al., 2016). Participants in the control group participated in the whole class ELM instruction, including the independent math practice. Fidelity was assessed three times over the course of the study, with 4 to 5 weeks of separation between each observation.

Each participant was assessed using the TEMA-3 (PRO-ED, 2007) and AIMSweb TEN (Clarke & Shinn, 2004) described previously. Results indicated that among those students identified as eligible for The Whole Number Foundations Level K, there were statistically significant gains among students provided with The Whole Number Foundations Level K over those in control classrooms on TEMA standard scores, but not the AIMSweb TEN total score. Additionally, the gains made by The Whole Number Foundations Level K intervention students exceeded gains by students who did not receive The Whole Number Foundations Level K by 1 standard deviation on the TEMA standard score but not on the AIMSweb TEN. The differential gain was statistically significant on the TEMA but was not on the AIMSweb TEN.

Bryant et al. (2011) evaluated the effectiveness of the Booster Lesson intervention by utilizing a sample of 161 pre-kindergarten to grade 2 students. Participants were measured using

the Texas Early Mathematics Inventories: Progress Monitoring (TEMI-PM; University of Texas System/Texas Education Agency, 2006) measure, and performance below the 25th percentile was qualification to assignment into the intervention condition. The experimental group consisted of 42 students, while the control group was composed of 119 students. The Booster Lesson group received four 20-minute booster lessons per week in addition to classroom mathematics curriculum, while the control group received only the classroom lesson. In addition to using the TEMI-PM to assign participants to conditions, the measure was also used in the winter and spring to assess student progress; the four subtests (Magnitude Comparison, Number Sequences, Place Value, and Addition/Subtraction) as well as an aggregate total score of the TEMI-PM were used to measure pre and post intervention student performance.

Results using regression discontinuity analysis indicated that students in the experimental condition outperformed comparison students by .5 of a standard deviation and demonstrated statistically significantly higher scores than comparison students on the TEMI- PM Total Score and three of the four subtests. There were no group differences on the Magnitude Comparisons subtest.

In conclusion, the ROOTS intervention seems to be a viable option for improving early numeracy skills of kindergarteners, while the effects of the Booster Lesson intervention are positive for grade one students.

Principles of effective Tier 3 intervention for students struggling with mathematics. There are common intervention features that literature has supported for use for individual students in need of Tier 3 support in mathematics, which will be discussed. Codding and Martin (2016) argue that these core components are matching treatment to skill needs, explicit

instruction, self-instruction, concrete–representational–abstract (C–R–A) instructional sequencing, providing productive opportunities to practice, and incorporating motivation.

Treatment by skill match involves doing more than merely identifying available interventions, it includes a problem-solving approach so that the treatment that is chosen matches the student's level of skill development (Codding & Martin, 2016). Selecting treatments using this problem-solving approach is a two-step process. First, the interventionist must identify the student's strengths and weaknesses in the specific skill. Next, the researcher must use a decision-making heuristic in order to match the student's skill level to an intervention strategy (Codding & Martin, 2016). Explicit instruction entails teaching specific skills and strategies by breaking them down into smaller, and thus more manageable steps (Codding & Martin, 2016). It is didactic instruction in which the interventionist provides detailed explanations of mathematical concepts and procedures. The interventionist demonstrates concepts by modeling, error correction, and guided practice. Self-instruction teaches the student to monitor his or her own problem solving through the use of interventionist modeled prompts (Codding & Martin, 2016). Implemented by students themselves, self-instruction strategies include the use of think-alouds, self-questioning, and simple heuristics (Codding & Martin, 2016). Concrete-representational-abstract instructional sequencing uses visual representations and concrete manipulatives along with numerals to teach mathematical concepts. Research supports the use of manipulatives first, and then fading them to proceed using visual representations (Codding & Martin, 2016). Once students can independently solve mathematical problems using visual representations, abstract symbols are introduced. Productive opportunities to practice mean that the student must be given ample opportunities to practice the skills he or she is learning. This practice must contain a cumulative review, in addition to drill and practice. The intervention must not only teach new

skills; it must also leave room for review of those skills already mastered. Motivation is concerned with the need to incorporate motivators in order to encourage the students to regulate their attention and work ethic (Codding & Martin, 2016). These motivators are especially important for individuals who are struggling with mathematics as they may need more reinforcement in order to regulate their attention on a skill on which they usually perform poorly. The next section will review programs that employ some or all of the elements discussed above.

Tier 3 standard protocol interventions in early numeracy. Evidence-based, Tier 3, or one-on-one early numeracy interventions will now be discussed. Math Recovery is an early numeracy program that has been evaluated for use at Tier 3. It is a one-on-one tutoring program that identifies children who are performing below expectations in an effort to remediate the problem (Smith, Cobb, Farran, Cordray, & Munter, 2013). The program is comprised of research-based strategies for supporting the development of children's numerical reasoning. It also a set of techniques for supporting instructors' acquisition of skills. Instructors use a learning framework and an instructional framework to assess children's arithmetical knowledge and tailor instruction to their current levels of arithmetical reasoning (Smith et al, 2013).

Math Recovery uses intervention features that literature has supported for use for individual students in need of Tier 3: concrete materials to promote conceptual learning, appropriate prompting, allowing students to reach an impasse, appropriately introducing tasks to the students, and being explicit in nature (Smith et al, 2013). The program is diagnostic in nature, meaning that instructors are expected to select instructional tasks and adjust probes and questions as informed by their initial and ongoing assessment of each student's mathematical skills (Smith et al, 2013). It is intended for use in kindergarten through fifth grade. Math Recovery lasts for 12-15 weeks, there are 4-5 sessions per week, and each session lasts 30 minutes.

An additional program evaluated for use at Tier 3 is called focusMath (Styers, Baird Wilkerson, 2011). It addresses student conceptual understanding of a mathematical concept by breaking it apart for the student. Students use new strategies in both guided and independent practice and are continually supported by teachers. These factors help the students to achieve higher levels of mathematical understanding. Each lesson in focusMath is scripted, thus allowing for ease of implementation. The program is intended for use in kindergarten through sixth grade and designed for any student performing below expectations in mathematics. Grade levels consist of three units, each built around a specific curriculum focal point. Each focusMath session is 45-60 minutes, with a recommended 3-5 sessions per week for 4-6 weeks per Unit workbook. The effectiveness of each program will be discussed below.

Effectiveness of Tier 3 standard protocol early numeracy interventions. The effectiveness of using the programs mentioned above with kindergarten students has not been evaluated; however, both programs have been assessed with use for older age groups. Smith et al. (2013) performed a 2-year evaluation of Math Recovery in 20 elementary schools. The participating schools recruited 18 teachers to receive training in Math Recovery and serve as tutors. The tutors selected first grade students to participate in the study by a screening interview and a Math Recovery Initial Assessment. The number of study participants before attrition totaled 517 in Year 1 and 510 in Year 2, of whom 172 received tutoring in Year 1 and 171 received tutoring in Year 2 (Smith et al., 2013). The Year 1 participants were followed until the end of second grade, and the Year 2 participants were followed until the end of first grade (Smith et al., 2013).

The researchers delayed (by either 12 or 24 weeks) the introduction of the Math Recovery intervention for two thirds of the sample. Both proximal and distal assessments that

measured each student's mathematical knowledge at varying time points was utilized. The Math Recovery Initial Assessment, which assesses mathematics attainment in concepts reflected by the intervention, as well as Math Recovery proximal assessments appropriate for the end of the first grade were utilized (Smith et al., 2013). The participants were also assessed using the Applied Problems, Quantitative Concepts, and Math Fluency tests of the Woodcock Johnson III Tests of Achievement (WJ III ACH).

Smith et al. (2013) examined the effects of receiving Math Recovery tutoring at the end of first grade by combining Year 1 and Year 2 participants. The results indicated large effects on the Math Recovery Initial Assessment (effect size 1.04), and small to moderate effects (effect sizes of .15–.30) on the Math Recovery proximal measure and the three WJ III ACH subtests (Smith et al., 2013). It is important to note that these effects were obtained when using a sample of grade one students. The outcomes of the current intervention when applied to struggling kindergarteners is unknown.

In an effort to assess the effects of focusMath, the other intervention discussed above, the publishers of the program contracted an external independent evaluation firm to conduct an independent evaluation of the program. The researchers used a randomized control trial design, and participants who qualified for math intervention were randomly assigned to treatment and control groups within the same school (Styers & Baird-Wilkerson, 2011). Inclusion criteria was performed at or below the 30th percentile on the KeyMath3 assessment at the beginning of the school year. Students in the treatment group received the focusMath intervention at least 2 days a week for 30 minutes per day. The intervention lasted 21 to 29 weeks. Students in the control group continued with current practices and control students did not receive math intervention (Styers & Baird-Wilkerson, 2011). The KeyMath3 was used as a measure of each student's

mathematical attainment. KeyMath3 is a standardized, individually administered test that three overarching areas (Basic Concepts, Operations, and Applications) and ten subtests.

Results indicated that students in the focusMath program has significant gains at midyear and posttest on the KeyMath Growth Scale Value. The effect sizes at midyear and posttest were medium to large. At the beginning of the year, 100% of the focusMath students performed below the 30th percentile on the KeyMath measure, and by the end of the year 61% did (Styers & Baird-Wilkerson, 2011). The researchers also analyzed the impact of focusMath at each grade point. Grade 3, outperformed control students on the Multiplication and Division subtest on the KeyMath3 (Styers & Baird-Wilkerson, 2011). Similarly, Grade 5 students outperformed control students on the Numeration, Geometry, Measurement, Mental Computation and Estimation, and Addition and Subtraction subtests of KeyMath3 (Styers & Baird-Wilkerson, 2011). It is important to note that these effects were obtained when using a sample of grade 3 to 5 students. The outcomes of focusMath when used with kindergarteners who experience difficulty in early numeracy is unknown. Also, of worth to mention is the notion that this is the sole study measuring the effectiveness of the focusMath program, and it was funded by the program developers.

The Current Study

Taking all of the aforementioned findings into account, it is apparent that effective, individualized interventions in early numeracy are vital for the success with later mathematical attainment, and thus in the long run, success in everyday functioning. The Whole Number Foundations Level K early numeracy intervention discussed above seems like a viable option to use for Tier 3 DBI; however, its effectiveness as a platform intervention for DBI has not been assessed. The aim of the current study is to use the Whole Number Foundations Level K

intervention previously used in small-groups as a DBI platform intervention, and thus expand early numeracy literature, and gain valuable insight into Whole Number Foundations' Level K effectiveness when implemented with individual students in kindergarten. The results of the current study are crucial for educators' understanding of early numeracy interventions at Tier 3 of RTI. If the Whole Number Foundations Level K intervention produces positive early numeracy gains, then it will be a meaningful option to use when intervening in early numeracy in the kindergarten classroom. This will allow educators to close the early numeracy learning gap and remediate the problem in a systematic way as soon as it is observed in the regular classroom. The current study attempted to individualize the Whole Number Foundations Level K and be among the first to show a viable implementation of it at the individual level.

In order to examine the utility of the modified Whole Number Foundations Level K intervention, the present study used a multiple probe design across four participants. Students' baseline early numeracy level was established, and then they participated in twelve weeks of individualized Whole Number Foundations Level K early numeracy intervention. The study aimed to answer the following research questions:

1. Does implementing the Whole Number Foundations Level K early numeracy intervention as a platform intervention for DBI improve early numeracy skills with kindergarteners who are struggling with mathematics in the general education classroom?
2. What (if any) amount of individualization of the Whole Number Foundations Level early numeracy intervention is required in order for effects to be demonstrated?

Chapter 3: Methodology

Participants

Four kindergarten students (2 males and 2 females) from a school in the Catholic Independent Schools Vancouver Archdiocese (CISVA) were recruited for the current study. Teachers from the selected school referred individual students using the following criteria: no special education designation, difficulties with grade level numeracy, scores of no more than 2 standard deviations below the mean on a brief test of cognitive functioning, and social and emotional behaviours that are conducive to participation in an individualized intervention. Teacher reports of difficulty with grade level numeracy and cognitive functioning were confirmed using screening measures. Social and emotional behaviours were informally assessed by a brief conversation with each participant. A convenience sample was utilized. All students came from the same classroom, and received the same classroom instruction in early numeracy. They were receiving no support in mathematics beyond classroom instruction and the current intervention. They all spoke English as their primary language and had no English Language Learner status. The two female students were twins; there was no other familial relation between the participants. The twins were retained a grade, and repeating kindergarten during the year of the current study. Students' names have been replaced with pseudonyms. The following table summarizes participant screening data results.

Table 1.

Participant Screening Data

	KBIT-2 (Classification)	**TEMA-3 (Classification)**
Participant 1	70 (Below Average)	65 (Very Poor)
Participant 2	73 (Below Average)	63 (Very Poor)
Participant 3	102 (Average)	102 (Average)
Participant 4	99 (Average)	97 (Average)

Measures

The current study employed a screening measure (The Kaufman Brief Intelligence Test, Second Edition), a diagnostic measure of early numeracy skills (Whole Number Foundations Level K– Math Check Points), a primary dependent variable measure (AIMSweb Test of Early Numeracy), and a secondary dependent variable measure (Test of Early Mathematics Abilities, Third Edition). Each of these measures will be discussed in detail below.

The Kaufman Brief Intelligence Test, Second Edition (KBIT-2). The KBIT-2 is a brief norm-referenced measure designed to screen individuals aged 4.0 to 90.11 for cognitive functioning (Kaufman & Kaufman, 2004). The KBIT-2 is a short screener used to assess cognitive functioning, requiring 15 minutes to administer. The KBIT-2 involves three subtests (Verbal Knowledge, Riddles and Matrices) that measure the two closest broad abilities to general intelligence. The KBIT-2 is reported as having strong levels of reliability (0.89 to 0.96). Moreover, validity evidence shows that the KBIT-2 has strong correlations with other intelligence and achievement tests (Kaufman & Kaufman, 2004).

Whole Number Foundations Level K– Math Check Points. The Math Check Points of the Whole Number Foundations Level K intervention are in-program mastery assessments that appear every fifth lesson through lesson 25, at lessons 34 and 42, and after lesson 50. The Math Check Points assess the individuals on concepts and skills presented in preceding lessons. For the purposes of the current study, the Math Check Points were used as a diagnostic measure to establish the appropriate starting point for the intervention, and to determine the adjustments to Whole Number Foundations Level K required (see Data-Based Individualization below, for more information on how the Math Check Points were used). The following table summarizes the specific skills evaluated on each check point assessment.

Table 2.

Skills Evaluated on Whole Number Foundations Level K Math Check Points

Math Check Point	Skills
1 (Lessons 1-5)	Rote count 1-3; Identify numerals 1, 2, 3
2 (Lessons 6-10)	Rote count 1-5; Identify numerals 1-5
3 (Lessons 11-15)	Rote count 1-5; Identify numerals 1-5; Count objects 1-5
4 (Lessons 16-20)	Rote count 1-8; Identify numerals 0-8; Count objects to 8
5 (Lessons 21-25)	Rote count 1-9; Identify numerals 0-9; Count objects to 9; Identify groups that are more and less; Count from a number other than one; Identify the numeral that is less
6 (Lessons 26-34)	Rote count 1-12; Identify numerals 0-12; Count objects to 12; Identify numerals that are more and less; Count on from a numeral other than one
7 (Lessons 35-42)	Rote count 1-15; Identify numerals 0-15; Count on from a number other than 1; Identify numerals that are less; Write the numeral that is one more; Write numerals for ten-frames 5-10
8 (Lessons 43-50)	Rote count to 20; Sequence numerals 11-20; Identify numerals 0-20; Count on from a number <20; Identify which of two numerals <20 is more and which is less; Identify missing numeral in a sequence of 3 numbers <20; Write answers to plus 1 equations with sums to 10; Given pictures, write equations for combinations of 5.

AIMSweb Test of Early Numeracy (TEN). Designed by Clarke and Shinn (2004), the AIMSweb TEN is composed of four 1-minute fluency measures (Oral Counting, Number Identification, Quantity Discrimination, and Missing Number) that assess key early numeracy skills and are based on the principles of curriculum-based measurement. Each 1-minute measure is fluency based and assesses critical early numeracy components. The AIMSweb TEN measures have been validated for use with kindergarten students, and have high concurrent validity with other measures of early mathematics including the Number Knowledge Test and the Stanford Achievement Test (Chard et al., 2005; Chard et al., 2008). Measures from the AIMSweb TEN can be summed to create a composite score. Each individual measure will be discussed below. Concurrent validity for each measure was assessed by examining their correlations with three criterion measures: Woodcock Johnson Applied Problems subtest (WJ-AP), Mathematics

Curriculum-Based Measurement (CBM-M), and the Number Knowledge Test (Clarke & Shinn, 2008). Predictive validity for each measure was assessed by examining their correlations with WJ-AP and CBM-M (Clarke & Shinn, 2008).

Oral Counting. The Oral Counting measure requires participants to count from 1 to as high as they can. The measure is scored based on the number of correct counts completed before and error is made, or the number of counts in one minute, whichever comes first. Concurrent validity correlations range from .49 to .70 and predictive validity correlations range from .56 to .72 (Clarke & Shinn, 2008). Additionally, alternate-form and 2-week test retest reliability exceed 0.80, while inter-scorer reliability is .78 (Clarke & Shinn, 2004).

Number Identification. The Number Identification measure asks participants to orally identify numbers between 0 and 10. Two pages of randomly selected numerals are given to participants. These numerals are formatted on an 8 by 7 grid, and there are 56 numerals per page. The measure is scored based on the number of correctly numbers identified in one minute. Concurrent validity correlations range from .60 to .70 and predictive validity correlations range from .60 to .72 (Clarke & Shinn, 2008). Additionally, all reliability coefficients (alternate-from, two-week test-retest, and interrater) were greater than 0.80 (Clarke & Shinn, 2004).

Quantity Discrimination. The Quantity Discrimination measure requires the participant to name the larger of two visually presented numerals, one number always being numerically larger. Participants are given a sheet of paper with a grid of individual boxes, and each box includes two randomly sampled numerals from 1 to 10. The measure is scored based on the number of correctly identified larger numbers in one minute. Concurrent validity correlations range from .71 to .80 and predictive validity correlations range from .70 to .79 (Clarke & Shinn,

2008). Additionally, all reliability coefficients (alternate-from, two-week test-retest, and interrater) were greater than 0.80 (Clarke & Shinn, 2004).

Missing Number. The Missing Number measure asks students to name the missing numeral from a string of numbers between 0 and 10. Participants are given a sheet with 21 boxes containing strings of three numerals, with the first, middle, or last numeral of the string missing. They are then instructed to orally state the numeral that was missing. The measure is scored based on the number of missing numbers correctly identified in one minute. Concurrent validity correlations range from .69 to .75 and predictive validity correlations range from .67 to .78 (Clarke & Shinn, 2008). Additionally, all reliability coefficients (alternate-from, two-week test-retest, and interrater) were greater than 0.80 (Clarke & Shinn, 2004).

Test of Early Mathematics Abilities, Third Edition (TEMA-3). The TEMA-3 is a standardized, norm-referenced measure designed to assess early mathematics skills of children aged 3:0 to 8:11. The TEMA-3 identifies student strengths and weaknesses in specific areas of early mathematics, and measures both formal and informal mathematic skills. The test contains 72 items that measure: numbering skills, number-comparison facility, numeral literacy, mastery of number facts, calculation skills, and understanding of concepts. The TEMA-3 has two alternate forms, and the reliability of these forms is 0.97. TEMA-3 test-retest reliability is strong, ranging from 0.82 to 0.93 (Ginsburg & Baroody, 2003). Concurrent validity with other criterion measures of mathematics range from .54 to .91. The TEMA-3 yields age and grade norms to calculate standard scores and percentile ranks. The current study used grade norms.

Procedures

Recruitment and screening. Four students, identified by their teachers as having early numeracy skills below their expected grade level were asked to participate in the study. Prior to

commencement of the study, parental or guardian consent and student assent was obtained. The assent was read to the students, and the process of the study was explained. Once the consent was obtained, students were screened using the KBIT-2, and TEMA-3 to ensure they met inclusion criteria. The KBIT-2 was administered as a brief measure of cognitive functioning. To meet the eligibility requirements of the current study, the students' score on the KBIT-2 had to be no more than 2 standard deviations below the mean (SS ≥ 70), which indicates at least average cognitive functioning. The TEMA-3 was used prior to any exposure to probe sessions as a comprehensive baseline assessment of early numeracy skills. The criterion for inclusion was performance below the 25th percentile on the TEMA-3. The Math Check Points of the Whole Number Foundations Level K intervention were used as a diagnostic measure to establish the appropriate starting point for the intervention. At the commencement of the study, each participant was administered the first math check point. Error analysis of the first mastery assessment allowed the implementer to individualize the first five lessons. If the participant already had the skills evaluated at the first math check point, the second was administered, and so forth. Prior to commencing the sixth lesson, the next check point was administered and the error analysis process repeated. Check points were utilized prior to commencing the first lesson comprising that specific check point (before lesson 1, 6, 11, 16, 21, 26, 35, and 43) in order to individualize the intervention. Individual lesson objectives were then used to assess which lesson within that check-point each participant should commence with. The analysis revealed Participants One and Participant Two's start point as lesson 1, Participant Three's start point as lesson 13, and Participant Four's start point as lesson 19.

Experimental design. The four selected participants participated in an individualized early numeracy intervention that integrated evidence-based early numeracy strategies in a

multiple baseline design (multiple probe technique). This design is particularly useful when a reversal design is not viable as the withdrawal of an effective treatment is not required to demonstrate a functional relation between the independent variable and the dependent variable (Kratochwill et al., 2010). Since the early numeracy skills gained in the current study are non-reversible, a multiple baseline design was the most appropriate design option to employ. The independent variable in the current study was participation in an individualized early numeracy intervention. The dependent variables were student early numeracy skills assessed by a curriculum-based measure (AIMSweb TEN), as well as a standardized measure (TEMA-3).

In a multiple baseline design (multiple probe technique), each participant's intervention phase begins in a delayed fashion which limits threats to internal validity that may arise when there is no additional comparison group in the study, as is the circumstance in single case designs (Kratochwill et al., 2010). Threats to internal validity such as history, maturation, testing and conditions are thus reduced by the use of concurrent multiple baseline (Kratochwill et al., 2010). The measures (Oral Counting, Number Identification, Quantity Discrimination, and Missing Number) used for the current study increased in complexity, and as such participants would likely get a score of zero on the more complex measures until they acquired the skills through the subsequent intervention lessons. Taking this into account, each measure was administered at the beginning of baseline and then probed intermittently for as long as the scores were not changing or were near zero. Regardless of performance on the measures, they were administered more densely before and after phase changes. The measures on which the student performed better than zero or close to zero on were administered three times per week, at every session. The researcher intermittently probed (once a week) on the measures that the student got a zero or

close to zero on. Once the researcher saw that the participant's performance on the measure was increasing, the measure administration increased to three times a week, after every lesson.

The current study utilized a fixed schedule for phase changes across participants; the skills assessed by the measures were not expected to vary greatly at baseline. At least five data points were collected over two weeks during the baseline phase for each participant before phase change occurred, which is in accordance to single case design standards (Kratochwill et al., 2010). Intervention sessions began first for those participants who had flat or stable baselines, and there was delayed implementation for those who had more variable or improving baselines. The intervention phase (12 weeks) commenced for the first participant at the beginning of the 3rd week of the study. Phase changes for the second, third, and fourth participant, occurred on the 4th, 5th, and 6th week of the study, respectively. Following intervention, the TEMA-3 was utilized again to measure the participants' generalized gains in early numeracy skills.

Kratochwill et al. (2010) state that at least three demonstrated basic effects at three different points in time are needed for an inference of experimental control. The current study was composed of four participants in order to control for the possibility of inconsistent effects and to ensure at least three demonstrations at three different time periods.

Intervention sessions. The intervention used was an individualized version of the Whole Number Foundations Level K (Davis & Jungjohann, 2009). In the current study, the Whole Number Foundations Level K intervention was adapted for use at the individual level; the participants' starting point was determined by diagnostic assessment of each participant's performance on the Whole Number Foundations Level K Math Check Points. Following baseline, each participant received the Whole Number Foundations Level K intervention for a total of 35 sessions across a 12-week period (approximately 3 times a week). Components of the

Whole Number Foundations Level K intervention, as described by Davis and Jungjohann (2009) as well as the how data-based individualization was utilized are presented below.

Conceptual framework. There were three main components of the Whole Number Foundations Level K program: mathematical models, mathematics-related vocabulary and discourse, and procedural fluency and automaticity. The intervention used mathematical models to represent important math concepts. Mathematics concepts are often abstract, thus representing them in a mathematical model allowed for ease of understanding. Models used include number lines, counting objects, finger models, tally marks, and ten-frames matched to numerals. The second element of Whole Number Foundations Level K involved identifying and explicitly teaching mathematics-related vocabulary and discourse. By scripting the lessons, the interventionist ensured that the mathematics concept was taught accurately. In addition to the interventionist teaching the student the mathematical vocabulary, lessons were designed so that the child used the newly acquired vocabulary. Additionally, teacher feedback was a crucial component of explicit teaching; the interventionist monitored each child's response and immediately corrected errors. The last component, procedural fluency and automaticity was accomplished by providing the student with systematic practice and review within a lesson, as well as across lessons to ensure mastery, maintenance, and generalization. "Math practice", the last activity in each lesson allowed for more practice of the newly acquired skill.

Instructional delivery. Instructional delivery was explicit, and based on the "I do, we do, you do" model by Levy (2007). In "I do", the interventionist modeled new tasks to the participant. This modelling occurred several times before moving on to "We do". "We do" consisted of the interventionist giving the child opportunities to practice the new skill by guiding him or her. Once the interventionist and child had sufficiently practiced the skill together, the

child moved to the “I do” phase. In this final phase, the student practiced the newly acquired mathematical skills independently.

Instructional manipulatives. The intervention used common math manipulatives such as teddy bear counters and connecting cubes. These manipulatives are commonly found in kindergarten classrooms. The materials required for each lesson were listed in the “Materials” box of the lesson overview.

Opening review routine. Each Whole Number Foundations Level K lesson began with a review of the skills the student should be mastering. Each participant was first asked to count from 1 to as high as they could. Next, each participant reviewed mastered numbers using the Quick Numeral routine, whereby the interventionist quickly displayed mastered numbers on cards and the child named them as quickly as possible. If the child made a mistake, the interventionist quickly corrected him or her and returned to the numeral after a couple of other numbers were shown and until the child could correctly identify it.

The opening review routine changed as each child progressed though the lessons. Starting at lesson 16, each child counted to a number specified by the interventionist. Participants were also asked to count sets of objects, and tell the interventionist how many there were. Starting at lesson 30 the interventionist asked children to identify which of two groups of objects has “more” and which group has “less.”

Curriculum layout. There was a shaded box at the beginning of each Whole Number Foundations Level K lesson which listed the lesson objectives, vocabulary words used in the lesson, and materials needed. New objectives and new vocabulary were noted by bold print, while review objectives and vocabulary were written in regular print. The lesson was divided

into activities that address one or more lesson objectives, and a header box described the activity and listed the important math vocabulary used in teaching the activity.

Lesson procedural check-list. Prior to, during, and after each lesson, the interventionist filled out a checklist of elements for each session, and record if any steps were missed. Please refer to Appendix A to review the checklist.

Data-based individualization. Each participant's starting point in the Whole Number Foundations Level K standard protocol intervention was determined based on performance on the Math Check Points. The procedure was as follows: 1) Administer each check point until the participant could not perform all tasks it required, 2) Perform error analysis by reviewing individual lesson content within that Math Check Point, and 3) Decide which lesson to start with by looking at the skills that needed to be targeted. The current study also employed an explicit mastery requirement, whereby the child had to receive a score of 100% on objectives at the end of each lesson. For example, at the end of lesson 1, the child must be able to identify numerals 1, 2, and 3; rational count to 3; make sets of objects to match numbers 1, 2, and 3; trace number 1; identify a circle. When this explicit mastery criterion was not met, the intervention was adapted.

Adaptations can be quantitative or qualitative in nature. Quantitative adaptations serve as the first step in the adaptation process, and include adjustments such as more time, and more prompting needs (National Center on Intensive Intervention, 2013). They may include longer duration of lesson when teaching a challenging mathematical concept, extended review time for confusing concepts in subsequent lessons, utilizing more explicit instruction than is used in the standard protocol, and providing additional practice opportunities with teacher feedback. An increase in time bolsters learning by allowing the child to receive more instruction, more practice with feedback, and increasing engaged learning time needs (National Center on Intensive

Intervention, 2013). Qualitative adaptations alter the way the content is delivered and are tailored to the specific learning needs of the individual. They may be in the form using alternative forms of error corrections and feedback, presenting information using more than one modality, frequent repetition of instructions and key words, more modeling than used in the standard protocol, and more checking for understanding than used in the standard protocol.

If adaptations are unsuccessful, the interventionist may need to modify the curriculum. Modifications are alterations to the content that is taught to a student. They involve changing or modifying the curriculum that is offered to a student. No adaptations were required for Participant Three and Participant Four. The adaptations and modifications implemented for Participant One and Participant Two will be discussed below.

Participant One. Participant One will hereon in be called by her pseudonym "Serena". At the onset of intervention, Serena struggled greatly with the content in lesson 1. The interventionist attempted to first use quantitative adaptations in which additional time and prompting was given, more explicit instruction was implemented than is used in the standard protocol, and supplementary practice opportunities with interventionist feedback were provided. Quantitative adaptations were not successful with Serena, so during the next three intervention sessions, the interventionist implemented qualitative adaptations which altered the way the content was delivered and were tailored to the specific learning needs of the individual. For Serena, the interventionist tried using alternative forms of error corrections and feedback, presenting information using more than one modality, frequent repetition of instructions and key words, more modeling and more checking for understanding than used in the standard protocol. Qualitative adaptations were not successful with Serena. She could not identify numerals 1, 2 or 3; count to 3; make sets of objects to match numbers 1, 2 or 3. It was established that Serena

lacked the basic math skills needed (i.e., magnitude, symbol representation, one-to-one correspondence, cardinality) to participate in lesson 1; subsequent phases involved more substantial modifications to the Whole Number Foundations intervention to teach these basic skills.

During Intervention Phase 2 (IV2), the interventionist introduced response cards and replicated and added to the procedure used by Skibo, Mims, and Spooner (2011) in an effort to teach Serena the numerals 1, 2 and 3 through magnitude and symbol representation. Response cards for the students were preprinted: numbers 1 to 3 were printed on 5 in. x 7 in. cardstock in large black ink with nothing else on the card. The interventionist's cards were printed on a white 8.5 in. x 11 in. sheet of cardstock paper in large black ink in the same font type as on the student's cards. The interventionist's cards also had symbols on them to represent numbers (e.g., three balloons). The procedure is as follows:

1. The intervention used a "least-to-most" prompting system to teach students to make the correct response with the response cards. She told the participant, "I will tell you a number and you need to hold up the card with a correct number 1–3 on it. The interventionist then asked, "show me number ____." The student was given 5 seconds to make an attempt to answer the question by raising the correct card with the same number as the interventionist had presented. When the participant answered the question correctly the interventionist would praise him or her. Numbers 1 to 3 were randomly selected as target numbers.
2. If the participant started heading to a wrong response the interventionist would block his or her response and redirect the student to the correct answer. If the participant offered no response within the 5 seconds the interventionist would

move to a verbal prompt of “find the number that matches mine” and again wait another 5 seconds.

3. If the participant indicated the correct response after the verbal prompt he or she was praised. If the student still provided no response the interventionist would model “Which number matches mine?” and point to the correct answer and again wait five seconds for the participant to respond. If there was still no answer from the student than the interventionist would give the participant a full physical prompt while saying “The number that matches mine is this one”.
4. The prompting level required was recorded on the Data Collection for Math Response Cards sheet (see Appendix B). Along with number identification, the experimenter asked the student to count the number of objects presented with the number as a way to enhance number sense.

The above procedure was repeated for a total of 10 times per lesson, and the number of correctly identified numerals without prompts was recorded. A score of 10/10 would mean that the participant has gained the prerequisite skills needed to participate in Whole Number Foundations; thus, a perfect score was set as the goal for the procedure. The response card procedure was implemented for a total of five lessons; however, Serena could not attain the goal needed to pass, therefore, a different, substantial modification was used in Phase 3.

Intervention Phase 3 (IV3) utilized an adapted version of the counting procedure outlined by the National Center on Intensive Intervention (2015). The main objective of the procedure was to teach the participants symbol representation, to count up 3 objects in a group using one-to-one correspondence and to connect counting to cardinality. Small blocks, teddy-bear counters, and colourful chips were materials used for the procedure. It proceeded as follows:

1. Review of rote counting to 3 (i.e., stating the number words in order)
2. Next, the interventionist told the student that counting is used to tell how many of something there is, and placed up to 3 objects in a straight line in front of the participant. She then demonstrated counting by touching each object one at a time, slowly, and stating the number word for each object as she touched it.
3. The interventionist then told the student the last number word said tells how many there are. "One…two…three. The last number I said was three, so there are three chips."
4. The interventionist told the student, "Let's do this together. I'll point and you count with me", and repeated touching and counting each object with the student doing the same procedure with her. The interventionist also presented the corresponding number card while the counting was performed in order to help the participant match the magnitude to the number symbol.
5. The interventionist then told the student, "Now I'm going to move the chips around so they're all mixed up" and took the same set of objects and rearranged them in a scattered assortment.
6. She then asked the student how many objects there are now and allowed the student to answer, then demonstrated counting again by touching each object one at a time, slowly, and stating the number word for each object as she touched it. Again, she told the participant that last number word said tells how many there are. "One, two, three. The last number I said was three, so there are three chips."
7. The interventionist confirmed with the student that the amount of objects (i.e., the set's cardinality) does not change simply because the objects have been moved

around; whether they are in a straight line or all mixed up, the total amount remains the same.

8. The above procedure was repeated once more with the current set of objects and another 2 times with at least 2 more sets of objects each. The number of correct counts was recorded on the Counting sheet (see Appendix C).
9. The participant practiced writing each numeral; she was presented a numeral in card form and in object form and was asked to find the numeral on the paper. She then practiced writing the numeral. Procedure was repeated for all three numbers.

A score of 6/6 would mean that Serena has gained the prerequisite skills needed to participate in Whole Number Foundations, thus a perfect score was set as the goal for the procedure. The counting procedure was implemented for a total of seven lessons, and at the end she attained the goal needed to pass, therefore lesson 1 of the Whole Number Foundations was implemented in Phase 4.

In Intervention Phase 4, lesson 1 of the Whole Number Foundations was again executed (back to IV1). Serena moved through the lesson with ease and received a score of 100% on the objectives at the end, thus no subsequent individualization ensued as she was able to master each succeeding lesson.

Participant Two. The individualization for Participant Two was very similar to that of Participant One. Participant Two will hereon in be called by her pseudonym “Venus”. During Phase 1 (IVI), lesson 1 of the Whole Number Foundations was implemented. Venus struggled to move through the lesson, and thus the interventionist attempted to adapt both quantitively and qualitatively (see above), but the prerequisite skills (magnitude, symbol representation, one-to-one correspondence, and cardinality) were not present and so the response card procedure ensued

in Phase 2. The response card procedure (see above) was utilized in Phase 2 (IV2) for a total of six lessons, however, Venus could not successfully attain a score of 10/10 after four sessions, and so the counting procedure (see above) was employed in Phase 3 (IV3). After six sessions in Phase 3, Venus attained the goal needed to pass, therefore lesson 1 of the Whole Number Foundations was implemented in Phase 4 (back to IV1). Venus moved through the lesson with ease and received a score of 100% on the objectives at the end; thus, no subsequent individualization ensued as she was able to master each succeeding lesson.

Progress monitoring. Each student's progress in early numeracy was collected every session, three times per week, using the AIMSweb TEN assessment. Students completed four one-minute numeracy fluency measures three times per week, during baseline. Because the AIMSweb TEN measures increased in difficulty, it was expected that the more challenging measures would receive scores close to or at zero during baseline. During intervention, a schedule was set whereby the four measures would be intermittently probed. The use of each measure became denser when student performance on that measure started to move beyond zero. Prior to baseline, and at the end of the intervention phase, the students were asked to complete the TEMA-3 as a measure of generalized gains in early numeracy.

Inter-observer agreement and procedural integrity. The interventionist for the current study was a graduate student in School Psychology who had previous experience with measuring and intervening on mathematics skills from graduate course work, work experience, and practicum. The use of one interventionist across all students and sessions was deliberate to ensure DBI was performed in the same manner for all participants.

In order to ensure fidelity of implementation, all intervention sessions were audio recorded and 30% of selected sessions in the baseline and intervention phases were analyzed by

an external reviewer for inter-observer agreement (IOA). Training for the external reviewer was provided by the student researcher and included practice scoring and co-scoring with the researcher until a scoring agreement level of ≥ 95% was demonstrated. The reviewer then rescored the AIMSweb TEN progress monitoring measures without knowledge of the initial interventionist's scoring. Each AIMSweb TEN measure's IOA rates were determined by dividing the total number of overall agreements by the total number of overall agreements plus overall disagreements and then multiplying the quotient by 100. The mean percent agreement was 95% (range: 82% to 100%).

Additionally, during intervention the interventionist completed a checklist of elements for each session, and record if any steps were missed. To determine procedural integrity, the external reviewer was given the aforementioned checklist and marked off the completed steps while listening to 30% of the audio recordings without knowledge of the initial interventionist's scoring. Each session was then given a procedural integrity score, which was calculated by dividing the number of completed steps by the number of total steps and then multiplying the resultant quotient by 100%. The mean score for procedural integrity across participants was 97% (range: 89% to 100%).

The aforesaid results suggest very good inter-scorer agreement and procedural integrity and meet or exceed the minimal threshold of 0.80-0.90 that is required to meet evidence standards (Kratochwill et al., 2013).

Data Analysis

A basic effect is one demonstration of an effect while a functional relation is at least three basic effects across the whole data set. In order to establish a functional relation at three different time points, and thus document experimental control as per Horner et al. (2005),

all participant data was examined in the way described below to determine a similar pattern of response. Student performance on the AIMSweb TEN measures (Oral Counting, Number Identification, Quantity Discrimination, and Missing Number) was assessed. The AIMSweb TEN data were graphed and analyzed in order to detect changes in level, trend, and variability from baseline to intervention, and thus determine the efficacy of the intervention. The relative slope change in each AIMSweb TEN measure score between the baseline and intervention phase was calculated. Effect sizes were calculated using a derivative of Tau-U as described by Parker, Vannest, Davis, and Sauber (2011). Original Tau-U is based on non-overlap between phases that controls for confounding baseline trend. The derivative used for this study, $Tau_{a \text{ vs. } b + b \text{ trend}}$, described by Parker, Vannest, Davis and Sauber (2011) combines nonoverlap between phases with trend from within the intervention phase, and offers several advantages over other effect size indexes including providing more statistical power than any other non-overlap indexes (Parker et al., 2011). Because it was expected that a change in trend would occur after intervention began, more so than a large and clear change level, the derivative described above was used.

Additionally, the TEMA-3 served as an indicator of skill generalization; data obtained using the TEMA-3 at the beginning of intervention, and at the end of intervention was compared to determine whether participants' broad early numeracy skills concomitantly improved.

Chapter 4: Results

Early Numeracy Skills

Gains in early numeracy skills related to the intervention were analyzed by comparing the participants' baseline data on each early numeracy measure to their performance in the intervention phase.

Oral counting skills. Participants' number of correct oral counts (COC) was analyzed to determine whether gains in oral counting occurred. Figure 1 below illustrates COC in baseline and intervention on the Oral Counting measure. Table 3 shows descriptive statistics for all participants on the Oral Counting measure. Table 4 depicts participant Tau values and statistical significance.

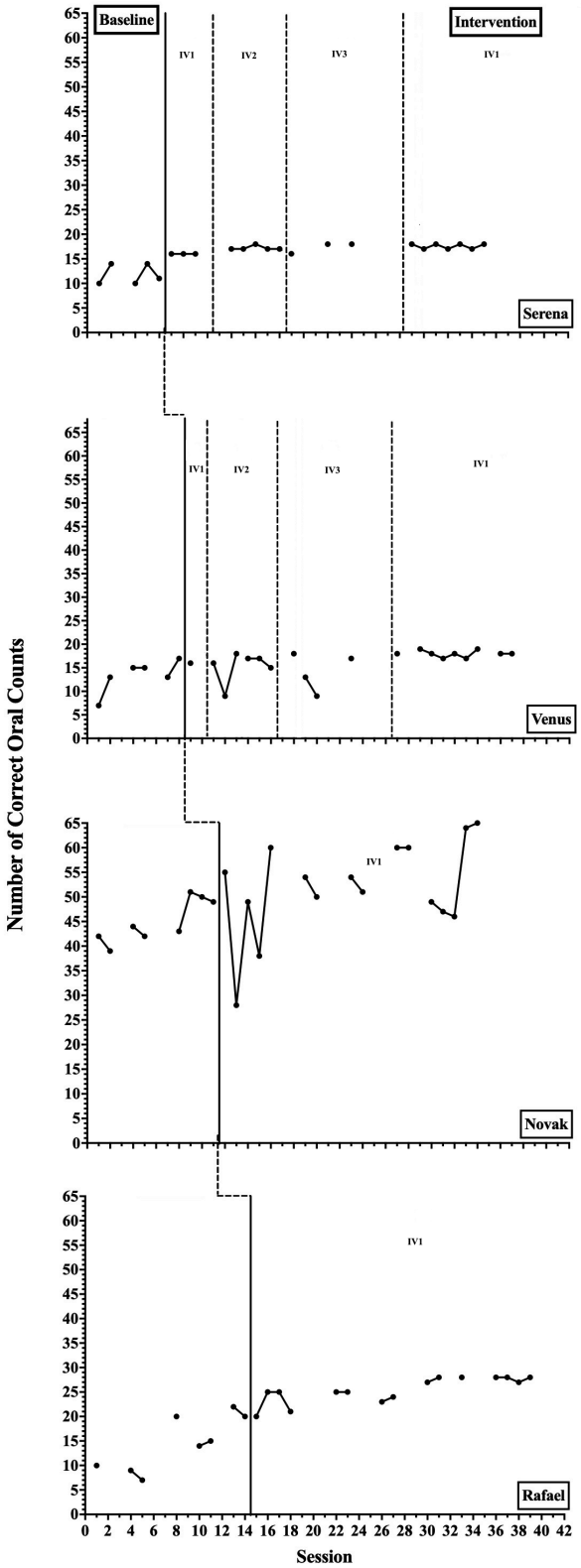

Figure 1. Correct oral counts per minute on the Oral Counting measure (Phase One, = IV1, Phase Two = IV2, Phase 3 = IV3, Phase 4 = back to IV1)

Table 3.

Descriptive Statistics for Oral Counting measure

Participant	Phase	Mean	Standard Deviation	Slope
Serena	Baseline	11.80	2.05	0.20
	Intervention	17.17	0.78	0.09
Venus	Baseline	13.33	3.44	1.43
	Intervention	16.35	2.87	0.20
Novak	Baseline	45.00	4.41	1.50
	Intervention	51.88	9.58	0.95
Rafael	Baseline	30.50	3.89	0.50
	Intervention	41.93	8.51	1.00

Table 4.

Differences in Correct Oral Counts from Baseline to Intervention

Student	Tau	*p*-value
Serena	0.680	<.001
Venus	0.506	<.001
Novak	0.378	.015
Rafael	0.573	.001

Serena. Serena experienced a flat trend in baseline and intervention (Baseline = 0.20; Intervention = 0.09). Further visual analysis of the data reveals an improvement in level ($M_{baseline}$ = 11.80; $SD_{baseline}$ = 2.05; $M_{Intervention}$ = 17.17; $SD_{Intervention}$ = 0.78). Consistent with visual analysis results, Tau reveals a small to moderate effect that is statistically significant (0.680, $p < .001$). Based on the change in level, consistency of trend, in addition to the magnitude and statistical significance of Tau, there is a demonstrated effect on oral counting, but only after extensive individualization of the intervention.

Venus. Venus experienced an improving trend in baseline which was not sustained throughout intervention (Baseline = 1.43; Intervention = 0.20). Further visual analysis of the data reveals an improvement in level ($M_{baseline}$ = 13.33; $SD_{baseline}$ = 3.44; $M_{Intervention}$ = 16.35;

$SD_{Intervention}$ = 2.87); however, data overlap and variability complicate the visual analysis, thus no basic effect can be inferred.

Novak. Novak experienced an improving trend in baseline which slowed, but continued throughout intervention (Baseline = 1.50; Intervention = 0.95). Additional visual analysis demonstrates an improvement in level ($M_{baseline}$ = 45.00; $SD_{baseline}$ = 4.41; $M_{Intervention}$ = 51.88; $SD_{Intervention}$ = 9.58); however, improving baseline trend and overlap of data between baseline and intervention complicate the visual analysis, thus no basic effect can be inferred.

Rafael. Rafael experienced an improving trend in baseline which accelerated during intervention (Baseline = 0.50; Intervention = 1.00), resulting in an improvement in level ($M_{baseline}$ = 30.50; $SD_{baseline}$ = 3.89; $M_{Intervention}$ = 41.93; $SD_{Intervention}$ = 8.51); however, improving baseline trend that continued into the intervention phase complicates the analysis, thus no basic effect can be inferred.

Summary. Overall, the data show a clear basic effect for one participant (who required extensive individualization of the intervention), while continuation of baseline trend and data overlap between baseline and intervention complicate analysis for the other three participants. Thus, there is insufficient evidence to support that this intervention affected the counting skills of participants.

Number identification skills. Participants' number of correct number identifications (CNI) was analyzed to determine whether there were gains in identifying numerals. Figure 2 below illustrates CNI in baseline and intervention on the Number Identification measure. Table 5 shows descriptive statistics for all participants on the Number Identification measure. Table 6 depicts participant Tau values and statistical significance.

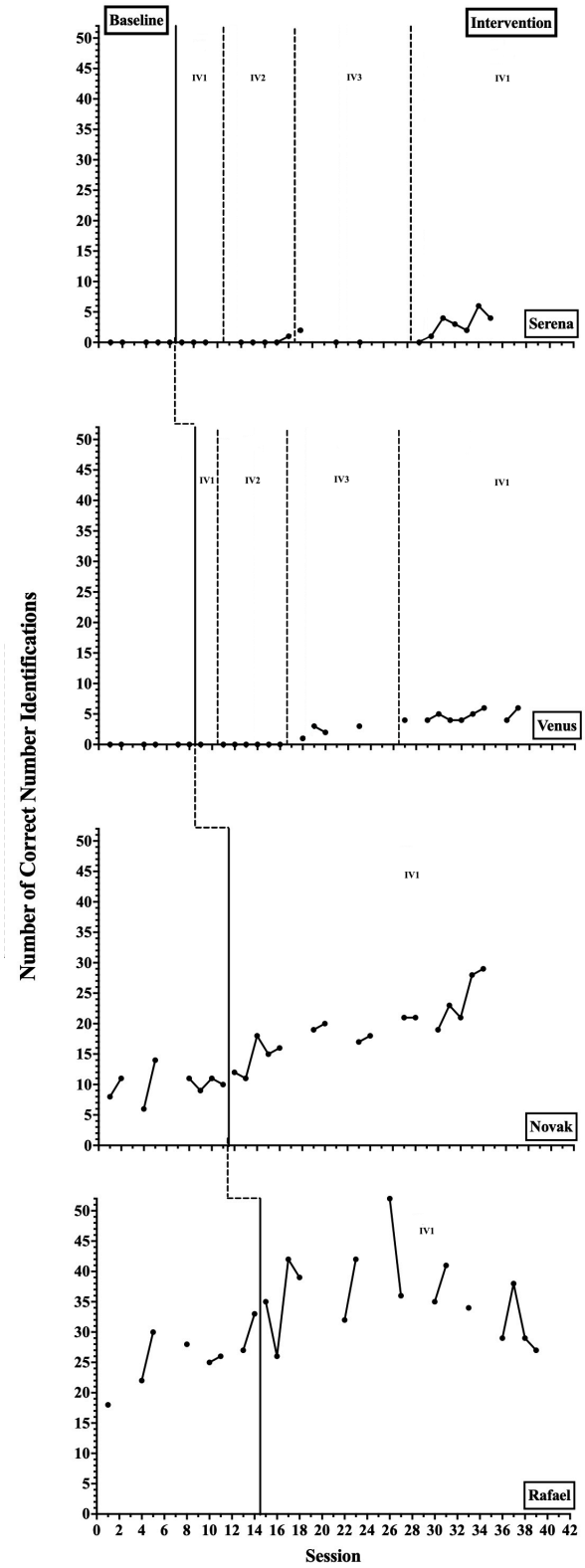

Figure 2. Correct number identifications per minute on the Number Identification measure (Phase One, = IV1, Phase Two = IV2, Phase 3 = IV3, Phase 4 = back to IV1)

Table 5.

Descriptive Statistics for Number Identification measure

Participant	Phase	Mean	Standard Deviation	Slope
Serena	Baseline	0.00	0.00	0.00
	Intervention	1.28	1.84	0.26
Venus	Baseline	0.00	0.00	0.00
	Intervention	2.55	2.24	0.36
Novak	Baseline	10.00	2.39	0.24
	Intervention	19.25	4.85	0.91
Rafael	Baseline	26.13	4.64	1.37
	Intervention	35.80	6.90	-0.40

Table 6.

Differences in Correct Number Identification from Baseline to Intervention

Student	Tau	*p*-value
Serena	0.655	.001
Venus	0.824	<.001
Novak	0.827	<.001
Rafael	0.288	.070

Serena. Because of the amount of individualization required for Serena (see Data-Based Individualization procedures above) Serena experienced a minimal increase in trend which was delayed from baseline to intervention (Baseline = 0.00; Intervention = 0.26) and eventually resulted in an overall increase in level in Phase 4 of the intervention ($M_{baseline}$ = 0.00; $SD_{baseline}$ = 0.00; $M_{Intervention}$ = 1.28; $SD_{Intervention}$ = 1.84). Tau reveals a small to moderate effect that is statistically significant (0.655, p = .001). Based on the change in level and trend, in addition to the magnitude and statistical significance of Tau, there is a demonstrated basic effect on number identification, but only after extensive individualization of the intervention.

Venus. Because of the amount of individualization required for Venus (see Data-Based Individualization procedures above), Venus experienced a minimal increase in trend which was

delayed from baseline to intervention (Baseline = 0.00; Intervention = 0.36) and eventually resulted in an overall increase in level in Phase 3, with further improvements in Phase 4 ($M_{baseline}$ = 0.00; $SD_{baseline}$ = 0.00; $M_{Intervention}$ = 2.55; $SD_{Intervention}$ = 2.24). Tau reveals a large effect that is statistically significant (0.824, $p < .001$). Based on the change in level and trend, in addition to the magnitude and statistical significance of Tau, there is a demonstrated basic effect on number identification, but only after extensive individualization of the intervention.

Novak. Novak experienced an increase in trend from baseline to intervention (Baseline = 0.24; Intervention = 0.91). This change in trend was consistent throughout the intervention phase and resulted in a large average improvement compared to baseline ($M_{baseline}$ = 10.00; $SD_{baseline}$ = 2.39; $M_{Intervention}$ = 19.25; $SD_{Intervention}$ = 4.85). Tau reveals a large effect that is statistically significant (0.827, $p < .001$). Based on the change to improving trend that was consistent throughout the intervention phase, in addition to the magnitude and statistical significance of Tau, there is a demonstrated basic effect on number identification.

Rafael. Rafael experienced an improving trend in baseline which initially continued during intervention, but then decelerated (Baseline = 1.37; Intervention = -0.40). There was some evidence of improvement in level ($M_{baseline}$ = 26.13; $SD_{baseline}$ = 4.64; $M_{Intervention}$ = 35.80; $SD_{Intervention}$ = 6.90). The continuation of baseline trend, and high variability in intervention complicates the analysis, thus no basic effect can be inferred.

Summary. Overall, the data show a clear demonstration of basic effects for three participants and suggest that the intervention led to improvements in number identification. Two of the three participants required extensive individualization of the intervention before this effect was found.

Quantity discrimination skills. Participants' number of correct quantity discriminations (CQD) was analyzed to determine whether there were gains in identifying larger numerals. Figure 3 below illustrates CQD in baseline and intervention on the Quantity Discrimination measure. Table 7 shows descriptive statistics for all participants on the Quantity Discrimination measure. Table 8 depicts participant Tau values and statistical significance.

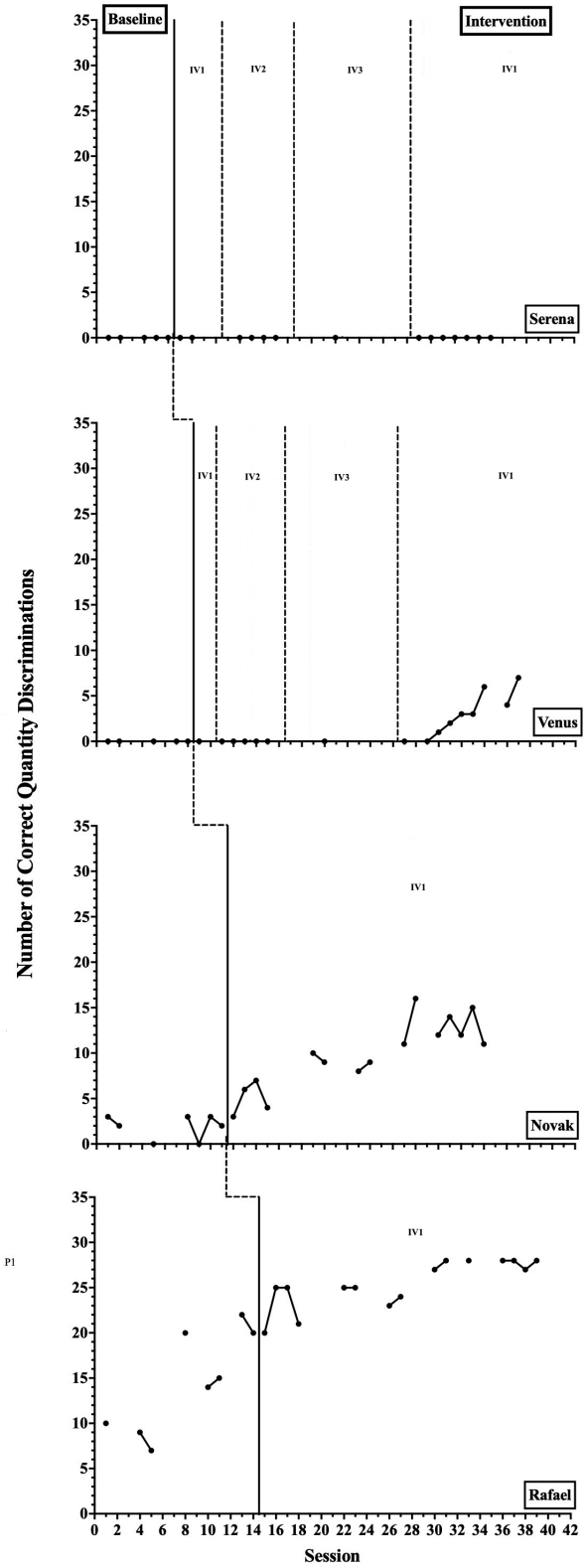

Figure 3. Correct quantity discriminations per minute on the Quantity Discrimination measure (Phase One, = IV1, Phase Two = IV2, Phase 3 = IV3, Phase 4 = back to IV1)

Table 7.

Descriptive Statistics for Quantity Discrimination measure

Participant	Phase	Mean	Standard Deviation	Slope
Serena	Baseline	0.00	0.00	0.00
	Intervention	0.00	0.00	0.00
Venus	Baseline	0.00	0.00	0.00
	Intervention	1.63	2.33	0.42
Novak	Baseline	1.86	1.35	-0.04
	Intervention	9.80	3.80	0.71
Rafael	Baseline	14.63	5.66	1.82
	Intervention	25.47	2.61	0.46

Table 8.

Differences in Correct Quantity Discriminations from Baseline to Intervention

Student	Tau	*p*-value
Serena	N/A	N/A
Venus	0.755	<.001
Novak	0.800	<.001
Rafael	0.760	<.001

Serena. Despite the individualization executed for Serena, her quantity discrimination skills remained at zero throughout intervention.

Venus. Because of the amount of individualization required, Venus experienced an increase in trend which was delayed from baseline to intervention (Baseline = 0.00; Intervention = 0.42) which eventually result in an overall increase in level in Phase 4 ($M_{baseline}$ = 0.00; $SD_{baseline}$ = 0.00; $M_{Intervention}$ = 1.63; $SD_{Intervention}$ = 2.33). Tau reveals a moderate to large effect that is statistically significant (0.755, $p < .001$). Based on the change to improving trend in Phase 4 that was consistent throughout the remainder of the intervention, in addition to the magnitude and statistical significance of Tau, there is a demonstrated basic effect on quantity discrimination, but only after extensive individualization of the intervention.

Novak. Novak experienced a change from flat to improving trend from baseline to intervention (Baseline = -0.04; Intervention = 0.71). Additional visual analysis demonstrates an improvement in level ($M_{baseline}$ = 1.86; $SD_{baseline}$ = 1.35; $M_{Intervention}$ = 9.80; $SD_{Intervention}$ = 3.80). Tau reveals a large effect that is statistically significant (0.800, $p < .001$). Based on the change to improving trend that was consistent throughout the intervention phase, in addition to the magnitude and statistical significance of Tau, there is a demonstrated basic effect on quantity discrimination.

Rafael. Rafael experienced an improving trend in baseline which slowed, but was sustained during intervention (Baseline = 1.82; Intervention = 0.46), resulting in an improvement in level ($M_{baseline}$ = 14.63; $SD_{baseline}$ = 5.66; $M_{Intervention}$ = 25.47; $SD_{Intervention}$ = 2.61); this continuation of improving baseline trend complicates the analysis, thus no basic effect can be inferred.

Summary. Overall, the data show a clear demonstration of basic effects for two of four participants, both of which required extensive individualization of the intervention before this effect was found. Data overlap and continuation of improving baseline trend complicate analysis for the additional two participants. There is insufficient evidence to support that this intervention affected the quantity discrimination skills of participants.

Missing number skills. Participants' number of correct missing numbers (CMN) was analyzed to determine whether there were gains in identifying missing numerals. Figure 4 below illustrates CMN in baseline and intervention on the Missing Number measure. Table 9 shows descriptive statistics for all participants on the Missing Number measure. Table 10 depicts participant Tau values and statistical significance.

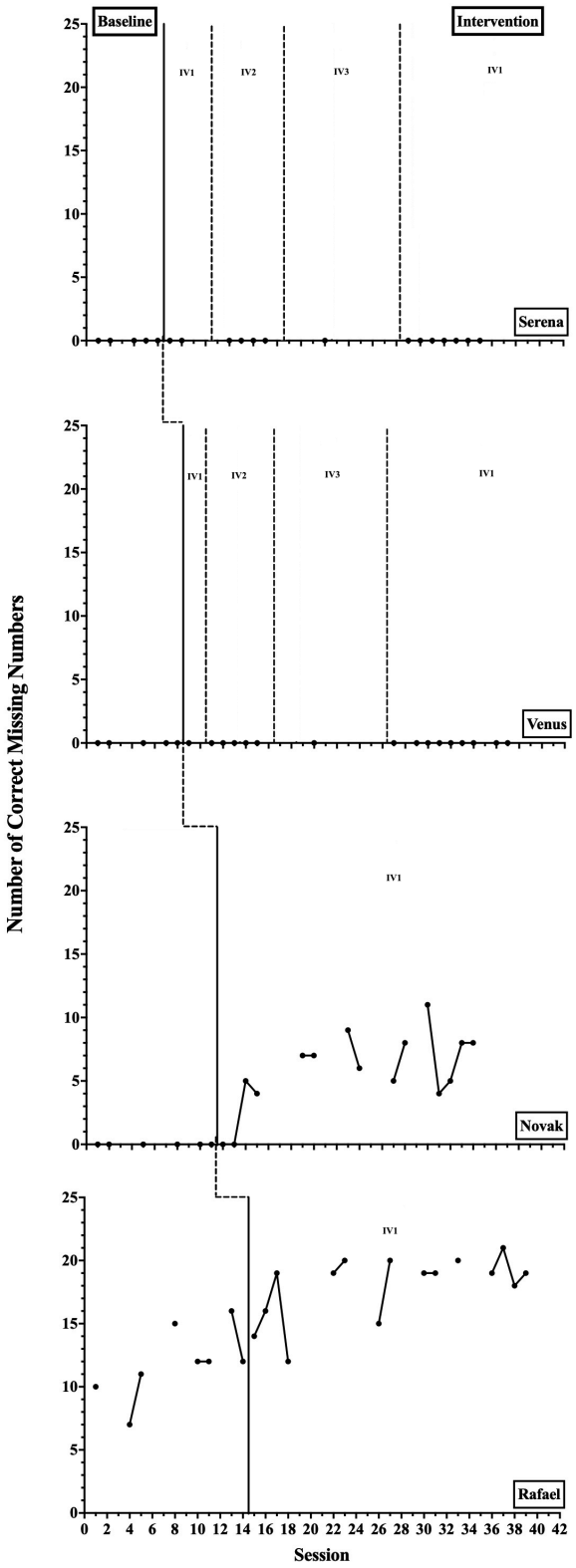

Figure 4. Correct missing numbers per minute on the Missing Number measure (Phase One, = IV1, Phase Two = IV2, Phase 3 = IV3, Phase 4 = back to IV1)

Table 9.

Descriptive Statistics for Missing Number measure

Participant	Phase	Mean	Standard Deviation	Slope
Serena	Baseline	0.00	0.00	0.00
	Intervention	0.00	0.00	0.00
Venus	Baseline	0.00	0.00	0.00
	Intervention	0.00	0.00	0.00
Novak	Baseline	0.00	0.00	0.00
	Intervention	5.80	3.05	0.41
Rafael	Baseline	11.88	2.80	0.70
	Intervention	18.00	2.56	0.32

Table 10.

Differences in Correct Missing Numbers from Baseline to Intervention

Student	Tau	*p*-value
Serena	N/A	N/A
Venus	N/A	N/A
Novak	0.651	<.001
Rafael	0.611	<.001

Serena. Despite the individualization which ensued for Serena, her missing number identification skills did not improve.

Venus. Despite the individualization implemented for Venus, her missing number identification skills did not improve.

Novak. Novak experienced a change to improving trend from baseline to intervention (Baseline = 0.00; Intervention = 0.41) which resulted in an overall increase in level ($M_{baseline}$ = 0.00; $SD_{baseline}$ = 0.00; $M_{Intervention}$ = 5.80; $SD_{Intervention}$ = 3.05). Tau reveals a moderate effect that is statistically significant (0.651, $p < .001$). Based on the change in level and trend, in addition to the magnitude and statistical significance of Tau, there is a demonstrated effect on quantity discrimination.

Rafael. Rafael experienced an improving trend in baseline which slowed, but was sustained during intervention (Baseline = 0.70; Intervention = 0.32), resulting in an improvement in level ($M_{baseline}$ = 11.88; $SD_{baseline}$ = 2.80 $M_{Intervention}$ = 18.00; $SD_{Intervention}$ = 2.56); this continuation of improving baseline trend complicates the analysis, thus no basic effect can be inferred.

Summary. Overall, the data show a clear demonstration of basic effect for one of four participants; thus, there is insufficient evidence to support that this intervention affected the missing number identification skills of participants.

Broad Early Numeracy Skills

Student performance on the standardized measure of early numeracy skills (TEMA-3) is shown in Table 11.

Table 11.

Student Performance on Standardized Measure of Early Numeracy

	***TEMA-3* Standard Score and Classification**	
Student	Pre-Baseline	Post- Intervention
Serena	61 (Very Poor)	65 (Very Poor)
Venus	55 (Very Poor)	63 (Very Poor)
Novak	76 (Poor)	102 (Average)
Rafael	87 (Below Average)	97 (Average)

The TEMA-3 results were used to form descriptive information about each participant's gain in broad early numeracy skills. For all four participants, there was an increase in broad early numeracy skills from pre-baseline to post-intervention. Serena's demonstrated some slight gains in broad early numeracy skills at the data collection points (pre = 61; post = 65) and her associated classification remained in the 'very poor' category. Similarly, Venus illustrated gains from pre-baseline (55) to post-intervention (63) and her associated classification remained in the

‘very poor’ category. Novak’s gains were very large (pre = 76; post = 102), and he moved from the ‘poor’ category to the ‘average’ category. Likewise, Rafael’s gains were large (pre = 87; post = 97), and he moved from the ‘below average’ to the ‘average’ category.

Chapter 5: Discussion

The purpose of the current study was to investigate the effectiveness of the Whole Number Foundations Level K intervention, previously used for small-groups, as a DBI platform intervention for individual kindergarten students who were struggling with early numeracy. To accomplish this goal, the intervention was administered to four participants from one classroom in Vancouver. The individualization involved teaching prerequisite numeracy skills before the first lesson commenced for two of the four participants. Other than altering the starting point, the remaining two participants received no adaptations or modifications to the intervention. The effectiveness of the intervention was assessed using a multiple baseline (multiple probe) across participants design. The effectiveness of the intervention was measured by student progress on a standardized early numeracy measure and by four early numeracy progress monitoring measures: Oral Counting, Number Identification, Quantity Discrimination, and Missing Number.

The study aimed to answer the following research questions:

1. Does implementing the Whole Number Foundations Level K early numeracy intervention as a platform intervention for DBI improve early numeracy skills with kindergarteners who are struggling with mathematics in the general education classroom?
2. What (if any) amount of individualization of the Whole Number Foundations Level K early numeracy intervention is required in order for an effect to be found?

The main hypothesis of the study was that the intervention would help to improve participants' early numeracy skills, and this would be reflected in each participants performance on the early numeracy measures and standardized measure.

Findings and Implications for Practice

A functional relationship (3 demonstrations of an effect) was found for Number Identification. For two of the three participants extensive individualization ensued before the above-mentioned effect was found. The fourth participant's lack of effect was due to improving baseline trend which complicated analysis. Additionally, there was an increase in broad early numeracy skills from pre-baseline to post-intervention for all participants. While a functional relationship could not be established for Oral Counting, Quantity Discrimination, and Missing Number, it is clear from the results that three of the four participants did make direct gains in multiple numeracy areas, and that for all participants response to intervention varied based on their initial level of numeracy skills. If the intervention was implemented "as-is", there would have been no response at all for two of the participants. Thus, this differential response to the intervention based on initial skill is the main finding of the current study.

To further this point, by tailoring the start point for Novak, visual and statistical analysis illustrates direct gains in number identification, quantity discrimination, and missing number skills. For Novak the use of the Math Check Points as a diagnostic measure to establish the appropriate starting point for the intervention, ensured that time was not wasted intervening on skills that he already had, and that was enough to accelerate his response to the intervention.

Serena and Venus had to be directly taught early numeracy skills prior to commencement of the intervention. It is due to this data-based individualization and direct teaching of prerequisite early numeracy skills that both had a response to the intervention. Visual and statistical analysis demonstrate direct gains for Serena in oral counting and number identification skills. Similarly, visual and statistical analysis reveal direct improvements in Venus' number identification, and quantity discrimination skills; both of which were not present at baseline and

would not have developed if data-based individualization, and teaching of precursor skills had not ensued. Thus, how and if participants responded to the intervention varied greatly according to initial early numeracy skills.

Serena and Venus' performance clearly illustrate the importance of individualization, but also reveal that there are certain precursor skills one needs to partake in the Whole Number Foundations Level K intervention. The manual for the intervention does not state which pre-requisite skills a participant must have to partake in the intervention. To participate in the intervention, the current study revealed that a student should have at least a beginner understanding of the concepts of magnitude perception and comparison, symbol representation, one-to-one correspondence, stable order, and cardinality. If one does not have at least a basic understanding of these concepts, it seems that one may have difficulty moving through lesson 1. The current study does bring to the forefront that there may be a role of precursors skills in moderating intervention performance, but to what extent?

The interaction between baseline skills and responsiveness to early numeracy intervention has been tested in several group design studies. A study by Clarke et al. (2019) examined the moderating role of initial numeracy skill in Whole Number Foundations Level K (called ROOTS in their study) performance. The study used a randomized block design with at-risk students (n = 592) within classrooms (n = 60) randomly assigned to one of two treatment conditions (a small group of two to five students) or control condition. Students with lower initial skills (between the 25th and 50th percentile), as measured by the TEMA-3, showed greater benefit from the intervention on two out of six kindergarten outcome measures used (Clarke et al., 2019). Novak and Rafael were between the 25th and 50th percentiles in the current study and did indeed seem to benefit greatly. However, Clark et al. (2019) did not assess the effectiveness of

the intervention for those who performed very poorly or below the 25th percentile, which is the case for Serena and Venus in the current study.

A study by Toll and Van Luit (2013) assessed the effects of a kindergarten numeracy intervention, looking specifically at effects for subgroups of students with low (between the 25th and 50th percentiles) and very low (below the 25th percentile) early mathematics skills. Study results revealed that the intervention was effective only for students who scored between the 25th and 50th percentiles on pretest measures of early numeracy; it was not beneficial for students with very low early number ability (<25th percentile) at the start of the intervention (Toll & Van Luit, 2013). One can thus infer that for the lowest students, individualization of the intervention must occur for an effect to be found, as was the case for Serena and Venus in the current study.

To summarize the findings of the aforementioned studies using data from the current study, it is likely that in the current study that Novak and Rafael benefited from modifying the starting point, but only because they had adequate baseline levels of numeracy skills. Serena and Venus on the other hand, would not have benefited from the intervention had it been used in the same way, as they did not have the skills required. The current study, as well as the two studies mentioned indicate that there seems to be a greater need for individualization for those students performing below the 25th percentile.

Serena and Venus' extremely low initial skill level also brings to question whether students assessed below the 25th percentile should progress all the way through the tiers or be immediately and directly placement in an individualized Tier 3 intervention. A study that sheds light on to this question was done by Al Otaiba et al. in 2014. It explored the effects of two RTI models on student reading performance. In the study, the researchers used initial screening data to group students into one of two conditions: "typical RTI" that followed the two-stage RTI

decision rules that wait to assess response at Tier 1 and subsequent tiers or "dynamic RTI" which provided Tier 2 or Tier 3 instruction immediately to those with the weakest reading skills (Al Otabia et al., 2014).

Results illustrated that when the students in the dynamic condition (who had the weakest initial skills) received the most intensive intervention, their reading performance was significantly stronger at the end of the year than students in the typical RTI condition (Al Otabia et al., 2014). This finding suggests that not all students should be put through the typical RTI model; some students may benefit more by being moved immediately to Tier 2 or Tier 3 depending on their level of performance on the initial screening. Although this research was done with reading, Serena and Venus' performance in the current study suggest that evaluation of dynamic RTI models may also be needed for early numeracy and reveal another critical factor to consider for practice.

It is also important to consider the implications of using fluency measures as a way to measure generalization of early numeracy skills gained in each lesson. At times there was a mismatch between the actual skill taught in the lesson and the skill the fluency measure assessed. This was certainly the case for Venus and Serena. They both initially experienced limited skill transfer (i.e., no increase in performance on fluency measures) despite demonstrating early numeracy skills in the instructional sessions and on the mastery assessments. Had the study directly measured the skills taught, their performance would have been much higher.

Limitations

There are several limitations for the current study with regards to generalizability, phase-change scheduling, and implementation bias. First, generalizability of current study results is limited by the low number of participants. All four participants also attended the same school,

were in the same class, had the same teacher, had similar socio-economic backgrounds, and were fairly heterogenous in baseline early numeracy skills. Complicating generalizability further is the fact that two of the four participants were twins, who shared similar genes and home environments. Although participant similarity reduces threats to internal validity in a multiple baseline design, it also limits generalization to the larger population as it is impossible to tease apart whether it is these common characteristics or whether it was the intervention that was the reason for study outcomes. This limitation, however, is characteristic of single-case research studies, and generalizability is typically established thought systematic replication in future studies; this will be further discussed as a recommendation for future studies below.

Next, because of limited time resources and an attempt to provide participants in need of early numeracy intervention with a maximum number of intervention sessions, the onset of intervention was set *a priori*, regardless of whether there was data variability or improving trend in baseline. This complicated a large portion of the analysis as there was continuation of accelerating baseline trend.

Lastly, all individualization and data collection were performed by one interventionist as a way to minimize inter-interventionist discrepancies. Thus, it may have also produced bias as the interventionist was aware of the study's objectives and made it difficult to separate the intervention protocol from the interventionist. The current study attempted to minimize these biases by using an external reviewer for inter-observer agreement and fidelity checks, but even so the extent of bias introduced is unknown.

Recommendations for Future Research

The following recommendations are based upon the current study's findings and

limitations. Firstly, exploring what specific profiles or baseline early numeracy skills predict non-response is imperative. Past research has explored effects of numeracy intervention, looking specifically at effects for subgroups split by performance percentiles, but no one has explored what specific profiles or baseline skills predict non-response. An additional precursor skill participants may need, that has not been widely examined with numeracy, may be matching to sample, which is a crucial first step to stimulus equivalence (Sidman, 1971). In a typical matching to sample procedure a participant is presented with a single stimulus called the sample (e.g., yellow square) and then with two choice stimuli called the comparisons (e.g., blue square, orange square). The participant is asked to select the compassion that matches the stimulus. Exploration of the relationship between matching to sample skills and response to the intervention is highly recommended. By exploring these profiles or precursor skills further, interventionists or teachers would be better equipped to intervene and modify the intervention based on the needs of each individual student. Development of a skills inventory that is used prior to intervention could also come out of this process.

Another recommendation is the replication of the current study across the participants performing below the 25th percentile (like Venus and Serena in the current study) to determine the effectiveness of the individualization used in the current study. The replication should follow a A – B (WNF) – C (WNF + individualization) design, and the individualization component ought to include the most effective individualization found (adapted National Center on Intensive Intervention counting routine; 2015) in the current study, without all the additional intervention phases. This would appropriately assess the effectiveness of the individualization used in the current study, and aid interventionists or teachers when faced with participants or students performing below the 25th percentile.

Moreover, exploring the cognitive determinants of non-response is also a key recommendation. For example, working memory (WM) or one's ability store information for short periods of time when engaging in cognitively demanding activities (Baddeley, 1986) has long been thought to plat important role in mathematics development (Peng, Barnes & Namkung, 2016). However, unlike higher level mathematics skills, research into the relationship between working memory and early numeracy has been inconclusive. Some researchers have found that, compared with other mathematics skills that require multistep procedures basic number knowledge is not significantly correlated with working memory (e.g., Kolkman, Kroesbergen, & Leseman, 2014; Passolunghi, Mammarella, & Altoè, 2008; Passolunghi & Siegel, 2004), while other studies demonstrate a relationship (e.g., Geary, Hoard, Nugent, & Byrd-Craven, 2008; Mazzocco, Feigenson, & Halberda, 2011). The extent to which one's working memory predicts non-response should be explored by direct measurement of this cognitive function before intervention. After the intervention is complete, working memory as a moderating factor ought to be explored.

Lastly, research into whether the poorest performing students benefit most from a dynamic RTI model has only been performed to do with reading interventions. Research to corroborate such findings for numeracy on a large scale is needed.

Conclusion

The current study explored whether implementing the Whole Number Foundations Level K early numeracy intervention as a platform intervention for DBI would improve early numeracy skills of kindergarteners. A functional relationship was found for the Number Identification measure; however, two of the three participants needed extensive individualization of the intervention before the above-mentioned effect was found. If no individualization took place, no

effect (basic effects for two participants or an overall functional) would have been found. In addition, there was an increase in broad early numeracy skills from pre-baseline to post-intervention for all participants as measure by a standardized early numeracy test. While a functional relationship could not be established for the Oral Counting, Quantity Discrimination, and Missing Number measures, the current study does illustrate findings that are critical for practice.

First, the study suggested that there are precursor numeracy skills that are necessary for one to be able to partake in the Whole Number Foundations Level K intervention These skills were shown to be at least a beginner understanding of the concepts of magnitude perception and comparison, symbol representation, one-to-one correspondence, stable order, and cardinality (i.e. identifying numerals 1, 2 or 3; counting to 3; making sets of objects to match numbers 1, 2 or 3).

Next, the current study was consistent with previous research supported previous research (Clarke et al., 2019; Toll & Van Luit, 2013) explored the moderating role of initial skill intervention performance. Like these studies, the current study that found that that for students whose initial early numeracy skills were between the 25th and 50th percentile, the intervention was beneficial and could be used "as-is". For those students performing below the 25th percentile on the other hand, individualization must ensue for the intervention to be effective; if it is used "as-is" no effect will be shown. The current study extended the aforementioned research by determining modifications that could improve effectiveness for those children performing below the 25th percentile.

Lastly, Al Otabia et al. (2014) that illustrated that not all students who are struggling with reading needs to go through the typical RTI model wherein students begin in Tier 1 and progress through subsequent tiers based on continued weak skills and slow growth. The researchers

illustrated that it may be more beneficial for those students performing the poorest to be moved immediately to Tier 3. The current study illustrates similar findings; there may be value in jumping straight to Tier 3 in the context of early numeracy as well.

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Appendices

Appendix A

Lesson Procedural Check-List

Preparing for the Lesson: Implementing with Fidelity

It is important to present all parts of the lesson, including the Math Practice. The achievement of the children will be directly related to implementing the curriculum with fidelity, which means as it was designed and written. Carefully constructed teacher wording, high rates of opportunities to respond, positive engagement techniques, partner activities and individual turns, and use of math models and manipulatives, are all designed to help children acquire important math concepts, skills, and strategic thinking. Use the following steps in preparing for daily lessons.

Preview the Lesson

- ❑ Read through the lesson so you know what concepts and skills will be introduced and reviewed.
- ❑ Review the lesson by header (numbered and shaded headings). Make sure you know the focus, sequence of tasks, teacher wording, etc. Highlight or make any notes on the lesson to help you when you're teaching the lesson.
- ❑ Practice aloud any parts of the lesson you're unsure about.

Organize for the Delivery

- ❑ Review the lesson one more time and anticipate how much time to spend on each part of the lesson.
- ❑ Gather and organize teacher and student materials for easy access.

Teach the Lesson

- ❑ Follow lesson activities and script.
- ❑ Provide lots of opportunities for children to respond (unison group responses).
- ❑ Provide specific positive reinforcement and confirmations of correct responses.
- ❑ Provide immediate corrective feedback followed by extra positive practice.
- ❑ Give individual turns to check on mastery at the end of each activity.

After the Lesson

- ❑ Reflect on the children's performance. Were they successful and engaged? Were there skills or concepts they weren't firm on?
- ❑ Are there individual children who need additional practice and monitoring?
- ❑ What adjustments will you make in your next lesson?

Appendix B

Data Collection for Math Response Cards Sheet

Data Collection for Math Response Cards

Student ID_____ Assessor _____ Date_____

_____1. Independently identifies first number after number is presented (+ = correctly identifies; - = does not correctly identify, NO=no opportunity)

Prompt level used: Verbal Model Physical and number presented

_____2. Independently identifies second number after number is presented (+ = correctly identifies; - = does not correctly identify, NO=no opportunity)

Prompt level used: Verbal Model Physical and number presented

_____3. Independently identifies third number after number is presented (+ = correctly identifies; - = does not correctly identify, NO=no opportunity)

Prompt level used: Verbal Model Physical and number presented

_____4. Independently identifies fourth number after number is presented (+ = correctly identifies; - = does not correctly identify, NO=no opportunity)

Prompt level used: Verbal Model Physical and number presented

_____5. Independently identifies fifth number after number is presented (+ = correctly identifies; - = does not correctly identify, NO=no opportunity)

Prompt level used: Verbal Model Physical and number presented

_____6. Independently identifies sixth number after number is presented for a second time (+ = correctly identifies; - = does not correctly identify, NO=no opportunity)

Prompt level used: Verbal Model Physical and number presented

_____7. Independently identifies seventh number after number is presented for a second time (+ = correctly identifies; - = does not correctly identify, NO=no opportunity)

Prompt level used: Verbal Model Physical and number presented

_____8. Independently identifies eighth number after number is presented for a second time (+ = correctly identifies; - = does not correctly identify, NO=no opportunity)

Prompt level used: Verbal Model Physical and number presented

_____9. Independently identifies ninth number after number is presented for a second time (+ = correctly identifies; - = does not correctly identify, NO=no opportunity)

Prompt level used: Verbal Model Physical and number presented

_____10. Independently identifies tenth number after number is presented for a second time (+ = correctly identifies; - = does not correctly identify, NO=no opportunity)

Prompt level used: Verbal Model Physical and number presented

_____11. Independently identifies 11th number after number is presented for a third time (+ = correctly identifies; - = does not correctly identify, NO=no opportunity)

Prompt level used: Verbal Model Physical and number presented

_____12. Independently identifies 12th number after number is presented for a third time (+ = correctly identifies; - = does not correctly identify, NO=no opportunity)

Prompt level used: Verbal Model Physical and number presented

_____13. Independently identifies 13th number after number is presented for a third time (+ = correctly identifies; - = does not correctly identify, NO=no opportunity)

Prompt level used: Verbal Model Physical and number presented

_____14. Independently identifies 14th number after number is presented for a third time (+ = correctly identifies; - = does not correctly identify, NO=no opportunity)

Prompt level used: Verbal Model Physical and number presented

_____15. Independently identifies 15th number after number is presented for a third time (+ = correctly identifies; - = does not correctly identify, NO=no opportunity)

Prompt level used: Verbal Model Physical and number presented

Appendix C

Counting Worksheet

Date:

Object:_____

Correct count #1? Y N

Notes:

Correct count #2? Y N

Notes:

Correct count #3? Y N

Notes:

Object:_____

Correct count #1? Y N

Notes:

Correct count #2? Y N

Notes:

Correct count #3? Y N

Notes:

Object:_____

Correct count #1? Y N

Notes:

Correct count #2? Y N

Notes:

Correct count #3? Y N

Notes:

Object:_____

Correct count #1? Y N

Notes:

Correct count #2? Y N

Notes:

Correct count #3? Y N

Notes: