

## Building the Early Numeracy Skills of Students with Moderate Intellectual Disability

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### **Abstract:**

This study investigated the effects of an early numeracy intervention package on early numeracy skill attainment for participants with moderate intellectual disabilities, including autism. The intervention taught students to use nonstandard and standard measurement, counting skills, calendar skills, how to create sets, and how to identify and work with patterns. A single-subject design across three classrooms was employed to evaluate the intervention package. Specifically, three special education teachers used engaging story-based math lessons with embedded systematic instruction to promote the early math concept acquisition of five students with intellectual disability. Results found that all students showed a significant increase in early numeracy skill acquisition after receiving the intervention package. The study's contributions to research, limitations, need for future research, and implications for practice are discussed.

**Keywords:** Special Education | Early Numeracy | Intellectual Disabilities | Math Education

### **Article:**

Math education has long been an important topic in research and practice across the grade levels. More recently, with the addition of the Common Core State Standards in mathematics and specific attention to preparing students to succeed in the 21st century, math education seems to have taken an even greater limelight. The National Council of Teachers of Mathematics (NCTM, 2000) specifically addresses the need for all students to gain math skills to participate in their everyday life leading to "significantly enhanced opportunities and options for shaping their futures" (p.1.)

For students with significant intellectual disabilities, math education has significantly evolved over the past decade from an over emphasis on money and time instruction to math skills aligned to grade-level standards. In a comprehensive literature review, Browder, Spooner, Ahlgrim-

Delzell, Harris, and Wakeman (2008) found 68 empirical studies that taught math related skills to students with severe intellectual disabilities. While 68 studies were found, 93% of them focused on simple discriminations within the domain of Numbers and Operations. However, with increased expectations for all students and high stakes accountability, the field of severe disabilities has begun to investigate ways to teach beyond money and time (Spooner, Knight, Browder, & Smith, 2011).

In 2009, Towles-Reeves, Kearns, Kleinert, and Kelinert, and again in 2011, Kearns, Towles-Reeves, Kleinert, Kleinert, and Thomas investigated student alternate assessments scores based on alternate achievement standards (AA-AAS). Specifically in 2011, Kearns et al. took a close look at student scores in seven states and, similar to the 2009 study, found that this population of students had limited early numeracy skills. Specifically, only 31% of students could count with correspondence and make sets of items to 10, 12% could rote count to 5, and only 4% could apply computational procedures to solve real life problems. In 2013, Browder, Jimenez, Spooner, Saunders, Hudson, and Bethune (2012) developed a conceptual model of early numeracy learning for students with significant intellectual disability. Primarily based in reaction to the findings of Kearns et al. (2011), Browder et al. state "If 88% of elementary students in AA-AAS cannot even count to five, clearly there is a need for more effective mathematical instruction for students with moderate and severe developmental disabilities."

Particularly in elementary school, many educators and researchers in the field of mild disability have long valued intensive instruction to build early numeracy skills, due to its correlation with student math progress in later years (Gersten & Chard, 1999; NMP, 2008). However, for students with severe intellectual disability, intensive support in early numeracy skills may occur or may be limited in depth and application to meaningful contexts. Currently research on math education for students with significant intellectual disability has shown that students can learn grade-aligned mathematics, such as algebra and geometry (Browder, Trela, Courtade, Jimenez, Knight; & Flowers, 2012; Jimenez, Browder, & Courtade, 2008). While students with severe intellectual disabilities continue to demonstrate growth in the general curriculum by accessing grade level standards, based on the findings of Kearns et al., student's accessibility to those standards is limited. For example, if a student is not able to count sets of materials to 5 items, their ability to access multiplication standards can only be a rote response without conceptual understanding. Without conceptual based knowledge, even at a basic level, students may not be able to apply and generalize these early numeracy skills to higher level math skills. Even at an alternate achievement level, most secondary math skills require students to know numbers, compose sets, perform simple addition and subtraction problems and generalize their learning to new contexts. If only 12% of students with severe disabilities can currently perform these basic math skills, a large majority of students with severe disabilities will not be able to access grade level standards at a meaningful level.

Browder et al. (2012) developed a conceptual model for building early numeracy skills with students who have an intellectual disability. The model is based on the premise that students with

severe disability should be given the opportunity to build a foundation of early numeracy skills throughout their elementary years. Additionally, through building this foundation, they should also continue to be provided ways to access the grade-level standards at the greatest depth possible. Within Browder et al.'s conceptual framework, pilot data was taken with 6 students with severe disability. The finding of this pilot data illustrated the positive effects of early numeracy skill instruction on student's skill acquisition, suggesting that when provided systematic math skill instruction students with severe disabilities could learn how to perform early numeracy skills, similar to those described in the findings of Kearns et al., 2011.

Through the growth of this model the Early Numeracy curriculum (Jimenez, Browder, & Saunders, 2013) was developed to address the need for more explicit instruction needed to build students with moderate and severe intellectual disability success in mathematics (Gersten & Chard, 1999). Using evidence based practices to teach academics to students with moderate and severe intellectual disability (Spooner et al., 2012), the Early Numeracy curriculum uses systematic prompting and feedback, task analytic instruction, and real life contexts for math. Because students need the opportunity to build early numeracy skills while accessing grade-level standards, lessons were developed to be both age-appropriate and can be embedded with more advanced mathematics of their grade level.

The purpose of this study was to expand the research base related to early math instruction for students with severe disabilities in response to the need to build early numeracy skills for students to gain greater access to grade-level standards as they progress through their school career. Specifically, the research question was: What is the effect of an early numeracy treatment package which includes story-based math problems, systematic instruction (time delay, least to most prompting systems), graphic organizers, and multiple exemplar training on student's demonstration of targeted early numeracy skills?

## **Method**

### *Participants and Settings*

*Students.* Ten elementary school students with moderate intellectual disability, including autism in two neighboring school districts (1 large urban and 1 small rural) were recruited to participate in the study. Selection criteria of the participants for the study included (a) diagnosis of a moderate or severe developmental disability, and/or autism, (b) participation in the North Carolina EXTEND 1 alternate assessment based on alternate achievement standards, (c) enrollment in an elementary school, (d) ability to recognize a number from a non-number, sort objects, and communicate a choice consistently, and (e) percentage of early numeracy skills mastered prior to intervention (below 80% of skills addressed). Based on these criteria, each teacher (n = 5) was asked to select two students to participate in the study. After informed consent was obtained for all students and teachers, baseline data collection showed two students did not meet the selection criteria. Additionally, another student was removed from the study in its

early stages due to personal medical needs. Finally, due to the end of the school year, two students did not enter the intervention phase of the study.

**TABLE 1** Student Demographics

<i>Participant</i>	<i>Gender/Ethnicity</i>	<i>Grade</i>	<i>Primary Diagnoses *IQ Scores Were Not Available</i>	<i>Primary Communication</i>
Eric	M, Caucasian	4	Autism, Moderate ID	Verbal (often perseverated on topics/requests)—responded best via pointing response
Jessy	F, African American	2	Moderate ID	Verbal
Jon	M, African American	4	Autism, Moderate ID	Verbal responded best via grasping response
Misty	F, Caucasian	3	Moderate ID, select mute	Nonverbal, limited sign and gesture, communication board was new in educational setting, she was learning to use
David	M, African American	3	Moderate ID	Verbal

A total of five students participated in the study, across three classrooms. All five students were served in self-contained classrooms for students with developmental disability, and/or autism. Three of the students were male and two female. Two of the students had a diagnosis of autism. Student characteristics are included in Table 1.

*Teachers.* Five special education teachers were recruited to participate in the study. One teacher did not participate in the study because one of her student did not meet the selection criteria (student had mastery of over 80% of early numeracy skills addressed), and the other student was removed from the study in its early stages. Additionally, due to the end of the school year the final teacher did not enter into the treatment package. Three self-contained special education teachers participated in this study. The teachers had a mean of eight years of experience with a range of 5-14 years working with students with moderate-severe intellectual disability. All three teachers obtained a bachelor degree in special education and one teacher was currently pursuing a master's degree in special education at the time of the study.

*Setting.* The setting included self-contained classrooms for students with moderate to severe intellectual disability, including autism. Two classrooms were located in public elementary schools and one classroom was located in a public separate setting for students with developmental disabilities. The schools were located within two neighboring school districts in the southeastern United States.

## *Materials*

An early numeracy curriculum developed for students with moderate to severe intellectual disability was used to teach and assess students during this study. The Early Numeracy Curriculum (Jimenez, Browder, & Saunders, 2013) is comprised of four units with six scripted lessons per unit. Units 1 and 2 were used for this study. Each lesson began with a story read-aloud by the teacher. Stories changed with each lesson (e.g., Unit 1, lesson 1-race cars, horses, motorcycles); however, the target skills remained the same for the entire unit, giving students the opportunity for repeated practice and to apply skills to new contexts. After five story-based lessons, the sixth lesson of both units was a review game, which consisted of a sports-related theme and game board.

Students were given several graphic organizers and response materials that remained constant across all lessons and units: (1) set maker-laminated piece of cardstock with two circles used for placing objects into a set and a third circle for combining the sets together, (2) line counter-a straight line drawn across the page used to count manipulatives, (3) pattern maker-a series of line drawn boxes on laminated cardstock, on which the students put objects to create a pattern (e.g., jewel, gold coin, jewel, gold coin). Additionally, students used small cards with symbols (=, <, and >) and a number line with Velcro numbers from 1-10. Each student received a "pile" of counting manipulatives. The manipulatives were theme-based and changed for each story. For example, in a story about pirates, the manipulatives used in that lesson were jewels from the treasure chest (i.e., rings, earrings). For each lesson, students were given several alternative response materials (i.e., assistive technology, communication boards, multiple options to respond) that were available to the students throughout all lessons and units in this study.

Teachers received scripted lesson plans to guide each lesson, including math stories. Each lesson was fully scripted to assist with fidelity of the teachers' use of systematic prompting and feedback, however, teachers were able to use the "script" as a guide, rather than to read verbatim as they gained confidence in implementing each math numeracy skill, prompting, and feedback. For example, the script may have read "Great job adding the cars together, you are a super counter", teachers understood this was a prompt to give specific praise and they could individualize as needed.

Finally, each lesson came with a poster that was used to provide a context for the lesson (e.g., race track with bleachers for Unit 1, lesson 1). The posters included a place for teachers to "role play" with the materials (e.g., pretend to have 2 cars line up to race, then another 1 car join the race later, in coordination with the story), and select graphic organizers embedded into the scene (e.g., pattern maker bleacher; red seat, green seat, red seat, green seat).

## *Research Design*

In this single subject study, the students received the intervention in a staggered multiple probe across students (3 groups) research design (Gast, 2010). Once baseline was stable and students

showed increased scores during the intervention phase, additional students in the next group were introduced to the independent variable. This design was chosen because continued baseline probes may have been frustrating and intrusive to some students (Gast, 2010).

### *Dependent Variables and Measurement*

*Early mathematics assessment.* The Early Numeracy (Jimenez et al., 2013) curriculum assessment was used to measure target math skill objectives embedded into each lesson taught. A script was provided that assessed each objective briefly through presenting materials and asking the student to perform a response (e.g., "make a set of 5"). Students were given 5 seconds to begin responding, and their answer was scored as correct (+) or incorrect (-). Feedback was given on performance only (e.g., "Great job! You are working really hard!"). The assessment was arranged by the related objectives from the four units (e.g., making a set) with assessment objectives progressively gaining difficulty across skill sets (e.g., number identification, calendar skills). The entire assessment was given to all students during baseline and intervention data probes, because it was not clear at the beginning of the study how many units would be able to be completed by teachers/students. While only two units were completed upon the completion of the study, it was still important to assess all units. This is due to the fact that some students may show generalization of numeracy skills across units prior to being directly taught those skills (e.g., addition with totals to 5 taught in unit 2 may lead to generalization to addition with totals to 10 taught in unit 3). Students were given two tasks for each objective. A ceiling was set so if students missed both tasks for a specific objective within a unit, the assessment was discontinued for that objective, and the assessor moved to the next set with the student. For example, in Unit 1, students were given two trials to create sets of 1-3 objects. The student was given 5-6 counters and a set maker and told, "Make a set of \_\_\_#1-3." If the student got at least one trial correct within this Unit 1 objective, the assessor moved to Unit 2. In Unit 2, students were given two trials to create sets of 1-5 objects. Again, if the student got at least one trial correct, the assessor moved to Unit 3. The assessment had a total number of 80 points. Units 1 and 2 had 22 points possible, and Units 3 and 4 had a total of 18 points possible. This assessment was administered individually by a member of the university research team in a quiet area of the special education classroom. Students were assessed bi-weekly. Two versions of the assessment were used to control for threats to internal validity (i.e., testing effects).

### *Experimental Design Procedures*

*Baseline.* During baseline, the students received their typical mathematics instruction in the special education classroom. To obtain baseline data, the members of the research team took a minimum of five data points by implementing the Early Numeracy Assessment. The teachers were staggered into the intervention based on the order in which the teachers returned their initial participation consent letters. Once baseline data was stable the first group of students began the intervention phase (teacher 1). The other students remained in baseline condition. Once group 1 showed a change in level and/or trend, group 2 began intervention. The same procedures were

used for group 3. Prior to entering the intervention phase, student groups received an additional probe to validate that the original baseline performance was stable. Participants then remained in the intervention phase throughout the entire study, moving from one unit to the next as time permitted (i.e., teacher 3 only completed Unit 1 due to the end of the school year). Generalization data were collected throughout the study as part of each probe (testing probes used different contexts to demonstrate numeracy skills than in lessons).

*Intervention.* The intervention was designed to provide intensive instruction on the specific early numeracy objectives outlined in Table 2. First, the teacher read the theme-based math story aloud providing opportunities for the students to see and manipulate the materials (e.g., toy cars and horses, play money, plastic worms). Next, the teacher used the scripted lesson to guide them through the math story again, but with opportunities to pause and perform the math skill. For example, in a story about a car race, the script would guide the teacher to reread the first two lines of the story, introducing two cars getting ready to line up at the starting line. The teacher would then use the designated prompting procedure indicated by the lesson plan script to allow the student to line up two cars (1:1 correspondence).

All skills were taught using a system of least intrusive prompts, except for number identification. Number identification was taught using time delay by naming the number immediately (zero delay) and then having the student repeat the name. During delay rounds, the teacher waited five seconds for the student to name the number. If the student was correct, specific verbal praise was provided (e.g., "Great, you found number 2!"). If the student was incorrect, she provided error correction (e.g., "This is 2. Remember, if you are not sure, wait and I will help you."). If the student did not respond within five seconds, error correction was provided. Students practiced identifying numbers both expressively (i.e., saying the name of the number) and receptively (i.e., pointing to number given by teacher).

Teachers engaged students in stories in various ways (specific to the teacher and students), some examples include pretending to be repulsed by the worms in the garden story or naming the race speedway the actual student's name "Jessy's Raceway"). The teacher repeated a lesson for at least three days before introducing the next lesson for that unit. The skills remained constant in each unit's lessons, but the materials and order of responding varied. For example, in the garden story, the student might count the worms first; in the Pow Wow, the student might begin by locating the date on the calendar.

**TABLE 2** Early Numeracy Scope and Sequence

<i>Early Numeracy Scope and Sequence</i>		
<i>Domain</i>	<i>Unit One</i>	<i>Unit Two</i>
Counting	1. Count 1–5 movable objects in a line. 2. Count 1–5 nonmovable objects in a line. 3. Rote count from 1–5.	1. Count out 1–5 movable objects from a group. 2. Count 1–5 scattered, nonmovable objects.

		3. Rote count from 1–10.
Sets	4. Make sets of 1–3. 5. Add premade sets with sums to 5.	4. Make sets of 1–4. 5. Add sets with sums to 5.
Symbol Use	6. Compare sets for same/equal. 7. Identify the symbol for equals (=).	6. Compare sets for greater than. 7. Identify the symbol for greater than (>).
Patterns Measurement	8. Identify an ABAB pattern. 9. Use a nonstandard unit of measurement	8. Extend an ABAB pattern. 9. Use a standard unit of measurement to measure 1–5 inches.
Calendar	10. Identify dates from 1st to 5th on a calendar. 11. Identify 1–5 days later in a week using a calendar.	10. Identify dates from 1st to 10th on a calendar. 11. Identify 1–5 days later across 2 weeks using a calendar.
Numeral Identification	12. Identify numerals 1–5.	12. Identify numerals 1–10.
Themes	Lesson 1: Math at the Speedway Lesson 2: Sunken Treasure Lesson 3: Gardening Lesson 4: A Day at the Beach Lesson 5: My Class Trip to Washington, DC Lesson 6: Baseball Review Game	Lesson 1: Mardi Gras Lesson 2: Chinese New Year Lesson 3: Fiesta Lesson 4: Family Feast Lesson 5: Pow Wow Lesson 6: Basketball Review Game

### *Reliability*

Reliability data were taken for the independent and dependent variables by a trained observer for at least 30% of the total number of baseline and intervention sessions. The data was collected by either the lead researcher or the second author, a doctoral student in special education.

Reliability data was taken by either of the researchers. Procedural fidelity for all measures was calculated by dividing the steps taught or assessed correctly by the total number of steps and multiplied by 100.

### *Independent Variable*

*Procedural fidelity: Teacher training.* The teacher training was conducted in a quiet classroom in the school before the intervention and after baseline for each student. A checklist was used to ensure all components of the curriculum were discussed and covered during the teacher training. A model-lead-test (Engelmann & Becker, 1982) format was used to train teachers in each early numeracy skill to insure their ability to instruct the math skill effectively using the lesson plan scripts. All teachers had to perform the skill with 100% accuracy during the "test" phase of the training before completion of the training session. Teacher training typically lasted from 1-1.5 hours. Before implementing the intervention, teachers were also provided access to a sample

video of a teacher using the curriculum with other students with disabilities. Procedural fidelity was 100% for all training sessions.

*Implementation fidelity.* The research team used a checklist of early numeracy skills to ensure all nine skills were taught during each story-based lesson by the special education teacher. Data was collected to determine that each skill was taught and embedded using the designated prompting and feedback provided in the curriculum's scripted lessons (e.g., taught number identification, used the correct prompting procedure, and if they gave praise appropriately as scripted and only for independent responses). Fidelity was taken during at least three lessons within each unit taught (60%). A fidelity checklist for each specific unit was created, as numeracy skills changed per unit (i.e., using nonstandard units of measurement in Unit 1 compared to measuring one to five inches with a ruler in Unit 2). Implementation fidelity was taken on four out of five lessons for teacher 1, three out of five lessons for teacher 2, and three out of five lessons for teacher 3. All three teachers had high fidelity of implementation of the Early Numeracy lessons, with an average of 97% and a range of 90 -100% steps completed correctly for each lesson.

#### *Dependent Variable*

*Interrater reliability (IRR) of the dependent variable.* IRR was taken by the two members of the research team on student assessment data across baseline and intervention conditions. A point-by-point agreement was calculated for each of the numeracy skills assessed on the Early Numeracy assessment. IRR sessions were either scored in person or via recorded assessment sessions depending on the availability of both researchers. Approximately, 50% of sessions were coded via pre-recorded assessment probes. IRR was taken on 44% of baseline sessions with a mean of 99.6% agreement. IRR was taken on 35% of intervention sessions with 100% agreement on all data collection probes.

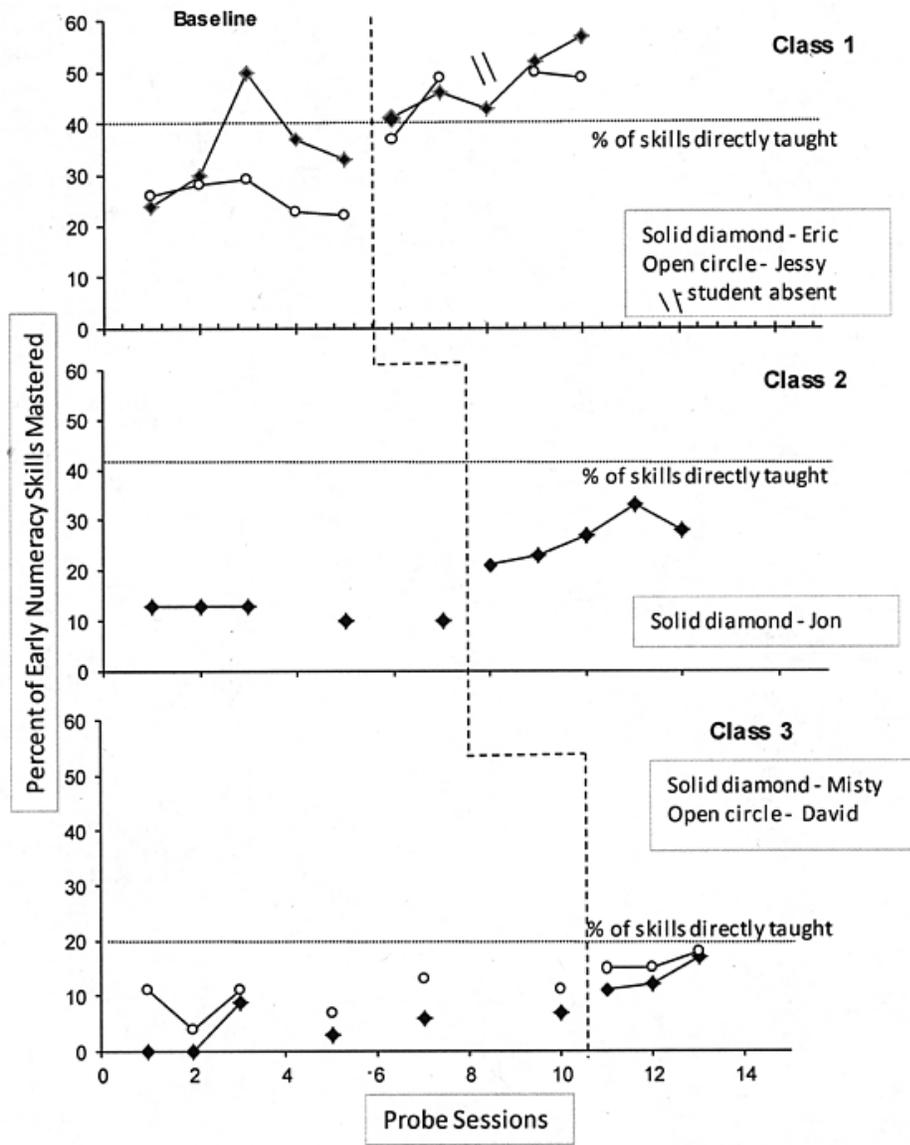
*Social Validity.* A teacher survey was used to determine teachers' perceptions of the feasibility and effectiveness of the mathematics instruction in early numeracy skills on students' learning of mathematical skills. Teachers were asked to complete a six-item questionnaire, which used a five-point Likert scale to rate their response to each question. At the conclusion of the study, all three teachers were asked to respond to questions regarding: (1) ease of lesson plan implementation of the Early Numeracy, (2) the degree of overlap between the instruction and the alternate assessment, and (3) how lessons directly or indirectly prepared students for the alternate math assessment.

## **Results**

The researchers utilized visual inspection of each participant's performance data to determine the presence of a functional relationship. The researchers also opted to analyze the percentage of non-overlapping data (PND) in each participant's results by (a) drawing a horizontal line across the greatest data point in the baseline condition for each student, (b) counting the total number of data points in intervention condition, and (c) dividing the number of data points above

the horizontal line in the intervention condition by the total number of data points in the intervention condition (Wolery, Busick, Reichow, & Barton, 2010). The percentage of non-overlapping data (PND; Scruggs, Mastropieri, & Casto, 1987) is an outcome metric for aggregating data across studies using single-subject experimental designs.

Overall, according to guidelines provided by Scruggs and Mastropieri (1998), the results of comparing PND demonstrate a highly effective intervention (0.90 -1.0) for all of the students, at 100% except for one, who participated in this study. Eric's performance data in Class 1 did not meet the recommendation of an effective PND of at least 0.50 with a PND of .40. Eric's highest baseline data point could be considered an outlier at 13 pts higher than the 2nd highest data point (see Figure 1), thus with the elimination of this outlier his PND would have been calculated at 100%.



**Figure 1.** Student baseline and intervention data.

Figure 1 shows each student's number of correct points for the assessment probes. Table 3 shows the mean percentage of correct responses on the Early Numeracy assessment for each student in each phase, as well as between Unit 1 and Unit 2 of the intervention phase.

*Eric.* During baseline, Eric's scores were variable with a decelerating trend, ranging from 24% to 50% out of a possible 100% (M = 34.8%). His performance showed an immediate change in trend after introduction of the independent variable. During intervention of Unit 1, his scores ranged from 41- 46% (M = 43.3%). During intervention of Unit 2, his performance continued on an accelerating trend with scores ranging from 51-57% (M = 54.5%).

*Jessy.* During baseline, Jessy's scores were stable, ranging from 23% to 29% out of a possible 100% (M = 26.5%). Her performance showed a change in trend after introduction of the independent variable. During intervention of Unit 1, her scores ranged from 22- 49% (M =36%). During intervention of Unit 2, her performance continued on an accelerating trend with scores ranging from 49 -50% (M = 49.5%).

**TABLE 3** Participant Mean Baseline and Intervention Scores

<i>Participant</i>	<i>Baseline</i>	<i>Unit 1</i>	<i>Unit 2</i>
Eric	34.8%	43.3%	54.5%
Jessy	25.6%	44%	54%
Jon	11.8%	23.6%	30.5%
Misty	4.2%	13.3%	n/a
David	9.5%	16%	n/a

*Jon.* During baseline, Jon's scores were stable, ranging from 10% to 13% out of a possible 100% (M = 11.8%). His performance showed an immediate change in trend after introduction of the independent variable. During intervention of Unit 1, his scores ranged from 21-33% (M = 26.4%).

*Misty.* During baseline, Misty's scores were stable, ranging from 0% to 9% out of a possible 100% (M = 3.6%). Her performance showed a change in trend after introduction of the independent variable. During intervention of Unit 1, her scores ranged from 7-17% (M = 11.75%).

*David.* During baseline, David's scores were variable, ranging from 4% to 13% out of a possible 100% (M = 9.2%). His performance showed a change in trend after introduction of the independent variable. During intervention of Unit 1, his scores ranged from 7-17% (M = .75%).

*Social Validity Data*

Results from the social validity survey indicate that all three teachers felt that their students benefitted from the curriculum and planned to use it in the future to teach early numeracy skills with other students. One teacher felt the curriculum was extremely easy to use, while the other two felt it was moderately easy to implement. All three teachers agreed that the early numeracy skills taught in the curriculum "indirectly" prepared their students to access the state alternate math assessment, based on alternate achievement standards. Two of the three teachers felt that the curriculum also "directly" prepared the students for the assessment.

## **Discussion**

The purpose of this study was to investigate the use of systematic and repeated instruction in early numeracy skills within a story-based math approach with students with moderate intellectual disability, including autism. Based on the visual analysis of the graphed data, all five students, across three classrooms, increased their early numeracy skills when taught using the Early Numeracy curriculum. Results from this study indicate a functional relationship between the use of the intervention package and student early numeracy skill mastery.

Research shows that students with moderate and severe intellectual disability learn best when taught using systematic instruction and repeated practice (Spooner et al., 2011). Additionally, research has shown that scripted lessons provide teachers the guidance to teach new skills with high-rates of fidelity of implementation (Jimenez, Lo, & Saunders, 2012). When scripted lessons are coupled with evidence-based practices, teachers are provided guidance on how to teach students. This study provided scripted lessons developed to include evidence-based instructional practices for students with intellectual disabilities, as well as research-based practices for teaching math to this student population (e.g., story-based math problems; Browder, Jimenez, & Trela, 2012). This study contributes to the literature in support of using systematic instruction (i.e., least-to-most prompting system, constant time-delay), story-based math lessons, and graphic organizers to teach math to students with moderate intellectual disability.

Browder, Jimenez, Spooner, et al. (2012) outlines a conceptual model for the math instruction of students with moderate to severe intellectual disability, beginning with intensive, systematic instruction in early numeracy skills to provide students the foundational early numeracy skills needed to access grade-level math standards at a deeper level across their school career. This study builds from their pilot study by providing experimental rigor (e.g., multiple-probe across groups of students) and replicates the effects with an additional five students. The social validity data collected from the teachers supports the need for research-based practices to teach early numeracy skills, and their indication of the effect of the learning on student access to alternate assessments aligns with the needs addressed by Kearns et al. (2011).

## **Implications for Practice**

The data found by Towles-Reeves et al. (2009) and Kearns et al. (2011) on elementary school age students who participate in alternate assessments based on alternate achievement standards

was consistent with the baseline data collected with our five study participants. Reliably our students demonstrated very little evidence of early numeracy skills prior to intervention, even over months of baseline probes. For example, the final two students to enter treatment participated in baseline data probes for over 4 months with little to no change in numeracy skills, even though teachers were not told to "stop teaching math". However, once students received the intervention they immediately began to show improved early numeracy skills. As noted by Browder, Jimenez, Spooner, et al. (2012) "If 88% of elementary students in AA-AAS cannot even count to five, clearly there is a need for more effective mathematical instruction for students with moderate and severe developmental disabilities". Teachers should look to the research-based practices for teaching this population academics (Spooner, Knight, Browder, & Smith, 2011), specifically mathematics, when planning instruction.

Additionally, story-based lessons are a research-based strategy to align academic standards with "real-life" and/or engaging contexts (Browder, Jimenez, & Trela, 2012; Jimenez, Browder, & Courtade, 2009). Finally, graphic organizers have been used as a form of assistive device to provide organization to complex skills for this population (Browder, Trela et al., 2012, Schenning, Knight, & Spooner, 2013). Classroom teachers should investigate their student's current early numeracy skills, identify specific skills that will provide increased access to grade-level standards (e.g., number identification, simple addition) and implement research-based practices to support effective instruction. While this may seem obvious, the baseline data of this study as well as those of Towles-Reeves et al. (2009) and Kearns et al. (2011) suggest that effective instructional strategies are not currently being utilized to teach early numeracy skills to elementary age students.

#### *Limitations and Recommendations for Future Research*

Four major limitations of this study were the number of data points taken per phase, group three only receiving instruction in Unit 1, Misty's communication needs, and the self-contained setting of the participants across all three groups. Due to time constraints at the end of the school year, the researchers were not able to measure the effectiveness of Unit 2 with the last group of students (Misty and David). With the end of the school year, only three data points were taken in the last intervention tier. The Institute of Education Sciences' What Works Clearinghouse (Kratovich et al., 2010) recommends a minimum of five data points per phase to meet evidence standards. All other tiers of the study meet the appropriate number of data points to meet evidence standards.

Additionally, if class three had received Unit 2 instruction, it is unknown if their skills would have continued to progress, similar to the progress of class one and class two. The Early Numeracy curriculum that was used in this study is comprised of four units. However, participants in this study were only able to complete Units 1 and 2 due to time constraints. A limitation of this study is that participants only completed two of the four units in the curriculum. In addition, the assessments that were used with the students, measured skills that were taught in

all four of the units so it may be possible that during the initial data point collection, students may have already known skills that were not introduced until Units 3 and 4 since the skills measured in the assessment protocols were not divided up by units in which skills were taught. Additional research should investigate which early numeracy skills were mastered consistently by all students, indicating which skills were harder to master. It may be possible that some skills were mastered immediately, while other skills took students completing Unit 1 and Unit 2 before it "clicked" and skills were learned.

While Misty did consistently show an increase in early numeracy skills only after intervention, it was noted by her teacher and the researchers that her communication skills also improved throughout the course of the study. When the study began, she had only recently begun working with her iPad to respond and communicate with others. A limitation of this study is that one could argue that Misty may have already possessed some math skills but not the communication skills to express that knowledge. As Misty's communication skills grew, she may have been able to communicate the prior knowledge as it pertained to the Early Numeracy math curriculum. Future research should continue to involve participants with complex communication needs. The field of severe disabilities does not only include students who communicate verbally with clear responses. For example, counting was a difficult task for Misty, because she had to touch the object, then touch the number, then touch the next object, then the number, potentially requiring more spatial organization than other students.

Finally, all three classes of students were served in a self-contained setting. Students taught in inclusive classrooms who have not yet gained these early numeracy skills may also need direct systematic instruction to gain mastery of these skills. Research is needed to build empirical evidence of instructional strategies to support student needs within the natural context of the inclusive classroom. It is possible that a paraprofessional could take a student aside and implement a curriculum such as this with one or two students; however, the question of how and when will the student have opportunities to generalize these early numeracy skills to the grade-level content (e.g., 4th grade math standards) is raised. More research is needed to support instructional strategies such as embedding instructional trials of early numeracy skills within the math lesson aligned to grade level standards (e.g., long division).

Research is also needed to support the extent to which building these early numeracy skills has on student access to grade-level standards. Research has supported students' mastery of complex math learning objectives, such as linear equations or coordinate planes (Browder et al., 2012), however; students who do not have basic numeracy skills (number identification) can only access these complex skills at a minimal depth. As students gain early numeracy skills, what is the impact of these early math skills on students' depth of accessibility to grade-level standards?

In summary, this study evaluated the effects of an early numeracy curriculum using systematic instruction, graphic organizers, and story-based math problems on math skill acquisition for five students with moderate intellectual disabilities, including autism. Similar to much of the

academic research in severe disabilities over the past decade, results from this study indicate that students with severe disabilities can learn new academic skills. Due to this new skill attainment, students will be able to access math curriculum at greater depths of knowledge than previously expected, if taught early numeracy skills with a succinct, personally relevant math curriculum.

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