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ORIGINAL ARTICLE

Teaching Early Numeracy Skills Using Single Switch Voice-Output Devices to Students with Severe Multiple Disabilities

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Abstract A multiple probe design across participants was used to evaluate the effects of a systematic instructional package with individualized adaptations (e.g., use of AAC and additional manipulatives) on the acquisition of early numeracy skills for three participants with severe multiple disabilities (i.e., severe physical disabilities, moderate intellectual disability, blindness) and complex communication needs. The intervention included scripted lessons, math story read-alouds, manipulatives, and graphic organizers that were adapted to meet participant needs. Voice-output single switch devices were used by participants to respond during instruction and assessment. Twelve early numeracy skills were embedded into each lesson and each lesson was taught three or four times before moving to the next. All participants demonstrated low numbers of correct responses during baseline. After intervention, participant data indicated a therapeutic change in trend and level, demonstrating a functional relationship between the intervention and number of correct early numeracy responses. Social validity measures were collected from the special education teacher. In addition, study limitations, implications for practice, and suggestions for future research are discussed.

Keywords Early numeracy skills · Severe disabilities · Physical disabilities · Multiple disabilities · Moderate intellectual disability · Blindness · Systematic instruction · Complex communication needs · Augmentative and alternative communication

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Providing quality standards-based mathematics instruction to students with disabilities has been a responsibility of special education teachers for many years and a fair amount of research has evaluated the effectiveness of strategies for doing so (e.g., Browder et al. 2012b; Creech-Galloway et al. 2013). Recently, researchers have focused on strategies for teaching early numeracy skills (Browder et al. 2012a; Jimenez and Kemmery 2013; Jimenez and Staples 2015) because these skills are important for mathematics development (Clements and Sarama 2014). In 2012, Browder, Jimenez, Spooner and colleagues developed a conceptual model for teaching early numeracy skills to elementary students with moderate intellectual disability (ID) and Autism Spectrum Disorder (ASD) that used: (1) scripted lessons built around math stories to help students master early numeracy skills that they had not yet learned but that were no longer taught in their grade level and (2) embedded systematic instruction in the general education math class to provide opportunities to use numeracy skills in the context of grade-level math content.

Since then, two studies have evaluated the effect of an early numeracy intervention and systematic instruction on acquisition of early numeracy skills for elementary students with mostly moderate ID (Jimenez and Kemmery 2013; Jimenez and Staples 2015). Of the eight participants in these two studies, in addition to moderate ID, one student was diagnosed with a hearing impairment, two with ASD, and one was nonverbal (i.e., selective mute). To deliver the intervention, special education teachers used scripted lesson plans and provided systematic instruction (e.g., time delay and system of least prompts) throughout each lesson. Each math lesson included a math story about familiar activities, graphic organizers, and theme-based manipulatives. Students learned to use nonstandard and standard measurement, counting skills, calendar skills, how to create sets, and how to identify and work with patterns. After the intervention, all students demonstrated an increase in early numeracy skills. While results from these studies are promising for students with moderate ID, a question remains as to whether the intervention is effective for students with severe disabilities.

As a group, students with severe disabilities are largely underrepresented in the literature (Courtade et al. 2015; Spooner and Browder 2015). In fact, in a comprehension review of the literature on mathematics instruction conducted by Browder et al. (2008), the researchers did not find enough high quality studies to draw any conclusions about the effectiveness of mathematics interventions for students in this subgroup because of the low number of participants with severe disabilities included in the studies reviewed.

Some possible reasons for this lack of inclusion in the research could be the challenges posed by students' limited communication. Research on literacy instruction for students with severe disabilities indicates that teachers tend to limit the range of goals and the type of instruction provided students who use augmentative and alternative communication (AAC; Ruppar et al. 2011). Limitations in facilitating communication development, including access to more complex AAC systems and devices, further impede students access to instruction in the general curriculum among other curricular and functional areas (Horn and Kang 2012; Naraian and Surabian 2014). In addition, the majority of research on expectations for learning in the general curriculum and instructional approaches for learners with significant and multiple challenges who use AAC primarily focuses on literacy and communication, with little attention to mathematics. Given the importance of early numeracy skills and the need for more research in the area of mathematics and AAC for students with severe disabilities, the purpose of this research study was to investigate the following research question:

1. What is the effect of a systematic instructional package with individualized adaptations on the acquisition of early numeracy skills for three participants with severe multiple disabilities and complex communication needs?

Method

Participants

Students with Disabilities Informed consent was obtained from the three participants before the study began and pseudonyms were used instead of their actual names to protect their identity. All participants received instruction in a separate special education classroom for students with severe ID and the assessment information reported in this study was taken from previously existing records from the students' cumulative folders. The first participant, Michael, was a fifth grade 11-year-old nonverbal Jordanian boy with multiple disabilities (i.e., ID and Orthopedic Impairment [OI]). Michael's IQ was 50 according to the *Bayley Scales of Infant and Toddler Development®, Third Edition* (Bayley 2005) and his adaptive behavior score from the *Vinland Adaptive Behavior Scale-2* (Sparrow et al. 2005) was 47. Michael received occupational therapy (OT), physical therapy (PT), and speech-language therapy (SLP). Michael had other medical issues including cortical visual impairment (CVI), cerebral palsy (CP), and seizures. Michael's seizures were controlled with medications but he needed extended time to process visual input (due to the CVI) and was non-ambulatory because of the CP. Michael had better range of motion moving his left arm backwards from his elbow; therefore, micro switches were placed at the back of his left elbow. He did not have any functional hand movements and was not able to use a pincer grasp. Michael had an IEP math objective to identify an ABAB pattern.

The second participant, Hoover, was a third grade 9-year-old nonverbal Caucasian boy with multiple disabilities (i.e., ID and OI). According to the *Developmental Profile™, Third Edition* (Alpern 2007), Hoover's IQ was 50 and his adaptive behavior score on the *Vineland Adaptive Behavior Scale – 2* (Sparrow et al. 2005) was 48. Hoover received OT, PT, and SLP. Hoover also had other medical issues, including hydrocephaly, CP, and seizures. Hoover had a shunt for the hydrocephaly and medications controlled his seizures. Due to the CP, Hoover used a manual wheelchair at school and at home. Hoover had two IEP math objectives—identifying ordinal numbers and identifying part/whole concepts.

The third participant, Jamie, was a fifth grade 11-year-old Caucasian girl with multiple disabilities (i.e., ID, OI, and blindness). Jamie had no IQ or adaptive behavior scores on record. Jamie received OT, PT, and SLP as well as monthly support from a vision teacher. In addition, Jamie also had CVI, seizures, stroke in-utero, esotropia (a form of strabismus, or "squint," in which one or both eyes turns inward), nystagmus (a vision condition in which the eyes make repetitive, uncontrolled movements), and optic atrophy (degeneration or malfunction of the optic nerve). Jaime had no vision and did not respond to visual stimuli. Her seizures were controlled with medicine and she used a manual wheelchair at school and at home. Jamie repeated numbers after hearing them and reached towards textured numbers when presented. She had one IEP math goal to identify the number of objects in a group. All three participants were assessed with their state's alternate assessment based on alternate achievement standards test for school accountability.

Receptive and Expressive Communication Michael demonstrated receptive language skills by smiling when greeted by others and by following one-step directions. Often, noises in the classroom caused an asymmetrical tonic neck reflex that Michael had to recover from before resuming an activity. Expressively, Michael used a variety of voice output single switch devices to respond to questions as well as to initiate communication. Two switches were strategically attached to his wheelchair that enabled quick access with the least amount of physical exertion. The 'no' switch was located behind his left elbow and the 'yes' switch was in front beside his right hand. Michael also used a Step-by-Step (AbleNet) voice-output device with levels. The switch was held behind Michael's left elbow to allow him to reach back to activate it (the same motion as the 'no' device). In addition, Michael used partner assisted scanning to make a selection from multiple options (e.g., Partner asks, "Is this your answer?" while pointing to each response option individually and participant responded yes or no to each option.)

Receptively, Hoover responded to questions and comments from others verbally by saying "uh uh" or by pressing a yes/no voice-output single switch. Expressively, he used a four location voice-output device placed on his wheelchair tray, which provided him options to say, "me, Hoover", "yes", "no", and "I'm finished". Additionally, he gained the attention of others using eye gaze, smiles, and vocalizations.

Receptively, Jamie could follow familiar one-step directions with guidance as needed. For example, she responded positively to hand-under-hand prompts but needed a verbal and/or tactile preparation prompt (e.g., "Let's touch…" or "Let's find") before beginning an activity. Expressively, Jamie used an adapted form of verbal communication that included 30 words. Some words had typical meaning (e.g., "done") and others were personally meaningful (e.g., "apple" for snack, "Logan" for her dog). Jamie verbally answered yes/no questions and told others when she was hungry, tired, or done. Jamie also used voice-output single switch devices to respond to and initiate communication with others.

Mathematics Instruction Prior to and during the study, participants were exposed to mathematics instruction during morning group time. This instruction included completing a daily attendance chart, counting the days of the month, and creating a weather chart of monthly weather conditions. While the early numeracy study was being conducted, no other formal mathematics instruction was delivered.

Experience with Systematic Instruction Two systematic prompting and feedback procedures were used in the math intervention—constant time delay (CTD) and system of least prompts (SLP). These procedures were not used on a regular basis in the special education classroom.

Special Education Teacher The special education teacher had 25 years of experience teaching students with disabilities, including 22 years with students with severe ID. She held a B.A. degree in Special Education, a MAEd degree in Special Education—Significant Disabilities, and a valid teaching license in Special Education-Adapted Curriculum. Two paraprofessionals and a student teacher also worked in the classroom while the study was conducted.

Setting

Elementary School The study was conducted in a special education classroom located in a small urban K-5 public elementary school in a large city in the southeastern United States. Of the 680 students who attended the Title 1 school, 69 % participated in the free and reduced lunch program, 50 % were black, 32 % white, 12 % Hispanic, 2 % Asian, and 4 % multiracial.

Special Education Teacher Training Training occurred at the table in the kitchen area of the special education classroom after the students had gone for the day.

Study Setting Baseline, ongoing probe, and intervention sessions occurred at a small rectangular table in the classroom. Two movable partitions were set up around the area to reduce noise from other activities occurring in the room at the same time. Study materials, switches, manipulatives, and graphic organizers were arranged on or near the table. A table-top easel to display materials was placed on the right-hand side of the table in the participants' optimal line of vision. Other materials were hung from clips on the wall for easy reach when needed.

Materials

Intervention Materials and Adaptations The intervention materials included materials from the curriculum kit (i.e., lesson manipulatives, student materials, teacher materials) and voice-output single switch devices were utilized for each participant.

Lesson Manipulatives Each of the five lessons centered on a theme (e.g., Math at the Speedway, Math Treasures) and the lesson manipulatives used throughout each lesson echoed the theme (e.g., race cars, treasure chests). Manipulatives were used for counting, making sets, and creating ABAB patterns.

Student Materials Student materials included magnetic work boards, number lines, number tiles, symbol tiles, pattern maker overlays, and set maker overlays. In addition, student used response books that contained response options and counting stimuli (e.g., a page containing two pictures of race cars were used to count nonmovable objects in a line).

Teacher Materials Teacher materials included three large graphic organizer posters for making patterns, and comparing and making sets; a script for each lesson (see Table 1);

a math-based story that corresponded with each lesson's theme; and an assessment tool. The lesson format included an anticipatory set to introduce the lesson theme, rote counting warm-up, time delay for numeral recognition, the math story, and application of numeracy objective to the math story. The lesson scripts and assessment tool are described in greater length under procedural and data collection sections.

Voice-Output Single Switch Devices Participants used a Step-by-Step (AbleNet) switch with levels to count. The switch was sequentially programmed with the numbers 1–6 (one more than the target numbers 1–5). The teacher reset the switch after each use so that it began counting at 1 for the next participant. The switch itself was not adapted in any way (e.g., no pictures/photographs were added). In addition, participants were provided separate "yes" and "no" switches during lessons to answer yes/no questions or use in partner-assisted scanning.

Adaptations for Participants with Physical Disabilities Velcro™ was added to manipulatives and graphic organizers so that the manipulatives could be attached to the posters and displayed on an easel. Some of the pages from the *Student Response Book* were enlarged, separated, and mounted on foam board so that participants could more easily indicate their responses. For some responses, (e.g., ABAB patterns), the teacher recreated the ABAB patterns by attaching objects to a foam board with Velcro™. The manipulatives included with the curriculum kit were adapted by affixing Velcro™ dots so that the objects could be affixed to graphic organizers or foam boards.

Table 1 Example of a teacher script from the lesson, Math at the Speedway

Objective 3 Rote count from 1 to 5		Say, **The race is going to begin in 5 s. Let's count, 1, 2, 3, 4, 5**. Count with the Ss and then choose one S to count to 5. **Michael, count to 5**.		
Cue	Materials needed	Wait for independent response	Provide a model	Assist and correct
Count to 5	Optional: AAC device preprogrammed for counting	S says the numbers in order without skipping a number. If correct, give praise, **Wow! You counted to 5 by yourself!** If no response or an error, provide a model.	Model counting: **1, 2, 3, 4, 5. Now you say it.** Note: If a S starts counting and stops in the middle of the sequence, or skips a number, have him or her start over from the beginning. If correct, give praise, **Terrific counting to 5!** If no response or an error, assist and correct.	If an error, say, **Next time, wait and I will help if you are not sure. Don't guess.** Help the S activate an AAC device if needed. **Count like this: 1, 2, 3, 4, 5.**

Adaptations for Participant with Blindness The set maker poster was adapted by replacing the circles on the poster with large plastic lids to enable the participant to feel the edges of the set. The calendar was substituted for a larger, desk-sized, monthly calendar and only the first week was used. Wiki sticks were added to the lines of the calendar to provide tactile information about the days of the week, and foam numbers, braille numbers, and Velcro™ dots (to receive manipulatives) were added to each calendar day. In addition, groups of dots (e.g., 1 dot for 1, 2 dots for 2) were added to the number line.

Research Design

A multiple probe design across participants (Gast 2010) was used to establish experimental control. A multiple probe design allowed for instruction to begin with one participant while periodic baseline sessions were conducted with all other participants, decreasing the threat of learning through prolonged testing and exposure to intervention materials. Study phases included baseline and intervention. During the baseline phase, a minimum of three data points were collected for each participant until performance data were low and stable or descending for independent correct responses. Once a stable baseline was obtained for all participants, the first participant began the intervention and other participants continued in baseline. A new participant entered intervention when a change in level and trend for independent correct responses was evident for the participant receiving intervention. Participants entered the intervention phase in a time-lagged manner until all participants had received intervention. Experimental control was demonstrated by a change in level or trend of participant independent correct responses from baseline to intervention conditions across participants.

Independent Variable The early numeracy intervention contained five different lessons in which instruction on the numeracy skills was embedded. Each lesson was taught three to four times before moving to a new lesson and participant(s) received instruction once a day. When more than one participant was receiving instruction at the same time, instruction was delivered in a small group format. Because it was not necessary to teach the lessons in order, participants could enter the intervention at any of the five lessons in the instructional unit; however, participants entered the study at the beginning of a lesson so that participants were receiving instruction on the same lesson (vs. having a participant on lesson one and another on lesson two).

Dependent Variable and Data Collection Procedures

Early Mathematics Assessment The *Early Numeracy* (Jimenez et al. 2013) curriculum assessment was used to measure participant progress. The dependent variable was the total number of independent correct responses on administered assessment test items. Twenty-six test items were used to assess 12 early numeracy skills embedded into each mathematics lesson (see Table 2). During assessment probes sessions, every

Table 2 Early numeracy skills assessed, test item directions, adaptations to assessment materials, and alternate responses for participants

Early numeracy skill	Adaptations to assessment materials	Alternate responses for participants with severe physical disabilities	Alternate responses for participant with blindness
Skill 1 – Count 1–5 movable objects in a line Test item – *Count the pennies. How many pennies are there?*	Adapted page by adding Velcro™ line below printed line and Velcro™ dots to backs of pennies. A bowl was provided for the student with blindness.	Setup: Page displayed on table easel. Researcher removed penny from the line each time participant counted with switch. Response: Touched voice-output single switch (switch) to count.	Setup: Page placed on wheelchair tray. Participant explored page using hand-under-hand guidance. Response: Picked up penny from the line, touched switch with penny to count, and then placed penny in bowl.
Skill 2 – Count 1–5 nonmovable objects in a line Test item – *Count the pennies. How many pennies are there?*	Adapted page by adding pennies to pictures of pennies with Velcro™.	Setup: Page displayed on table easel. Researcher pointed to penny each time participant counted with switch. Response: Touched switch to count.	Setup: Page placed on wheelchair tray. Participant explored page using hand-under-hand guidance. Response: Touched penny on the line and touched the voice-output switch to count. (Note –researcher placed her hand over pennies on line once they were counted. This enabled participant to find her place when she left the line to count.)
Skill 3 – Rote count from 1 to 5 Test item – *Count to ___. Start now.*	none	Response: Touched switch to count.	Response: Touched switch to count.
Skill 4 – make sets of 1–3 Test item – *Make a set of ___ in the circle.*	Adapted page by outlining circle with hot glue to make tactile. Added Velcro™ to inside of circle and Velcro™ dots to counting cubes.	Setup: Several counting cubes placed on wheelchair tray (more than needed) and page was displayed on table easel. Researcher placed counting cube in circle after participant counted with switch. Response: Touched a switch to count.	Setup: Page and several counting cubes (more than needed) placed on wheelchair tray. Participant explored page using hand-under-hand guidance. Response: Participant picked up counting cube, touched the counting cube to switch to count, and placed counting cube in circle on page.

Table 2 (continued)

Early numeracy skill	Adaptations to assessment materials	Alternate responses for participants with severe physical disabilities	Alternate responses for participant with blindness
Skill 5 – Add premade sets with sums to 5 Test item – *How many altogether?*	Adapted page by enlarging graphic organizer (i.e., ○+○=○) to 11×14 inch poster (about two times original size) and laminating. Each circle on poster was outlined with hot glue to make tactile. Velcro™ was added to inside of each circle and Velcro™ dots were added to counting cubes.	Setup: Poster placed on table easel and counting cubes were placed on set maker as indicated. Researcher moved counting cubes to "altogether" set (set after equals sign) as participant counted with switch. Response: Touched a switch to count.	Setup: Counting cubes placed on set maker as indicated and placed on wheelchair tray along with a bowl. Participant explored page using hand-under-hand guidance. Response: Picked up counting cube from sets, touched the counting cube to switch to count, and put counting cube in bowl.
Skill 6 – Compare sets for same/equal Test item – *Show me which set is equal to your set?*	Page adapted by adding foam shapes to pictures on response options to make tactile. Page contained three response options. Velcro™ dots were added to counting cubes.	Setup: Page placed on table easel and a set of counting cubes was placed on wheelchair tray. Researcher pointed to each of three responses on page and asked, "Is this set equal to/same as your set?" Response: Participants touched a switch to answer yes or no.	Setup: Page and a set of counting cubes placed on wheelchair tray. Using hand-under-hand guid ance, participant explored set on her tray and response options on page. Response: Participant made selection by pointing to one of three response options on page.
Skill 7 – Identify the symbol for equals (=) Test item – *Show me the symbol that means equals.*	Page adapted by adding foam shapes for pictures to make it tactile.	Setup: Page placed upright on table easel. Magnetic symbols (+, =, >) were displayed on magnetic board and held up by researcher. Researcher pointed to each symbol on the board and asked, "Is this the equals sign?" Response: Participants touched switch to answer yes or no.	Setup: Page and three plastic symbols (+, =, >) affixed to a foam board using Velcro™ were placed on wheelchair tray. Using hand-under-hand guidance, the participant explored the page on her tray and each symbol. Response: Participant made selection by touching one of three symbols.
Skill 8 – Identify an ABAB pattern. Test item – *Point to the ABAB pattern.*	Page adapted by adding two different textures (i.e., hard and soft Velcro™ squares, silk fabric and puff balls) to patterns.	Setup: Page placed on table easel. Researcher pointed to each of two options on page and asked, "Is this the ABAB pattern?" Response: Participants touched a switch to answer yes or no.	Setup: Page placed on wheelchair tray. Participant explored page using hand-under-hand guidance. Response: Participant selected response by touching one of the two options.

Table 2 (continued)

Early numeracy skill	Adaptations to assessment materials	Alternate responses for participants with severe physical disabilities	Alternate responses for participant with blindness
Skill 9 – Use a nonstandard unit of measurement to measure 1–5 Test item – *How wide is the picture frame? Use the paperclips to measure.*	Page adapted by adding objects (e.g., popsicle sticks, foam square) to pictures to make them tactile. A line of Velcro™ was added below printed line on page to provide a place to receive paper clips used for measuring and Velcro™ dots were placed on back of several large paperclips.	Setup: Page displayed on table easel and paper clips used for measuring were placed on wheelchair tray. Researcher moved a paper clip to the line of Velcro™ under the object being measured after participant counted with switch. Response: Touched a switch to count.	Setup: Page and paper clips placed on wheelchair tray. Using hand-under-hand guidance, the par ticipant explored the page and was oriented to the paper clips. Response: Picked up paperclip, touched paperclip to switch to count, and placed paper clip on line of Velcro™ under object being measured.
Skill 10 – Identify dates from the 1st to 5th on a calendar. Test item – *Point to September 5*.	Page provided by assessment was substituted for the first week of a large desk calendar. Wiki sticks were added to lines to provide tactile information. In addition, foam numbers, braille dots and Velcro™ dots (to receive manipulatives) were added to each calendar day.	Setup: Calendar placed on table easel. Researcher pointed to each of three options on calendar and asked, "Is this [September 5]?" Response: Touched switch to answer yes or no.	Setup: Calendar placed on wheelchair tray. Using hand-under-hand guidance, participant explored calendar. When finished, participant's hands were moved to a neutral position. Response: Made selection by touching a date on calendar.
Skill 11 – Identify 1–5 days later in a week using a calendar. Test item – *Show me 3 days later.*	Calendar adapted as previously described and Velcro™ was added to wooden stars.	Setup: Calendar placed on table easel. Researcher placed counting cube on date indicated and moved counting cube to next date on calendar after participant counted with switch. Response: Touched a switch to count.	Setup: Calendar placed on wheelchair tray. Using hand-under-hand guidance, participant explored calendar, including the date where counting cube was placed. Researcher moved counting cube to next date on calendar after participant counted with switch. Response: Touched switch to count.
Skill 12 – Identify numerals 1–5 Test item – *Point to [insert number].*	This page provided in the assessment was not used. Instead, two participants used large 3-inch plastic numbers that were placed linearly, in no particular order, on a rectangular foam board using Velcro™.	Setup: For one participant, the foam board with the numbers was placed optimally on his wheelchair tray. Response: Made selection by touching number. Setup: For another participant, 1-inch magnetic numbers were arranged on a magnetic board	Setup: The foam board containing the numbers was placed optimally on her wheelchair tray. Using hand-under-hand guidance, the participant ex plored the numbers and, when finished, her hands were placed in a neutral position away from the foam board.

Table 2 (continued)

Early numeracy skill	Adaptations to assessment materials	Alternate responses for participants with severe physical disabilities	Alternate responses for participant with blindness
	The other student used the magnetic numbers and magnetic board provided in curriculum materials.	three at a time, and presented to the participant. The researcher pointed to each number individ ually and asked, "Is this number ___?" Response: Touched a voice-output single switch to answer yes or no (two different switches) to each question.	Response: Made a selection by touching one of the numbers on the foam board.

Operational definition for correct/incorrect responses for responses involving voice-output single switch responses: If the participant paused for 15 s following reaching the correct number response, the response was recorded as correct. If the participant paused for 15 s before reaching the correct number or continued to count after reaching the correct number, the response was recorded as incorrect test item but one (i.e., identify the equals sign) was preceded by a demonstration item to ensure that participants understood what was being asked in the test item. There was not a demonstration item for 'identifying the equals sign' because providing one would reveal the answer to the test item. A demonstration item was similar to the test item in the skill being assessed, but different in form and not scored. For example, the demonstration item for identifying dates from the 1st to 5th on a calendar was, "Point to September 1" and the test item was "Point to September 5".

A script was provided that assessed each of the early numeracy skills briefly through presenting materials and asking the participant to perform a response (e.g., "Count the pennies. How many pennies are there?"). Due to their physical disabilities, participants were given 10–15 s to begin responding and their answer was scored as correct (+) or incorrect (−). General verbal praise was given on performance only (e.g., "I like how you looked at all the options.") The entire assessment was given during baseline and ongoing probe sessions.

Adaptions to the Assessment Manual The assessment manual was adapted to make it accessible for participants. First, individual pages were freed from the binding and mounted on a foam board page. Because the manual pages were printed front and back, a photocopy was made of the back page (directions and script) and affixed to the back side of each foam board page. The foam board pages were organized chronologically in a large plastic container. Second, texture and actual objects were added to the pages. For example, for counting pennies on a line, a line of Velcro™ was added below the line on the page and to the backs of the pennies, allowing the pennies to be affixed to the line. Third, some materials were enlarged (e.g., set maker) or reduced (i.e., only the first week of the calendar was presented instead of the entire month). Last, due to the physical and sensory limitations of the participants, test item responses were changed to behaviors the participants could perform while preserving the skill being assessed. Table 2 contains a description of participants' responses for each early numeracy skill objective.

Social Validity The special education teacher completed a social validity form about the appropriateness and feasibility of the intervention for students with severe multiple disabilities after the study was completed. The form included five statements to which the special education teacher rated her level of agreement or disagreement using a five-point Likert scale (i.e., 1=Strongly Agree; 5=Strongly Disagree) and one open ended question.

Data Collection Independent correct responses were scored a "+" and incorrect responses were scored a "–". When the participant paused for 15 s following reaching the correct number response, the response was counted correct. When the participant paused for 15 s before reaching the correct number or continued to count after reaching the correct number, the response was counted incorrect. The total number of independent correct responses was graphed. Each data point on the graph represents the number of independent correct responses for a different math lesson (that is, math lessons were taught multiple times, but ongoing probe data were only collected once for each lesson for each participant).

Procedures

Special Education Teacher Training Before the study began, the researcher met with the special education teacher two times for intervention training (i.e., 2 h total). The researcher and teacher reviewed the *Early Numeracy* (Jimenez et al. 2013) curriculum and the researcher demonstrated how to deliver a scripted lesson, use the manipulatives, and record participant responses during a lesson. Because the special education teacher was familiar with systematic instructional procedures (i.e., CTD and SLP) and detailed instructions were provided in the script for delivering systematic instruction within the lesson, little additional training was needed to meet criteria. After a brief review of the procedural steps, the teacher demonstrated competency by independently completing 100 % of the task-analyzed steps for teaching a lesson during a role play activity where the researcher pretended to be the participant.

Baseline and Ongoing Probe Sessions Baseline and ongoing probe sessions were conducted by the researcher (first author) at a small table in the special education classroom. Two movable partitions were placed around the table to reduce distractions. The researcher set next to the participant and a table-top easel to display the assessment pages was placed in front of the participant. The switches needed by participants for responding were optimally placed on their wheelchair or wheelchair tray. Participants responded to each of the 26 test items in the assessment. Independent correct responses were recorded as a "+" and incorrect responses were recorded as a "–". Participants received only general verbal praise (e.g., "I like the way you are working."). Ten to 15 s of wait time was provided for participants to initiate a response. When no response was given, a "–" was recorded. Each ongoing probes session took 50–70 min.

Intervention Sessions The special education teacher taught the lessons in the intervention individually or to a small group of two and 12 early numeracy skill objectives were embedded into each lesson. The intervention contained five different math lessons and each lesson was taught a minimum of three times. Typically, each lesson was taught 3–4 times a week. It was not necessary for the lessons to be taught sequentially so participants could start the intervention with any lesson; however, participants entered the intervention when a new lesson was beginning. In this way, students receiving intervention were taught the same lesson for the week. The first participant, Michael, received instruction on all five lessons. The first two lessons were taught in a one-to-one setting and the last three were taught in a small group with Hoover. Hoover entered the intervention at lesson three and received instruction on four lessons (i.e., lessons 3, 4, 5, and 1)—all in a small group format with either Michael (i.e., lessons 3, 4, and 5) or Jamie (i.e., lesson 1). Due to illness and the school year ending, he was unable to complete lesson 5. Jamie entered the intervention at lesson one and received instruction on two lessons—lesson one with Hoover and lesson two in a one-to-one format. Jamie was unable to complete the final three lessons due to a family vacation and the school year ending.

First, the teacher introduced the day's theme with an anticipatory set (e.g., "Today, we are going to the speedway to do some racing") and read the math story aloud, providing participants with opportunities to manipulate the materials (e.g., small race cars, play money). Because the same math story was read multiple days, red print in the story indicated where the numbers could be changed during subsequent readings. For example, in a math story about a car race, a line from the story read, “My ticket costs $3.” “3” was printed in red indicating that the teacher could change the ticket price to another number when the story was read again to keep the story fresh and give participants practice with each target number. Next, the teacher used a scripted lesson to guide participants through the math story again, but this time provided opportunities for participants to perform the math skills. For example, in a math story about sunken pirate treasure, the teacher reread the first two lines of the story which introduced pirates going on a treasure hunt. The pirates were going to be ready to leave in five minutes. The teacher then asked participants to count to five with her (i.e., rote counting 1–5).

Systematic prompting and feedback was used to teach the embedded early numeracy objectives and detailed scripted prompts (see Table 1 for an example) for how to support participant learning was provided for each lesson. Constant time delay procedure was used at the beginning of each lesson to review numeral recognition. During the first round (i.e., 0-s), the teacher showed a number and said the name, and then asked participants to find the number on their number lines. During the second round (i.e., 10–15 s delay), the teacher said a number and waited 10–15 s for participants to find the number on their number line. Michael responded using partner assisted scanning (i.e., answered the question, “Is this the number 4?” using his yes and no switches). Hoover responded by pointing to the number on his number line. Jamie responded by touching the number 4 on a brailed number line. For all other embedded skills, participants were given a chance to independently respond and, if no response or an error was made, a model prompt was provided using the SLP. Specific verbal praise was given for correct responses (e.g., “Wow, you found 3 by yourself!”) and error correction was given for incorrect responses (e.g., “This is 3. Find 3 with me.”) Participants were actively engaged in math lessons by counting with a switch, touching story-related manipulatives, feeling the number line and counters, and answering yes/no questions with switches.

Procedural Reliability Procedural fidelity was collected on a minimum of 20 % of the lessons delivered during intervention. A trained second observer recorded the completion of each of the intervention’s 20 task-analyzed steps for the purpose of calculating procedural fidelity. A check mark was made beside a step when it was completed and the number of completed steps was counted after each lesson. Procedural fidelity was calculated by dividing the number of steps completed by the total number of steps planned and then converted to a percentage by multiplying by 100 (Billingsley et al. 1980).

Procedural fidelity was also collected on a minimum of 30 % of baseline and ongoing probe sessions for all participants. A trained second observer recorded whether each test item was delivered as indicated in the assessment manual. A check mark was made beside a test item when it was delivered according to the script. Procedural fidelity was calculated by dividing the number of test items delivered correctly by the total number of test items in the assessment and then converted to a percentage by multiplying by 100 (Billingsley et al. 1980).

Interobserver Agreement Interobserver agreement (IOA) was collected on participant responses by a trained second observer during a minimum of 30 % of baseline and ongoing probe sessions. Agreement data were computed by comparing participant responses for each trial point-by-point. If both observers recorded the same score on a trial, an agreement was recorded. If the observers recorded different scores, a disagreement was recorded. Interobserver reliability data were calculated by dividing the number of agreements by the number of agreements plus disagreements and then converted to a percentage by multiplying by 100.

Data Analysis

Data for the dependent variable is summarized in Fig. 1. The graph was visually inspected to identify changes in trend, level, and variability and to determine if a functional relationship existed between the independent and dependent variables.

Results

Reliability

Procedural fidelity data were collected for 50 % of baseline sessions and 33 % of ongoing probe sessions and was 100 % for all participants. Procedural fidelity data were collected on teacher behaviors for 20 % of the lessons taught during intervention and was 100 %. Interobserver agreement data were collected on participant responses for 50 % of the baseline sessions (i.e., $m=98$ %; range of 85–100 %) and 100 % of ongoing probe sessions (i.e., $m=99$ %; range of 96–100 %).

Participant Data

Michael During baseline probe sessions, Michael's independent correct responses are low (i.e., $m=7.6$, range 4–10) with a downward, nontherapeutic trend. While he is able to answer some items correctly during baseline sessions, the most correct responses he obtains are 10 in session two; leaving room for growth given that there are 26 correct responses possible. Immediately following intervention, Michael's independent correct responses increase (i.e., $m=19.2$, range 15–23), demonstrating a change in level and subsequent data display an upward, therapeutic trend.

Hoover During baseline probe sessions, Hoover's independent correct responses are low (i.e., $m=3.75$, range 2–8) and stable. Immediately after intervention, Hoover's independent correct responses increase (i.e., $m=19.75$, range 14–25), demonstrating a change in level and subsequent data display an upward, therapeutic trend.

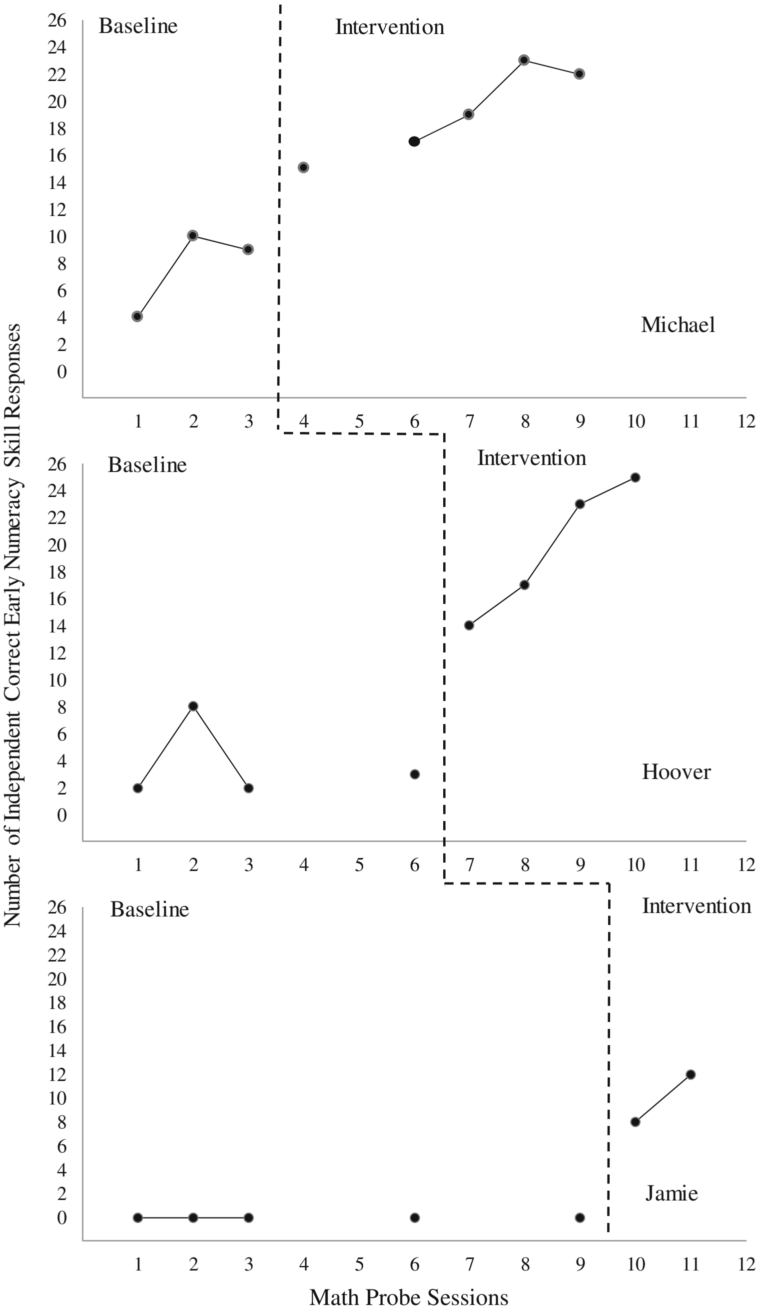

Fig. 1 Each data point indicates the number of independent correct responses during baseline and ongoing probe sessions. The maximum number of correct responses possible each session was 26

Jamie During baseline probe sessions, Jamie's independent correct responses are 0. Immediately after intervention, Jamie's independent correct responses increase (i.e.,

m=10, range 8–12), demonstrating a change in level and subsequent data display an upward, therapeutic trend.

Social Validity

The special education teacher indicated strong agreement for each of the following statement: (1) the early numeracy intervention met the needs of my students with severe multiple disabilities who participated in the study, (2) teaching the early numeracy intervention did not take a lot of my time, (3) the early numeracy intervention allowed students with severe multiple disabilities to participate more fully in the early numeracy curriculum, (4) the adaptations necessary for my students were time consuming to create, and (5) I would use this intervention with other students with severe multiple disabilities. In the space for additional comments, the special education teacher emphasized the need to adapt curriculum materials for accessibility and provide voice-output devices for participants.

Discussion

It is evident from the graphed data in Fig. 1 that the intervention had a positive and immediate effect on all participants' acquisition of early numeracy skills. During baseline probe sessions, participants answered few of the assessment items correctly. Following intervention, all participants' correct responses increased, demonstrating a change in level and trend from baseline to intervention, the hallmark of a functional relationship between the independent and dependent variable. For Michael, the mean number of independent correct responses in baseline (i.e., m=7.6) nearly doubled after intervention began to 15. For Hoover, the mean number of independent correct responses in baseline (i.e., m=3.75) nearly quadrupled after intervention began to 14. Likewise, Jamie, who had no independent correct responses in baseline, had 8 independent correct responses after one week of intervention.

Additionally, two participants, Hoover and Jamie, increased the number of independent correct responses each time they were assessed. Michael also increased the number of correct responses throughout the intervention, with the exception of the last assessment probe session (i.e., 5th lesson), where his independent correct responses decreased by one from 23 to 22. For both Michael and Hoover, the number of independent correct responses approached the maximum number possible in an assessment probe session (i.e., 26). In the fourth intervention lesson, Michael scored 23 and Hoover scored 25.

These results indicate that the systematic instructional package with individualized adaptations (e.g., use of AAC and additional manipulatives) was effective for teaching students with severe multiple disabilities and complex communication needs targeted early numeracy skills. Additionally, these results are similar to results found in other studies that evaluated the effect of the intervention on the acquisition of early numeracy skills for students with moderate ID and ASD (Jimenez and Kemmery 2013; Jimenez and Staples 2015). This finding is especially exciting given the lack of research on academic learning for this population.

There are several reasons the intervention might have been effective with these students. While these are the first participants with severe multiple disabilities and complex communication needs to be the focus of a research study evaluating the effects of an intervention on early numeracy skills, several of the intervention's components are evidence-based practices for teaching mathematics to students with significant cognitive disabilities. In a comprehensive review of the mathematics literature, Browder et al. (2008) found three evidence-based practices for teaching mathematics to these students: in vivo instruction, systematic instruction, and opportunities to respond. Each of these evidence-based practices is used in the intervention.

In vivo instruction is an approach that involves "teaching a real life application for the principle to be learned and teaching in, as well as for, real life settings" (Browder et al. 2008, p. 426). In the intervention, participants solved real-life mathematics problems presented in the theme-based story. For example, in a story about planting a garden, the participants were presented with a problem about worms in the garden (e.g., *When we planted the carrots, we found 3 worms. YUCK! When we planted the onions, we found 2 worms. YUCK again! How many worms did we find altogether?*) The participants used a graphic organizer (i.e., set maker) and manipulatives (i.e., plastic worms) to solve the problem.

Systematic instruction was also identified as an evidence-based practice for teaching mathematics by Browder and colleagues (2008). Systematic instruction involves defining a specific response or set of responses and teaching to mastery using defined, consistent prompting, feedback, and explicit prompt fading (Collins 2007). Two systematic instructional prompting procedures—SLP and CTD—where utilized in the scripted lessons. When using the SLP procedure, a prompt hierarchy is determined and the learner is first given the opportunity to independently perform a behavior before being provided with the least intrusive level of assistance from the hierarchy until the target response is performed correctly (Collins 2007). This assistance is naturally faded over time. In the intervention, a model prompt was given if participants failed to respond or made an error. For example, in measuring the length of a treasure chest using nonstandard units (i.e., paperclips), the teacher first gave participants a chance to measure on their own, saying, "*How many paperclips long is the treasure chest?*" If participants failed to respond or made an error, the teacher modeled measuring, saying, "*When we measure, we line the paperclips from end-to-end like this. Then we count them. The treasure chest is ___ paperclips long. Your turn to try.*" If no response or an error was made at this point, the teacher assisted the participants in measuring, saying, "*This is how you measure. Line the paperclips up from end-to-end and count. See 1, 2, 3. The treasure chest is ___ paperclips long.*"

Constant time delay was another systematic instructional prompting procedure used in the intervention. With CTD, a controlling prompt is provided after a delay interval (0 s during initial instruction and a larger increment during subsequent instruction) and the procedure naturally fades as learners begin to perform the correct response before the delivery of the prompt (Collins 2007). In the scripted lessons, CTD was used to review numeral recognition at the beginning of each lesson. During the 0-s delay rounds, the teacher said and showed participants the number she wanted them to find, and then had them find the number; during 10-s delay rounds, the teacher said the number she wanted them to find and waited 10 s for participants to initiate their response. For both SLP and CTD, participants received descriptive verbal praise.

Opportunities to respond is a third evidence-based practice identified by Browder and colleagues (2008) from the mathematics literature. Opportunities to respond is a teacher behavior that invites or solicits a student response (Simonsen et al. 2010). In the early numeracy lessons, the teacher read the story once completely, and then reread the story, stopping at predetermined points to give participants opportunities to practice the early numeracy skills.

In addition to the evidence-based practices for teaching mathematics, each lesson used a math-based story that was read aloud. Math-based stories have been used to access grade-aligned mathematics content (i.e., algebra, geometry, measurement, and data analysis/probability) for middle school students with moderate ID (Browder et al. 2012b) and high school students with moderate and severe developmental disabilities (Browder et al. 2012c). While the use of math-based stories to teach mathematics is not an evidence-based practice, Hudson and Test (2011) found read-alouds to be an evidence-based practice with a moderate level of evidence for use in teaching literacy skills in students with extensive support needs. Read-alouds (or shared story reading) is a practice used to access age-appropriate literature through reader-listener interaction in which a story is read aloud and student interaction with the reader and the story is supported. In the intervention, the math-based stories provided a format for the math problem using activities elementary participants would likely find interesting (e.g., hunting for pirate treasure, a day at the beach) and the interactive nature of the read-aloud kept participants engaged during instruction.

The Role of Expressive and Receptive Communication and the Impact on Teaching and Learning

The role of expressive and receptive communication in this study is straightforward but critical. Specifically, the participants were required to receive instruction, direction, and feedback and to communicate learning, questions or confusion, as well as engagement or disengagement in the session. Participants demonstrated receptive language sufficient for verbal directions, instruction, and feedback. Expressively, participants predominately used a switch, which is an important but limited tool in communication and communication development. While adequate for a response, the single voice-output switches did not allow them to comment, ask questions, or elaborate on their responses. Additional AAC methods could be incorporated to allow students to make comments, pose questions, and contribute their viewpoint. Though not experimentally analyzed, informal observations of the video-taped sessions by a university level expert in deafblindness and communication development (second author) suggest that participants utilized expressions, gestures, vocalizations, and physical movements to communicate beyond the academic responses made via switches. These communicative behaviors were similar to those reported by Chung et al. (2012) as typical communicative interactions between students who use AAC and peers without disabilities in general education.

While research continues to support the importance of AAC and other assistive technology to increase student outcomes, these tools remain under-utilized in schools, particularly in the area of AAC (Naraian and Surabian 2014). Yet, appropriately complex AAC ensures that the challenges faced by students are those presented by the instruction and not the effort to respond. A variety of communication factors can increase students' opportunity to learn and demonstrate their learning, including an ongoing program that fosters communication development integrated into academic instruction as well as other activities across the student's school day (rather than being an isolated instructional target). Equally important for students with limited communication is access to varied and increasingly elaborated AAC to enable increasing complex communication.

The communication limitations of the participants in this study posed many challenges for instruction and the participants' learning that was not related to the curriculum. Specifically, the time and effort required to structure instructional prompts and participant responses in a way that both maintained the integrity of the assessment, curriculum, and instruction and facilitated participant responses was extensive, in large part because it was organized around a switch response which allowed for limited expression. Participants' formal responses with the switch and their non-formal communication were the only ways in which the teacher could check for receptive understanding of directions and the task, as well as determine participant learning.

Limitations

The results of this research should be considered in light of several limitations. The first is that one participant, Jamie, had only two data points in intervention. Jamie did not have any independent correct responses during baseline probe sessions. After 1 week of instruction on lesson one, her score increased to 8/26 independent correct responses and, after a week of instruction on lesson two, her scored increased to 12/26 independent correct responses. No other assessment probes could be administered because she went on a family vacation and then the school year ended. While there were only two data points in intervention, these data demonstrated a dramatic increase over baseline that was equivalent to or greater than the other two participants. While it is impossible to know if this would have continued, the first two probe sessions indicate that Jamie was learning from the intervention.

Relatedly, the researcher noted anecdotally that Jamie did not have an effective strategy for scanning multiple response options which was necessary for answering four of the assessment items. For example, item 10 (i.e., compare sets for same/equal) on the assessment probe involved giving Jamie a set of three manipulatives and asking her to "Show me which set is equal to your set". She was then given three response options from which to select her answer. Even though the response options were made tactile, Jamie did not have an effective strategy for exploring them. Until Jamie learns an effective strategy for making a selection from an array, it is likely that future data may not demonstrate the gains Jamie is making in instruction. This highlights the need for participants like Jamie to receive instruction in strategies that compensate for her lack of vision. Ideally, students with blindness and visual impairments (VI) are served by specially trained teachers because of the unique needs imposed by the disability. As a low-incidence impairment, most special education teachers rarely have training or experience with students with vision loss. Conversely, few VI teachers have training and experience with students with additional disabilities such as cognitive and physical disabilities. Future research should investigate models for collaboration necessary to create the 'collective expertise' required to meet the needs of students with visual and additional disabilities like Jamie.

The second limitation of this research is that much time was needed to plan and adapt the curriculum materials so that they were accessible for participants with severe multiple disabilities and complex communication needs. While the time needed to make the assessment and instructional materials accessible was great, the initial investment could be offset by reusing the materials from year to year or in using the adapted materials to teach other academic content.

The third limitation of this research was that the study was conducted solely in a separate special education classroom. Research has shown that students with moderate and severe disabilities can learn grade-aligned academic content in general education settings (see Hudson et al. 2013, for a review on this literature). Future research should investigate ways in which students with severe multiple disabilities and complex communication needs can participate with their peers without disabilities in general education math class. One idea is to have students use the early numeracy skills they are learning during ongoing math activities in general education. For example, in the Browder et al. (2012a) pilot study, paraeducators used systematic prompting and feedback to embed targeted early numeracy skills into ongoing math lessons in 3rd, 4th, and 5th grade general education math classes.

Implications for Practice and Suggestions for Future Research

There are several implications of this study for practice and future research. For students with significant disabilities, the relationship between instruction across academic and life skills curricula, communication development, and AAC cannot be underestimated. Specifically, this consideration includes research into the ways in which: a) communication and access to AAC limit or foster access to instruction, b) communication and access to AAC enable demonstration of learning and consequent instruction in increasingly complex content, and c) teacher preparation addresses mathematics instruction for AAC users. Understanding the intersection of communication and teaching and learning in mathematics is critical in order to apply evidence based practices with fidelity and identify and validate effective instructional practices for students with limited communication. Building this knowledge base is critical in order to prepare teachers to provide AAC users with effective content instruction, including mathematics.

Another implication is that participants' expressive communication was supported through the use of a single switch. Providing them with AAC afforded them access to the early numeracy curriculum. Without AAC, participants would not have been able to actively engage in math lessons or demonstrate their learning of targeted early numeracy skills. Participants relied on AAC for expressive communication; however, this effort appeared to be physically exhausting for two. Future research should investigate AAC strategies and tools for expressive interaction during academic instruction that is less physically taxing for students like Michael and Hoover.

A final implication of practice is the fact that teaching early numeracy skills in a small group was possible for all participants in the study; however, after including Jamie in a small group for one week, the teacher asked to teach her individually. Group instruction that included Jamie was a more of a challenge because of her limited compensatory strategies due to her vision loss. Jamie had few skills for interacting with materials and exploring her space. If she had more sophisticated strategies for using her tactile/kinesthetic senses for learning, she might have been able to participate in a larger group. Research has described benefits of group instruction for students with moderate and severe disabilities (e.g., Doyle et al. 1990). Future research should continue to explore group instruction, especially with learners of diverse abilities.

Summary

This study evaluated the effects of an early numeracy systematic instructional package intervention with individualized adaptations (e.g., use of AAC and additional manipulatives) on early numeracy skill acquisition for students with severe multiple disabilities and complex communication needs. When provided with a simple switch, these participants were able to meaningfully interact in an early numeracy curriculum and demonstrate their learning during assessment. The results of this study are strong evidence for continued research and practice to insure effective access to general curriculum content such as mathematics.

Additionally, these results emphasize the importance of an integrative approach to teaching and learning across developmental, academic, and functional domains so that communication and compensatory strategies for physical and sensory limitations are evolving along with academic knowledge. In order for this to occur, collaboration across disciplines is critical in order to craft and validate practices that respond to the complexity of the participants challenges as posed by their combination of disabilities.

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Compliance with Ethical Standards All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Conflict of Interest The authors declare that they have no conflict of interest.

References

Alpern, G. D. (2007). *Developmental profile* (3rd ed.). Torrance: Western Psychological Services.

Bayley, N. (2005). *Bayley scales of infant and toddler development, third edition*. Pearson/Psych Corp.

Billingsley, F., White, O. R., & Munson, R. (1980). Procedural reliability: a rationale and example. *Behavioral Assessment, 2*, 229–241.

Browder, D. M., Spooner, F., Ahlgrim-Delzell, L., Harris, A. A., & Wakeman, S. (2008). A meta-analysis on teaching mathematics to students with significant cognitive disabilities. *Exceptional Children, 74*, 407–432.

Browder, D. M., Jimenez, B. A., Spooner, F., Saunders, A., Hudson, M., & Bethune, K. S. (2012a). Early numeracy instruction for students with moderate and severe developmental disabilities. *Research and Practice for Persons with Severe Disabilities, 37*, 308–320.

Browder, D. M., Jimenez, B. A., & Trela, K. (2012b). Grade-aligned math instruction for secondary students with moderate intellectual disability. *Education and Training in Autism and Developmental Disabilities, 47*, 373–388.

Browder, D. M., Trela, K., Courtade, G. R., Jimenez, B. A., Knight, V., & Flowers, C. (2012c). Teaching mathematics and science standards to students with moderate and severe developmental disabilities. *The Journal of Special Education, 46*, 26–35.

Chung, Y., Carter, E. W., & Sisco, L. G. (2012). Social interactions of students with disabilities who use augmentative and alternative communication in inclusive classrooms. *American Journal on Intellectual and Developmental Disabilities, 117*(5), 349–367.

Clements, D. H., & Sarama, J. (2014). *Learning and teaching early math. The learning trajectories approach* (2nd ed.). New York: Routledge.

Collins, B. (2007). *Moderate and severe disabilities. A foundational approach*. Upper Saddle River: Pearson.

Courtade, G. R., Test, D. W., & Cook, B. G. (2015). Evidence-based practices for learners with severe intellectual disability. *Research and Practice for Persons with Severe Disabilities, 39*, 305–318.

Creech-Galloway, C., Collins, B. C., Knight, V., & Bausch, M. (2013). Using a simultaneous prompting procedure with an iPad to teach the Pythagorean Theorem to adolescents with moderate intellectual disability. *Research and Practice for Persons with Severe Disabilities, 38*, 222–232.

Doyle, P. M., Gast, D. L., Wolery, M., Ault, J. J., & Farmer, J. A. (1990). Use of constant time delay in small group instruction: a study of observational and incidental learning. *The Journal of Special Education, 23*, 369–385.

Gast, D. L. (2010). *Single subject research methodology in behavioral sciences*. New York: Routledge.

Horn, E., & Kang, J. (2012). Supporting young children with multiple disabilities: what do we know and what do we still need to learn? *Topics in Early Childhood Special Education, 31*(4), 241–248.

Hudson, M. E., & Test, D. W. (2011). Evaluating the evidence base for using shared story reading to promote literacy for students with extensive support needs. *Research and Practice for Persons with Severe Disabilities, 36*, 34–45.

Hudson, M. E., Browder, D. M., & Wood, L. (2013). Review of experimental research on academic learning by students with moderate and severe intellectual disability in general education. *Research and Practice for Persons with Severe Disabilities, 38*, 17–29.

Jimenez, B. A., & Kemmery, M. (2013). Building the early numeracy skills of students with moderate intellectual disability. *Education and Training in Autism and Developmental Disabilities, 48*, 479–490.

Jimenez, B. A., & Staples, K. (2015). Access to the common core state standards in mathematics through early numeracy skill building for students with significant intellectual disability. *Education and Training in Autism and Developmental Disabilities, 50*, 17–30.

Jimenez, B. A., Browder, D. M., & Saunders, A. (2013). *Early Numeracy: A skill building math program for students with moderate and severe disabilities*. Verona: Attainment Company.

Naraian, S., & Surabian, M. (2014). New literacy studies: an alternative frame for preparing teachers to use assistive technology. *Teacher Education and Special Education, 37*(4), 330–346.

Ruppar, A. L., Dymond, S. K., & Gaffney, J. S. (2011). Teachers' perspectives on literacy instruction for students with severe disabilities who use augmentative and alternative communication. *Research and Practice for Persons with Severe Disabilities, 36*, 100–111.

Simonsen, B., Myers, D., & DeLuca, C. (2010). Teaching Teachers to use prompts, opportunities to respond, and specific praise. *Teacher Education and Special Education, 33*, 300–318.

Sparrow, S. S., Cicchetti, D. V., & Balla, D. A. (2005). *Vineland adaptive behavior scales, second edition*. Pearson/PsychCorp.

Spooner, F., & Browder, D. M. (2015). Raising the bar: significant advances and future needs for promoting learning for students with severe disabilities. *Remedial and Special Education, 36*(1), 28–32.