Early Numeracy Instruction for Students with Moderate and Severe Developmental Disabilities

By: Diane M. Browder, Bree A. Jimenez, Fred Spooner, Alicia Saunders, Melissa Hudson, Keri S. Bethune

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Abstract:

Competence in early numeracy skills highly correlate with success in mathematics in later years; however, many students, including students with moderate and severe disabilities, lack a sound foundation in early numeracy skills. For this population, the gaps in skills widen as students progress through academic years, making it more difficult for students to access the general curriculum, and consequently, students exit school without the skills needed for the 21st century. This article provides a conceptual model for teaching early numeracy skills to elementary students with moderate and severe developmental disabilities, as well as pilot research in both special and general education settings. Limitations and suggestions for future research are included.

Keywords: mathematics | severe disabilities | moderate disability | severe disability | access to the general curriculum inclusion

Article:

In recent years there has been a growing awareness of the importance of mathematics for students to graduate with the skills needed to function in the 21st century (Kilpatrick, Swafford, & Findell, 2001). The National Council of Teachers of Mathematics (2000) stresses the importance of all students having mathematical competence and the ability to use mathematical skills in everyday life because these skills provide "significantly enhanced opportunities and options for shaping their [all students] futures" (p. 1). In addition, changes in technology have increased the need for mathematical competence in jobs that once relied primarily on physical abilities. For example, machinists who once operated drill presses or lathes with levers and switches now rely on the use of computerized numerical control (CNC) machines, which must be programmed using knowledge of trigonometry.

Besides the overall increasing demands in American society for mathematical competence, there are at least three reasons to reconsider new learning targets for students with moderate and severe developmental disabilities. First, there is new research in early mathematics learning that suggests that students develop mathematical thinking and reasoning beginning in infancy, and this grows extensively during the first 5 years (Sarama & Clements, 2009). Both new theory and research supports the capacity of very young children to acquire substantive mathematical ideas (Sarama & Clements, 2009). Researchers have found that infants and preschool age children demonstrate complex mathematical skills such as patterning, exploring shapes and spatial relations, comparing magnitudes across contexts, and counting objects (Baroody, 2004; Kilpatrick et al., 2001). Research shows that children whose development is delayed also develop more advanced mathematical concepts in the early years of life than once thought possible (Baroody, 1998).

A second reason to rethink targets for mathematical learning is the increasing evidence of the importance of early opportunities to learn this content. Educators are beginning to recognize that possession of number sense is indicative of mathematical success in later years (Denton & West, 2002; NMP, 2008). The National Council of Teachers of Mathematics defines number sense as an individual's ability to understand numbers and operations and use these concepts and strategies to make mathematical judgments and conduct complex problem solving (McIntosh, Reys, & Reys, 1992). This term encompasses a variety of foundational early numeracy skills and includes (a) number identification; (b) rote counting; (c) representation of numbers and counting with one-to-one correspondence; (d) number conservation; (e) composing and decomposing numbers; (f) magnitude of numbers; (g) early measurement concepts, such as identifying things as bigger/smaller and quantities as more/less; (h) understanding the effects of operations, such as adding and subtracting; and (i) patterning.

Besides the capacity for young children to learn mathematics and the importance of this early opportunity to later learning, a third reason to rethink learning targets specifically for students with moderate and severe developmental disabilities is the restricted opportunities students may have had. Although some children acquire early numeracy skills before having any formal schooling, others may not have these critical skills due to lack of experiences or exposure within their environment, culture, education (e.g., high-quality preschool instruction), or because of slow developmental progressions (Hart & Risley, 1995; Sarama & Clements, 2009). For children with mild developmental delays, educators have advocated more intensive early interventions in mathematics by explicitly teaching early numeracy skills beginning in kindergarten and extending through the elementary years (Bruer, 1997; Gersten & Chard, 1999).

For children with moderate and severe developmental disabilities, these early opportunities for mathematical learning may not exist or be limited to rote learning. Research by Towles-Reeves, Kearns, Kleinert, and Kleinert (2009) on students who participate in three states' alternate assessments based on alternate achievement standards (AA-AAS) revealed some important insights about mathematical learning. Towles-Reeves et al. found that only 23% of elementary students on AA-AAS could count with correspondence and make sets of items to 10, a mere 7.7% could rote count to 5 (i.e., of the students who could not count with 1:1 correspondence), and only 3.3% could apply computational procedures to solve real-world or routine problems. Kearns, Towles-Reeves, Kleinert, Kleinert, and Thomas (2011) found similar results in a later study with seven states. Kearns et al. found only 31% of elementary students in AA-AAS 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 world or routine problems. If 88% of elementary students in AA-AAS cannot even count to 5, clearly there is a need for more effective mathematical instruction for students with moderate and severe developmental disabilities.

Evidence does exist that students with moderate and severe developmental disabilities can learn some basic mathematics. In a comprehensive review of the literature, Browder, Spooner, Ahlgrim-Delzell, Wakeman, and Harris (2008) found 68 empirical studies that taught math skills to 493 individuals with moderate and severe developmental disabilities. Of these 68 studies, 93% of the studies addressed the standards of Numbers and Operations. In contrast, most of these were focused on simple discriminations or performing operations.

Just as young students need opportunities to gain skills like phonemic awareness and listening comprehension to move towards becoming readers, they need explicit instruction in early numeracy skills to succeed in mathematics (Gersten & Chard, 1999). For students with moderate and severe developmental disabilities, this instruction will need not only to be explicit but also contextually meaningful. Although students can learn to communicate "4" when shown "2 + 2 =" through drill and practice, the process has no meaning until students gain competence with combining sets.

In recent years, some early numeracy curricula have emerged that challenge students to understand mathematical concepts at a younger age. For example, the curriculum *Number Worlds* (Griffin, Clements, & Sarama, 2008) was developed to address number sense while building computational and problem-solving skills. *Number Worlds* was targeted for at-risk and high incidence populations. Students with moderate and severe developmental disabilities will likely need for skills to be taught in smaller chunks, with many more repetitions, using much more explicit instruction. Browder et al. (2008) found effective mathematical instruction for this population used systematic prompting, task analysis, and applications to real-life contexts. Students with moderate and severe developmental disabilities may also need the opportunity to continue gaining a foundation in early numeracy in the elementary years. This means instruction will need to be both age-appropriate and embedded with the more advanced mathematics of their grade level. For example, a l0-year old student needs not only to comprehend the concept of the numeral "4" but also to be able to apply it to the activities of a typical fifth grade class, such as finding the perimeter of an object. The purpose of this article is to propose a conceptual model for learning mathematics to elementary-aged students with moderate and severe developmental disabilities. After describing our conceptual model, we then provide descriptive data from a preliminary investigation of this approach with students in public schools.

Conceptual Model

Our conceptual model was developed based on the premise that early numeracy skills, which promote mathematical competence for students with high incidence disabilities, will also produce advanced learning for students with moderate and severe developmental disabilities. We hypothesized that it was not the "what" of early numeracy learning that differs for students with moderate and severe developmental disabilities to gain competence in mathematics but the "how." Our goal was to identify teaching strategies to promote more learners who could count, compute, and apply these skills across a variety of mathematical problems.

Prior research on mathematical learning for this population (Browder et al., 2008) suggests that academic instruction needs to be intensive, including many opportunities for practice with systematic prompting and feedback on small sets of objectives. We did theorize that students could acquire multiple skills together if they were related thematically. For example, a student might be able to learn to rote count, create sets, and combine sets if related to an activity (vs. massed trials of learning one skill like rote counting). Because students would need many repetitions, we theorized that changing the activity while keeping the target skills constant would maintain motivation and promote generalization. Given the literature on the use of read alouds with students with severe disabilities (Hudson & Test, 2011), we determined that reading a math story would create a context for learning and give meaning to the mathematical processes. Students could then use mathematical manipulatives related to that story to aid in performing operations while building conceptual understanding. An additional challenge was the fact that the mathematical content of the students' assigned grades would be substantially more advanced than these early numeracy skills. Browder et al. (2012) demonstrated how to teach grade-aligned mathematical standards to older students (i.e., middle and high school age) with moderate and severe developmental disabilities in self-contained educational settings by (a) using stories about familiar events, such as going out to eat; (b) providing assistive technology in the form of graphic organizers and number lines; and (c) utilizing systematic instruction to follow a task analysis to perform the mathematical concept (e.g., finding a point on a plane, creating a bar graph). In the this study, we decided that teaching students to apply these early skills within the context of learning more advanced content in general education (e.g., to work on identifying "4" while working with a group on division) would provide students an opportunity to learn the early nurneracy skills while working on grade-appropriate mathematics standards.

Using this thinking, we defined our conceptual model based on four active components to produce mathematical learning: (a) target early numeracy skills, (b) use systematic prompting and feedback, (c) vary daily instruction using story-based lessons, and (d) promote generalization to grade-level content learning through inclusive embedded instruction. We used the research on early mathematics summarized by Sarama and Clements (2009) to derive the targeted skills. These were cross-referenced with the scope and sequence guides from several early mathematics curricula to be sure the most frequently targeted skills were included. This scope and sequence was then submitted to university-level early mathematics content expert for further validation and clarification. From the review of literature on mathematics (Browder et al., 2008) and additional reviews on evidence-based practices to teach academics to this population (Spooner, Knight, Browder, & Smith, 2011), the most effective strategies for teaching these early numeracy skills were incorporated. The prior work of Browder et al. (2012) provided a model for how the mathematical skills could be made meaningful by using stories that are appealing to the learner and set up the operations to be performed. Concrete manipulatives, graphic organizers, and a number line were provided to help students understand the operations being performed (Marsh & Cooke, 1996; Smith & Montani, 2008). Most prior research in mathematics provided the intervention in 1:1 or small group formats (Alacantara, 1994; Browder, Snell, & Wildonger, 1988; Colyer & Collins, 1996; Denny & Test, 1995; Matson & Long, 1986). We used a small group format (three to four students with disabilities) during daily story-based mathematic lessons. Additionally, several investigators have shown students can learn academics through systematic instruction embedded in general education (Jameson, McDonnell, Polychronis, & Riesen, 2008; Jimenez, Browder, Spooner, & DiBiase, 2012; Johnson, McDonnell, Holzwarth, & Hunter, 2004; McDonnell, Johnson, Polychronis,& Riesen, 2002;Wolery, Anthony, Snyder, Werts, & Katzenmeyer, 1997), so we embedded trials of the early numeracy skills using systematic instruction in typical general education mathematics classes. The purpose of the embedded instruction was to promote learning grade-level content through teaching early numeracy skills during typical general education mathematics lessons. Figure 1 summarizes this conceptual model. Each of the four components is described in more detail in the methods (see Figure 1).

Method

Participants and Settings

Three special education teachers participated in this study. Teacher 1 was a third year teacher who was licensed to teach students with moderate/severe disabilities and was completing a Master's degree in special education. Teacher 2 had 11 years of teaching experience, was licensed in mild/moderate disabilities, and had a master's degree in special education. Teacher 3 had 6 years of teaching experiences, was licensed in moderate/severe disabilities, and had a master's degree in special education. Three paraprofessionals participated in this study with 19,9, and 2.5 years of experience as a paraprofessional in a self-contained classroom for students with disabilities, respectively. All three paraprofessionals had high school diplomas with some college coursework. Three elementary, general education teachers participated in this study. The third grade general education teacher had 7 years of teaching experience, the fourth grade teacher had 9 years of teaching experience, and the fifth grade teacher was a first year teacher. All had state licensure in elementary education. Three doctoral students in special education provided support to the teachers and paraprofessionals. All doctoral students had prior experience teaching in classrooms for students with severe disabilities, as well as prior experience conducting research focused on general curriculum access in classrooms for students with severe disabilities. Eight students participated in this study; however, one student was dropped from the study due to poor attendance (e.g., missed >20 days of school in one quarter). Student demographic information can be found in Table 1 (see Table 1).

Two settings were used for the study. Small group instruction on the story-based math lessons was delivered by each special education teacher at a table in their special education classroom. Embedded instruction was delivered by the paraprofessional in each of the general education mathematics classrooms during ongoing general education instruction. None of these students had been included in general education for core academic content prior to this study (they were included in social contexts and electives). The research team negotiated the opportunity for the students to attend math classes that matched their chronological age. Two students attended a third grade class, two attended a fourth grade class, and three attended a fifth grade class. Prior to including the students with disabilities in the general education setting, the research team provided the general education students in each of the classrooms with a brief introductory lesson about students with disabilities. Then, students with disabilities attended the class daily for the duration of the study and sat in cooperative groups. Each paraprofessional embedded instructional trials during naturally occurring breaks and individual seatwork. The students participated in all activities of the general mathematics class including listening to lectures, doing hands-on activities, and participating in cooperative learning groups.

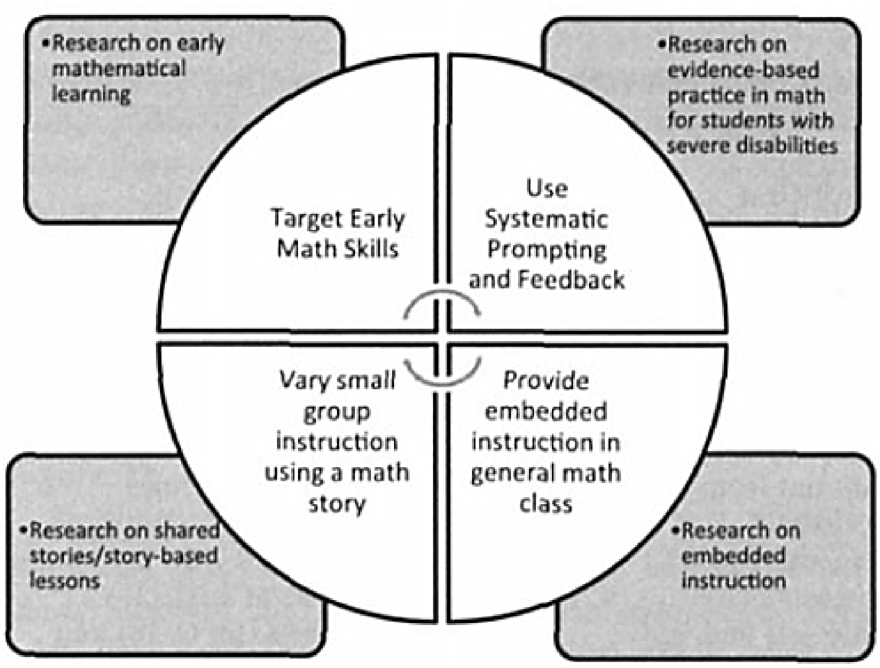

Figure 1. Conceptual model for teaching early numeracy skills to students with moderate/severe developmental disabilities.

Table 1. Student Demographics

Participant	Gender/age/ethnicity	Grade	Primary/secondary diagnoses	IQ	Adaptive behavior composite score	Math ability
1	M, 8 Caucasian	3	Moderate 10, William's Syndrome	DAS-II: 51 (0.1%)	ABAS-II: 72, 3% (teacher) 50, <0.1% (parent)	TEMA:<l%, AE <3-0 years
2	M, 9 Hispanic	3	Moderate 10, Down's Syndrome	DAS-II: 51 (0.1%)	Vineland: 60, 1%	TEMA:<l%, AE <3-0 years
3	F,9 African American	4	Autism, Moderate 10	not available; CARS: 33.5, "mildly moderately autistic range"	Vineland: 58, <1%	Brigance: GE preK-lst grade
4	M,8 African American	4	Autism	not available; CARS: range 30-37, "mildly moderately autistic range"	Vineland: 64, 1%	TEMA: 58, <1%
5	F, 10 African American	5	Moderate ID	WISC: 55, (0.1%)	Vineland: 70, 2%	WIAT: 55, <0.1%
6	F, 11 Hispanic	5	Moderate ID, Down Syndrome	WNV:42	Vineland: 68, 1%	TEMA: 58, <1%,AE <3-0 years
7	F, 10 African American	5	Moderate ID	WISC: 51, (0.1%)	Vineland: AE 6.6 to 6.11 years, "moderately low range" (no composite score reported)	Woodcock Johnson: 37, AE 5.3, <K.O

AE =age equivalence; GE =grade equivalence; DAS-II =Differential Ability Scale, 2nd ed.; WISC =Weschler Intelligence Scale for Children, 4th ed.; WNV =Weschler Nonverbal Scale of Ability; CARS =Childhood Autism Rating Scale; Vineland =Vineland Adaptive Behavior Scales, 2nd ed.; TEMA-3 =Test of Early Mathematics Ability, 3rd ed.; Brigance =BRIGANCE Comprehensive Inventory of Basic Skills (CIBS); WIAT =Weschler Individual Achievement Test, 2nd ed.; Woodcock Johnson =Woodcock Johnson III Normative Update (NU) Tests of Achievement.

Table 2. Themes and Objectives for Units of Early Numeracy Instruction

	Unit 1	Unit 2	Unit 3
Lessons	1.1 Math at the Speedway 1.2 Sunken Treasure 1.3 Gardening 1.4 A Day at the Beach 1.5 My Class Trip to Washington, DC 1.6 Baseball Review Game	2.1 Mardi Gras 2.2 Chinese New Year 2.3 Fiesta 2.4 Family Feast 2.5 Pow Wow 2.6 Basketball Review Game	3.1 Flowers for Mother 3.2 Bugs 3.3 Gone Fishing 3.4 Off to the Zoo 3.5 Ribbit, Ribbit, Hop 3.6 Soccer Review Game
Objectives taught	• Counts 1-5 across line (movable) • Counts 1-5 (in-line, nonmovable) • IDs 1-5 • Make sets of 1~3 • Add pre made sets (sums to 5) • Symbol use (=, same value as) • Identify ABAB patterns • Nonstandard units of measurement (1-5) • Calendar skills: identify date to 5th, move 5 days or less, across 1 week on calendar (e.g., 2 days later: Wednesday-Friday)	Count 1-5 (scattered, nonmovable) • Count out from Groups 1-5 • IDs 1-10 • Rote Count 1-10 • Make sets of 1-5 • Create sets and add (sums to 5) • Symbol use (>, greater than) • Extend ABAB patterns • Measure in inches (1-5) • Calendar skills: identify date to 10th, move 5 days or less, across 2 weeks (e.g., 4 days later: Thursday-Monday)	• Counts 1-10 across line (movable) • Counts 1-10 (in-line, nonmovable) • Rote Count 1-15 • Make sets of 1-10 • Create sets (up to 10) and add (sums to 10) • Symbol use <, less than) • Create ABAB patterns • Measure in inches (1-10) • Calendar skills identify date to 10th, move 10 days or less, across 2 weeks on calendar

Selection and Validation of Target Skills

The learning trajectories for teaching early numeracy skills, developed by Sarama and Clements (2009), were used as the foundation for building this curriculum. These were then cross-referenced with multiple early mathematics curricula designed for students with disabilities to identify the most prevalent objectives. Based on this cross-reference, a list of prioritized objectives was developed and submitted to a university-level mathematics expert for validation and revisions. The prioritized objectives included counting with one-to-one correspondence, number identification, rote counting, composing sets, addition with sets, comparing sets, patterning, linear measurement, and calendar skills. Finally, the researchers broke down the prioritized objectives into smaller targeted skills and divided them across four units to be taught using the evidence-based practices. The objectives and targeted skills are laid out in Table 2, along with the thematic topic for each lesson (see Table 2).

Curriculum and Materials

The target skills for this study were developed into a scripted curriculum by Jimenez, Browder, and Saunders (2013). The curriculum was comprised of four units with six scripted lessons per unit. Each lesson began with a story that the teacher read aloud. Although the stories changed with each lesson, the target skills remained the same for the entire unit, giving students the opportunity for repeated practice and to apply these skills to new contexts. After five story-based lessons, the sixth lesson of every unit was a review game, which had a sports-related theme and a game board. Students drew a game card and practiced each skill by performing the task written on the game card. Teachers were also given SMART Board™ templates and poster boards with each theme for all lessons. Students were given several graphic organizers and response materials that remained constant across all lessons and units. The first was a set maker that was a laminated piece of cardstock with two circles used for placing objects into a set and a third circle for combining the sets together. The second was a line counter that was a straight line drawn across the page used to count manipulatives. Students also received a pattern maker, which was a series of line drawn boxes on laminated cardstock, on which the students put objects to create a pattern. The students had small cards with symbols (=, <, and > and a number line with removable numbers from 1 to 10. Each student received a "pile" of counting manipulatives. The manipulatives were theme based and changed for each story (e.g., rubber worms for the gardening story).

Small group lessons focused on topics of interest and appeal to the students (e.g., family reunion), as well as some cultural themes to build in interdisciplinary instruction (e.g., Chinese New Year). All cultural themes were reviewed by a member of the cultural group for accuracy and appropriateness. Each lesson was fully scripted to assist with the fidelity of the teachers' use of systematic prompting and feedback while keeping the flow of the theme-based lesson. A sample script and set maker are shown in Figure 2 (see Figure 2).

Students took all graphic organizers and response materials in a notebook to the general education math class. Students had their own general education workbook and textbook for their assigned grade level. As needed, they also received additional response materials (e.g., graphic organizer for fractions) to promote participation in the general education lesson. The paraprofessionals had a data sheet that included a sample script on the top for how to use the systematic prompting and feedback during the embedded instruction.

Dependent Variables and Measurement Assessment

The primary dependent variable was the number of correct items on a curriculum-based assessment with 60 items targeting the various progressions for each of the nine targeted objectives (e.g., 16 items targeted Unit 1 skills, 16 items targeted Unit 2 skills, 14 items targeted Unit 3 skills, and 14 items targeted Unit 4 skills). Students were assessed weekly after one entire lesson had been taught across 4 days. Students were assessed an average of six times per unit (range 6-8). To control for threats to internal validity (e.g., testing effects), two forms of the assessment were used, which tested the same skills but with different numbers. All assessments were administered individually by a member of the research team in a quiet area of the special education classroom.

Instructions and a script were provided for each assessment item. Students were given 5 s 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 organized by the nine targeted objectives, and the tested skills within each objective got progressively more difficult. A ceiling was set so if students missed both skills for a specific objective within a unit, the assessment was discontinued for that objective, and the assessor moved to the next objective with the student. For example, in the targeted objective for composing sets in Unit 1, students were given two trials to create sets of one to three objects. Students were given five to six counters and a set maker and told, "Make a set of _ (#1-3)." If the student missed both trials within this Unit 1 skill, the assessor terminated that objective's set of test items and moved to the next objective's test items. If the student got at least one trial correct within this Unit 1 skill, the assessor moved to Unit 2's skill for composing sets. In Unit 2, students were given two trials to create sets of one to five objects. Again, if the student got at least one trial correct, the assessor moved to Unit 3's skill for composing sets.

Good job! I got **2 (point to first set and write "2" underneath)** *envelopes from my parents and* **3 (point to second set and write "3" underneath)** *envelopes from my uncles.* ***How many envelopes did I get altogether?*** (Do not move counters for students. Students should move all counters into the last circle and add together with the cue "how many altogether?").

Skill	Cue	Materials Needed	A. Wait for Student's to Try Independent Correct	B. If Student Waits for Model	C. If Student Makes an Error-Does Not Wait for Help
E. **Create sets and add (sums to 5)**	"How many red envelopes did I get altogether?"	Teacher: Set Maker, red envelopes from previous two skills in the first and second circles. Students: Set maker with counters from previous two skills in the first and second circles.	Student moves all counters to last circle and counts (or points as teacher says numbers). If correct, praise That's it! There are ___ red envelopes altogether. If no response or error go to B.	Push all the counters into the last circle. Count them altogether with me…1, 2, 3, 4, 5 (etc.) Move counters back to sets and have student repeat skill. Your turn. Note: don't say "plus"; just count the items. If correct, praise, You added with some help! If error go to C.	Push all the counters into the last circle. We count to add like this, 1, 2, 3, 4, 5 …etc. Next time wait and I will help if you are not sure. Don't guess.

How many red envelopes did I buy altogether? See if a student will answer "5." If not, count the red envelopes in the set makers again. If still incorrect, say "5" and move on. If correct, praise: You got it! It's 5! Write answer underneath last set and read addition sentence (e.g., "2 + 3 = 5").

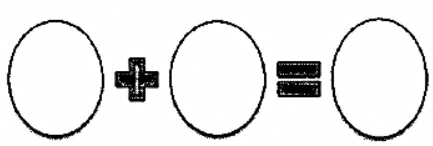

Figure 2. Sample script from Unit 2, Lesson: Chinese New Year. The skill is creating sets and adding with sums to 5. The graphic organizer for this skill is included below the script. Lighter font indicates what the teacher should say. The script above the table is part of the story-based

lesson. The script inside the table indicates what the teacher should say for the systematic instruction.

Generalization to inclusive mathematics class

The secondary dependent variable was the percentage of skills performed correctly in the general education setting during embedded instruction. Only skills being taught in the current unit during story-based lessons were assessed (see Table 2 for a list of skills taught in each unit). Although paraprofessionals could embed each of the nine skills four times during the general education class, only the student's first response was graphed. Paraprofessionals were asked to embed a minimum of six of the nine skills of that unit during the general education lesson. Because the number of trials varied daily, generalization data were summarized as percent of independent correct responses.

Interrater reliability

Interrater reliability (IRR) was taken by a second member of the research team on student assessment data across baseline and intervention conditions. Additionally, IRR was taken on generalization data in the general education classroom by a member of the research team during the intervention condition only (students did not attend inclusion classes during baseline). IRR was computed by dividing the number of agreements by the total number of agreements plus disagreements and multiplied by 100.

Teacher survey

A teacher survey was used to determine teachers' perceptions of the effects of the intensive mathematics instruction in early numeracy skills impact on students' AA-AAS performance. The teachers who participated in the study along with their corresponding paraprofessionals were asked to respond to the survey. Respondents were asked to complete a six-item questionnaire, which used a 6-point Likert scale to rate their response to each question. After the teachers administered the state's alternate assessment, they were asked to respond to questions about (a) if the instruction prepared students for the alternate assessment, (b) the degree of overlap between the instruction and the alternate assessment, (c) if the instruction indirectly prepared the students for the alternate assessment by teaching prerequisite skills, and (d) if the instruction directly prepared the student for the alternate assessment. In addition, the teachers were asked if they felt the students benefitted from the instruction and the inclusive experience.

Procedures

Baseline

During baseline, the students received their typical mathematics instruction in the special education classroom, which consisted of skills like counting and using a calculator. During baseline, the member of the research team implemented the assessment daily for a minimum of 5 data points or until a stable baseline was observed. The student received frequent praise for participation.

Story-based small group mathematics lessons

The first component of the intervention was designed to provide intensive instruction on the objectives delineated in Table 2. First, the teacher read the story aloud providing opportunities for the students to see and interact with the materials, but without pausing to perform the math skill. Next, the teacher reread the story pausing to allow students to perform the math skill. When the teacher paused to present this opportunity to respond, she used the designated prompting procedure indicated by the lesson plan script. For all skills except number recognition, the teacher used a system of least intrusive prompting. For number recognition, the teacher used time delay by first naming the number immediately (0 s delay) and having the student repeat the name. During delay rounds, the teacher waited 5 s for the student to name the number. If the student was correct, she provided specific verbal praise (e.g., "Yes, you found number 4!"). If the student was incorrect, she provided error correction (e.g., "This is 4. Remember, if you are not sure, wait and I will show you."). If the student did not respond within 5 s, she provided error correction only. Students practiced identifying numbers both expressively (i.e., saying the name of the number) and receptively (i.e., pointing to number given by teacher). The teacher maintained motivation by enacting aspects of the story (e.g., praising the response in pirate brogue during the pirate story or pretending to by repulsed by the worms in the garden story). The teacher repeated a lesson for four consecutive school days before introducing the next lesson in the unit. The skills remained constant across each unit, but the story, materials, sequence of skills, and numbers used in each math problem varied. The story-based lessons were trained 4 days a week for a 30 min period. Students worked on these skills across units from October through March.

Embedded instruction

In the general education class, the paraprofessional embedded at least six of the nine targeted skills for the current unit using systematic prompting and feedback. The targeted responses were the same ones as those being learned in the small group story-based lessons, but they were distributed across the general education class lesson. When possible, they also were embedded with the general education activity and materials (e.g., find the number on the same worksheet everyone was using).

Research team members trained the paraprofessionals to embed the instruction by modeling how to do so in the general education class for the first 1-2 weeks of intervention. After 1-2 weeks, their support was faded and the paraprofessional began to provide student support. For each embedded trial, the paraprofessional would give the student the direction (e.g., "count these," "point to 6," "find the ABAB pattern") and then waited for the student to respond. Using time delay, the paraprofessional would provide an immediate model of the correct response on the first day of instruction. Then the paraprofessional waited 5s for the student to respond on subsequent days. If correct, the paraprofessional praised the student. If incorrect, the paraprofessional repeated the model prompt. A 5s delay was used for all embedded trials that were scored for data collection. Paraprofessionals unobtrusively embedded skills during natural breaks in the lesson, when other students were doing independent seatwork, during the lesson itself (e.g., identifying a number on the worksheet all students completed), or during the classroom warm-up while other students were getting organized, copying assignments, and completing warm-up exercises.

Embedded instruction trials only took a small portion of the 45 min general education math period. The remainder of the time, students participated in grade-aligned mathematics activities with their same-age peers (e.g., coloring in fractions; using string to measure perimeter). Because the general education teachers used many principles of UDL and cooperative instruction, the students with disabilities were able to participate in most activities with minimal adaptation and through natural peer supports. A member of the research team continued to attend the general education classes daily, per agreement with the school principals, and provided additional support/instruction as needed to the students to promote appropriate behavior and ensure receipt of a minimum of six trials of the targeted skills.

Procedural fidelity

Procedural fidelity data were collected by a member of the research team for story-based lessons and embedded instruction using a checklist of skills to ensure all nine skills were taught during the story-based lesson by the special education teacher and a minimum of six out of nine skills were embedded within the general education classroom. Data were collected to ensure skills were taught correctly using the designated prompting procedure. Procedural fidelity data on assessments were collected by a secondary member of the research team. Procedural fidelity was calculated by dividing the steps taught or assessed correctly by the total number of steps and multiplied by 100.

Research design

This field test included progress monitoring for seven individual case studies with additional data on performance in a general education math class setting. The field test monitoring included a series of AB designs where the A Phase represented the baseline and the B Phase was the intervention delineated by monitored Unit performance, replicated across students.

Results

Performance on Mathematics Assessment

Results of the primary dependent variable are shown in Figure 3. All students showed an overall increasing trend across units. Students also generalized some skills to untrained math skills (e.g., once they learned to count sets of five objects and could rote count to 10; they could also count sets of 10 without further instruction). In baseline, no skills had been taught, but most students could do at least 20 of the 60 target skills (e.g., identify some numbers). By the end of the third unit, the students had received instruction on 46 of the 60 skills (the school year ended before Unit 4 could be taught). By Unit 3, Students 5, 6, and 7 were consistently performing well above 46 indicating both mastery and generalization to the final untaught set of 14 skills. Students 1 and 3 were consistently at or above 45 skills. Although Student 2 only performed from 30 to 40 skills by Unit 3, this was well above his baseline of 10-15. Student 4 had 2 days of performance above 46 skills in Unit 3; suggesting some generalization to untrained skills, but with some regression in performance (see Figure 3).

Performance on Embedded Trials

Results of the secondary-dependent variable are shown in Figure 4. For Figure 4, the percent correct for the target unit on the Numeracy Assessment (e.g., number correct out of 16 skills in Unit 1) were compared to percent correct trials during embedded instruction (e.g., number correct out of six or more embedded trials). Students did not go to the general education math classroom during baseline; therefore, so no data were available during baseline for embedded instruction. Generally, students performed more skills correctly in the general education setting during the embedded instruction trials after receiving the small group instruction in special education than they did on the Numeracy Assessment (see Figure 4).

IRR and Procedural Fidelity

The IRR for the Numeracy Assessment was conducted for 31.3% of all assessments and averaged 99.8%. The IRR for the embedded instruction data collection was conducted for 20.5% of the intervention sessions (embedding did not occur in baseline) and was 100%. As was noted previously, IRR in the general education setting was intrusive to the classroom environment; therefore, the percentage is lower but still at an acceptable level (Cooper, Heron, & Heward, 2007).

Procedural fidelity for the administration of the Numeracy Assessment was taken on 28.4% of all assessments across students and averaged 99.3%. Procedural fidelity for the story-based math lessons was collected for 28.4% of sessions for all special education teachers and averaged 99.3%. Procedural fidelity for embedded instruction was taken on 26.1% of sessions and averaged 98.3%. In addition, results indicated that paraprofessionals embedded an average of eight out of nine skills daily in the general education setting, even though they were only required to embed six out of nine skills.

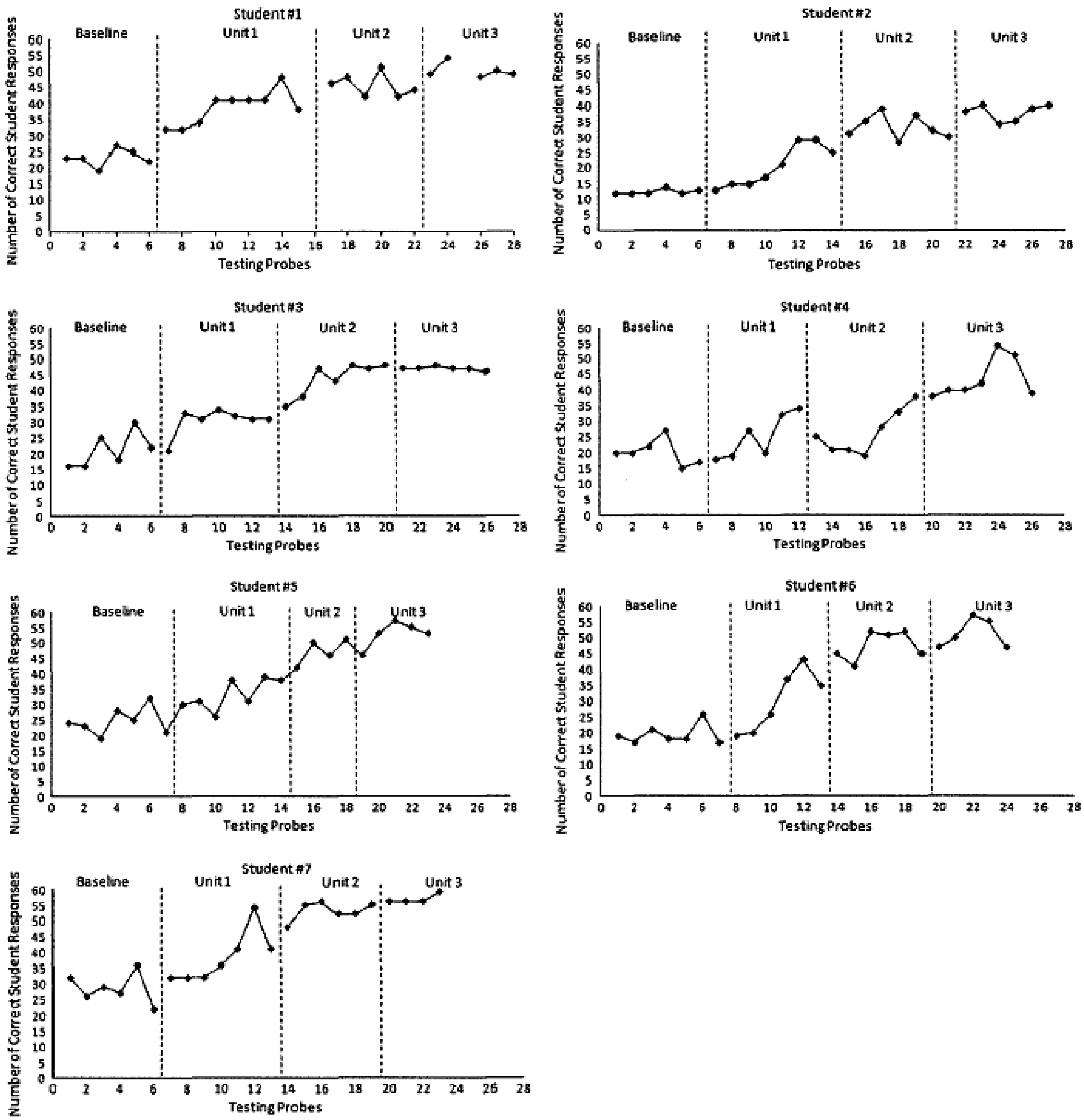

Figure 3. Number of correct student responses on the Early Numeracy assessment. The phase lines separate the unit of instruction being taught in the classroom at the time of the assessment.

Teacher Survey

A 6-point Likert scale was used to rate teacher responses by both the special education teachers and paraprofessionals (e.g., strongly agree, agree, somewhat agree, somewhat disagree, disagree, strongly disagree). One respondent agreed and the rest strongly agreed that students benefitted from the study and from inclusion. Half of the teachers strongly agreed that the intervention indirectly prepared the students for the state's alternate assessment; two agreed and one somewhat agreed. Five somewhat agreed that it directly prepared the students for the state alternate assessment (AA-AAS); but one disagreed. The researchers asked the teachers to rank the percentage of overlap in skills between the intervention and the AA-AAS. One teacher ranked the overlap 1-20%, four teachers ranked the overlap 21--40%, and two teachers ranked the overlap 41--60%.

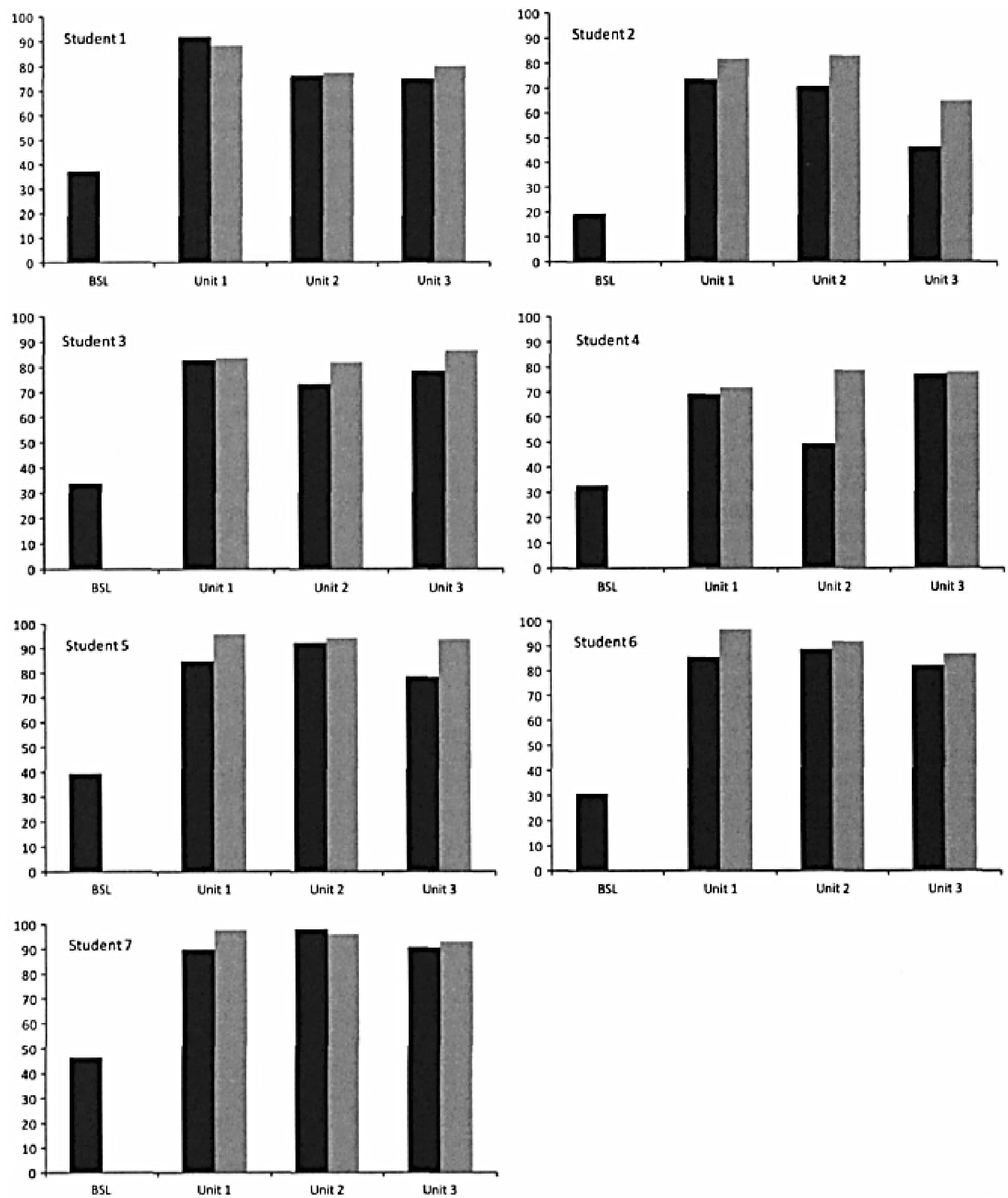

Figure 4. Mean student performance data on Early Numeracy assessments and embedded instruction skills in the general education classroom by unit of instruction. Note. Black =percent correct on ENSB assessment after instruction in special education classroom broken down by assessment items targeting specific unit; Gray =percent correct on trials embedded in general education math class by paraprofessional.

Discussion

This study was implemented through funding from the Institute for Education Sciences Goal 2 Research to develop and pilot a new intervention. The purpose of Goal 2 projects is to demonstrate the promise of an intervention that can then be evaluated through a future efficacy study with an experimental design. The major limitation of a development study of this type is that efficacy cannot be inferred because of the multiple threats to internal validity. For example, the increasing skills across units might be attributed to practice with the assessment, student maturation, or some other unidentified variable in the students' environment. A second limitation of this investigation was that student progress on grade-level mathematics content was not evaluated as a function of embedded instruction.

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The small group story-based mathematics lessons gave the students the opportunity to learn the skills with a reason for the mathematical processes. The intervention used multiple exemplar training by presenting the same targeted skills but changing the stories and materials. For example, a student might practice adding to five using plastic worms in a story about gardening 1 week and then practice adding to five using feathers in a story about a Pow Wow the next. These stories provided the word problems typically used in mathematics instruction, but with theme-based manipulatives for added interest. While not implemented in general education, one option for future replications and practice would be to use stories of this type in the mathematics class as a learning center activity for all students.

The students also were able to generalize the target skills to the general education class through embedded instruction. There is a growing research base to support embedded instruction with students with moderate and severe developmental disabilities in general education (Jameson et al., 2008; Jimenez et al., 2012; Johnson et al., 2004; McDonnell et al., 2002; Wolery et al., 1997). In the current study, the paraprofessional embedded the targeted skills using systematic instruction. In these studies as well as others, the trials have been delivered by paraprofessionals (McDonnell et al., 2002; Riesen, McDonnell, Johnson, Polychronis, & Jameson, 2003), general education teachers (Johnson & McDonnell, 2004; Wolery et al., 1997), and general education peers (Jameson et al., 2008; Jimenez et al., 2012).

A question to consider in future research is whether the outcomes could be achieved by using the embedded instruction alone. Jameson, McDonnell, Johnson, Riesen, and Polychronis (2007) compared the effectiveness of one-to-one embedded instruction in a general education classroom to one-to-one massed trial instruction in a special education classroom. Both the special education teacher (special education classroom) and the paraprofessional (general education classroom) taught four middle school students to identify or define vocabulary aligned with the general education class in which they participated (e.g., Earth Science) using embedded instruction. While both instructional strategies were effective, results also suggested that embedded instruction can be held as a promising instructional strategy to support inclusive education for students with disabilities. It would be a misinterpretation of the current study to assume that the embedded instruction was superior to the small group special instruction because students scored higher. The higher scores may have been the result of already having the small group instruction on the skills that were then applied in the general math class. Future research is needed to see if students could master this number of skills in this timeframe with embedded instruction alone.

Recommendations for Future Research

One way the relative contribution of each intervention could be identified would be to compare embedded instruction with embedded instruction plus small group story-based lessons in a multielement design (Ulman & Sulzer-Azaroff, 1975). This comparison would not necessarily need to occur in two different settings. Students might work on the story-based numeracy lessons with peers in a learning center context. More research also is needed to demonstrate how students acquire and generalize the skills. In this study, students were applying their emerging skills to a wide range of materials with the changing stories/manipulatives. Surprisingly, they also began to apply learned skills to untaught skills. A multiple probe across participants design (Horner & Baer, 1978) could be used to show experimental control for the effects of the intervention and minimize the threats to internal validity that exist with only a baseline and intervention. By including periodic probes of untrained, related skills, a pattern of generalization might also be demonstrated.

The participants in this investigation were in the moderate range of functioning for students with intellectual disability. Additional research is needed to extend this mathematical training to students with more significant cognitive impairments who might need additional lessons, fewer target responses per lesson, precursor skill instruction (e.g., 1:1 correspondence), or additional assistive technology (e.g., voice output device to count).

Recommendations for Practice

The outcomes reported by Kearns et al. (2011) and Towles-Reeves et al. (2009) provide a discouraging picture of the mathematical abilities of students who participate in AA-AAS. The need exists for an increased emphasis on mathematics instruction using more effective methods. The intervention reported here took a twofold approach to helping students increase mathematical competence. Mathematics stories were used to help students master early numeracy skills that they had not yet learned but that were no longer taught in the grades of their age level. This remedial instruction would not necessarily need to occur in a special education class. Peers might enjoy teaching the engaging story lessons. The stories also might be adapted for a cooperative learning strategy with some students required to provide the early numeracy responses (e.g., locating the numbers in the story problem) and others performing the more advanced math responses (e.g., computing surface area). The second component of the twofold approach used here was to teach students to use their current numeracy skills in the context of more advanced mathematical content during the embedded instruction. One way students can do grade-aligned mathematics is to learn to apply whatever skills they have to the current content and compensate for unlearned skills with assistive technology. For example, students were able to solve for perimeter, if the problems in general education were adapted to be numbers less than 5. Students also learned to apply their skills to add fractions when denominators were held constant and the numerators were less than 5.

Summary

A new conceptual model for early numeracy skill instruction is needed for students with moderate and severe developmental disabilities. Students' early attainment of number sense greatly impacts their success in gaining deeper grade-aligned content knowledge of mathematics. This field test demonstrated how students acquired and generalized early numeracy skills through a combination of a story-based approach in a small group and individualized support to embed these skills in general education.

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