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Andrew Wojcik Ph.D.
King's College, Department of Education

Alison R. King Ph.D.
Longwood University, College of Education and Human Services

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Teaching Students with Intellectual Disability to Create a Slope-Intercept Equation

Andrew Wojcik, Ph.D.[1] and Alison R. King, Ph.D.[2]
[1]King's College, Department of Education
[2]Longwood University, College of Education and Human Services

Increasingly individuals with Intellectual Disability (ID) are showing the capability of learning abstract mathematical skills like algebra. The purpose of the study was to show a method for teaching high school-aged individuals with ID the algebra skill of creating an equation from a line using a time-delay strategy and equation template. We employed a non-concurrent multiple probe across participants design with four participants who showed an increase in performance after the intervention. All participants showed improvements with a percentage of a nonoverlapping data effect size of 86.84%. The study supplied more evidence that the use of time delay approaches can help individuals with ID make progress within the general education high school curriculum.

Keywords: developmental disabilities, inclusion, algebra, time delay

Knowledge of mathematics, like reading and writing, provides individuals with tools that enhance independent living, employment, and recreation (Kim et al., 2015; National Governors Association Center for Best Practices & Council of Chief State School Officers [NGACBP & CCSSO], 2010; Rodriguez, 2016a & 2016b). Categorically, the National Council of Teachers of Mathematics (NCTM) organizes mathematics into five instructional domains including (1) numbers and operations, (2) algebra, (3) geometry, (4) data analysis and probability, and (5) measurement (NCTM, 2000). NCTM (2000) links the categorical domains of mathematics with a conceptual framework of mathematical skills that includes five strands. Kilpatrick et al. (2001) defined the strands as

> *Conceptual understanding*- comprehension of mathematical concepts, operations, and relations; *procedural fluency*-skill in carrying out procedures flexibly, accurately, efficiently, and appropriately; *strategic competence*-ability to formulate, represent, and solve mathematical problems*; adaptive reasoning*-capacity for logical thought, reflection, explanation, and justification; *productive disposition* -habitual inclination to see mathematics as sensible, useful and worthwhile, coupled with a belief in diligence and one's own efficacy. (p. 5)

In the early 2000s, curriculum developers worked to integrate the instructional domains and the skills strands throughout the K-12 curriculum (NCTM, 2000; NGACBP & CCSSO, 2010). For example, NCTM (2000) embedded algebra throughout the K-12 curriculum because algebra is essential to access high school science, technology, engineering, and math instruction (STEM; Kendall, 2011; Kress, 2005; NGACBP & CCSSO, 2010). The integration of algebra across the K-12 curriculum affects individuals with disabilities who were prevented from learning algebra found in the special education classroom prior to 2004 (Creech-Galloway et al., 2013; Foegen & Morrison, 2010; Jimenez et al., 2008, Johnson et al., 2013). The Individuals with Disabilities Education Improvement Act in 2004 (IDEIA) called for "… high expectations for … [children with disabilities] … ensuring their access to the general education curriculum in the general education classroom, to the maximum extent possible..." Despite the language found within the law, schools continue to place 93% of individuals with Intellectual Disability (ID) in separate classrooms/schools without direct access to the general education classroom (Agran et al., 2020; Kleinert, 2015; Kleinert et al., 2020). IDEIA defines ID for school aged individuals, as a condition where measured general intellectual functioning and adaptive behavior fall below 2.5 standard deviations. For students identified with ID, exclusion from the general education curriculum occurs because some believe students with ID will not benefit from the general education environment or content, the student needs extensive modification to the curriculum, or the student needs communication support (Agran et al., 2020; Greenstein & Baglieri, 2018, Kleinert et al., 2015). Additionally, exclusion occurs because special educators may be unfamiliar with abstract math content, and general educators may be unfamiliar with inclusive pedagogy (Agran et al., 2020; Creech-Galloway et al., 2013; Greenstein & Baglieri, 2018; Johnson et al., 2013).

Algebra for Individuals with ID

The general education algebra requires students with and without disabilities to develop abstract algebraic reasoning skills (Creech-Galloway et al., 2013; Greenstein & Baglieri, 2018; Kilpatrick et al., 2005; Monari Martinez, 1998; NGACBP & CCSSO, 2010), and there is a limited body of research providing examples of students with ID learning the abstract algebraic curriculum. Most studies demonstrated elementary arithmetic or functional life skill mathematics (Hord & Bouck, 2012; Hudson et al., 2018).

Research exploring High-school level Algebra course inclusion for students with ID began with Monari Martinez (1998), who described and theorized the benefits for teaching abstract algebra instruction to students with ID. Noting, social and self-esteem benefits, they predicted individuals would benefit from exposure to logical thinking and to the language of mathematics.

Logical thinking can be demonstrated as students develop procedural abilities (Kilpatrick et al., 2001), and much of the existing research shows individuals with ID developing procedural fluency to solve one-step equations (Baker et al., 2015; Bowman et al., 2019; Hudson et al., 2018; Jimenez et al., 2008). Similar procedural studies show individuals with ID learning procedures to find the lengths for different sides of a triangle with the Pythagorean Theorem, or solving algebraic word problems (Creech-Galloway, 2013; Root and Browder (2019). Logic can also lead to communication development (Monari Martinez, 1998), and research shows students with disabilities having conversations about algebra. Göransson et al., (2016) observed and documented students with ID building conceptual understanding. In the study, students discussed how a balance beam served as a model for the concept of equations. Similarly, Rodriguez (2016a) observed individuals creating symbols language to represent concepts (e.g. variables were represented with "_").

How much or how well students with ID can learn algebra remains a focus of the literature which was also the primary focus in a series of studies conducted by Monari Martinez and colleagues. In all their studies, students with ID participated and completed a high school level High-school level Algebra course (see Monari Martinez & Benedetti, 2013; Monari Martinez & Neodo, 2020; Monari Martinez & Pellegrini, 2010). In one study, 15 participants demonstrated improvements working with fractions, solving equations, and word problems (Monari Martinez & Pelligrini, 2010). Qualitative work samples from the participants were published separately in Monari Martinez and Benedetti (2013). The work samples showed a variety of algebraic problems solved including equations involving the compound interest formula ($A = P\ (1 + r/n)^{nt}$) which required the participants to use logarithms to solve for variables.

Monari Martinez and Neodo (2020) extended the skills taught to include manipulation of linear equations. In their study, six students with ID could learn to manipulate variables for linear to create linear equations on a Cartesian Plane. Although comprehensive with their demonstration of skills development, the studies did not show students preforming the inverse skill of taking information from the Cartesian (e.g., a line) and creating an equation.

Creating Slope-Intercept Equations

One skill found throughout the K-12 algebra curriculum involves converting graphical information into a formula, and as a skill, it is introduced when teaching linear functions (e.g., $y = mx + b$) from graphs of lines or other functions (Kaput, 2008; NGACBP & CCSSO, 2010). The concept resurfaces throughout the general education mathematics and science curriculum because the skill has utilitarian applications for all individuals even for individuals with ID (Kaput, 2008; Kaufman et al., 2017; Monari Martinez & Benedetti, 2011; Yoon et al., 2001). Parts of the concept are introduced as early as second grade, before learning about fractions, where students are asked to plot, graph, and interpret data. In grade six, students are introduced to the direct variations, linear equations where the y-intercept is 0 (e.g. $d = rt$). Grade six science also begins to overlap with mathematics where science activities can include displays of data on Cartesian Planes or the use of linear formulas (see Virginia Department of Education, 2018).

To solve the problems, individuals must read critical information from a graph (b and m) to fill in parts of an equation (e.g., $y = mx + b$). At present, few examples show a method for instructing individuals with ID creating equations from graphs (Hord & Bouck, 2012; Hudson et al., 2018). Without explicit examples in the literature, individuals with ID are more likely to be excluded from high school academic activities (Agran et al., 2020; Creech-Galloway et al., 2013; Jimenez et al., 2008; Johnson et al., 2013, Kleinert, et al., 2015; Kleinert, 2020).

When learning to create formulas, students are introduced to the concept of slope, and slopes are needed to interpret data from line-graphs. Students may use the skill in educational settings where individuals set goals or self-monitor growth where student data is displayed on a line graph (see Figarola et al., 2008). As a concept, a similar skill is required to interpret data presented in newspapers (e.g., COVID-19 Graphs). More directly, slope intercept equations are needed in recreational activities involving computer games, computer coding, or robotics. During these activities students may be asked to direct a robot to move diagonally through space (on an imaginary coordinate plane) (Taylor, 2018). Similarly, when learning computer languages like BASIC, LOGO, and Scratch, individuals command graphical elements to move across a screen by substituting values into the $y=mx+b$ formula (see Matthes & Drakopoulos, 2019; Taylor, 2018).

For older students, teaching students to create formulas (functions) from graphical data could translate to employment. Manipulating functions is an essential part of using Microsoft Excel, and employers are willing to employee individuals with ID in data entry positions (Ameri, 2017; Wehman et al. 2020). As noted by Monari Martinez and Benedetti (2010), learning algebra skills makes it easier for individuals with ID to gain employment in the banking industry.

Teaching Techniques

Pedagogically, researchers have explored instructional options to teach algebra to students with ID (Bowman et al., 2019; Hudson et al., 2018). Monari Martinez and Neodo (2020) described participants solving problems in tutoring sessions delivered by a general educator in consultation with a special educator. Göransson et al. (2016) documented the use of inquiry-based questioning as a strategy (e.g., what will happen when we add or take away numbers from this side or that?), and Rodriguez (2016a, 2016b) embedded math instruction within naturalistic project-based learning. In one example, students mapped space in a greenhouse by using formulas to calculate the space needed for each variety of plant. Pedagogically, most studies demonstrate ways to support students using computer-aided instruction, concrete representations, video modeling, or graphing calculators (e.g., Creech-Galloway et al., 2013; Hammond et al., 2012; Hord et al., 2019; Hord & Xin, 2015; Yakubova & Bouck, 2014). Finally, scholars have demonstrated a version of behavior approaches, sometimes described as structured teaching, systematic direct instruction, or schema-based instruction (Browder et al., 2012; Creech-Galloway et al., 2013; Jimenez et al., 2008; Root & Browder, 2019; Root et al., 2017; Root & Browder, 2019; Spooner et al., 2017).

Time Delay

As part of the behavioral interventions, a systematic prompting strategy was often employed. Specifically, a version of a time delay (TD) strategy was employed in multiple studies (Bowman et al., 2019). For instance, Jimenz and colleagues (2008) described a constant time delay strategy as a strategy for teaching one-step equations, and Creech-Galloway and friends (2013) used a simultaneous prompting strategy. The TD strategies have a storied history in special education.

Learning occurs when the individual consistently decides the response needed for a given set of stimuli (S^D) in the environment (Touchette, 1971). In general, an individual with ID is presented with a stimulus (S), and the individual is prompted to complete the task after a delay and provided with reinforcement for correct responses (Neitzel & Wolery, 2009; Saunders et al., 2013). A TD procedure provides teachers with a method to ensure the individual with ID will receive positive reinforcement for a correct response reducing the errors found in natural trial and error learning (Touchette & Howard, 1984). Teachers can implement TD as part of an overall systematic instructional system to teach various functional and academic skills (Collins, 2012; Halle et al., 1979; Neitzel & Wolery, 2009; Saunders et al., 2013). Variations or extensions of TD include simultaneous prompting (prompting after zero-seconds for all trials), progressive time delay (beginning with zero-second TD incrementally increases over time), and constant time delay (introduces a skill with a zero-second time delay and then supplies a predetermined amount of time) (Collins, 2012; Snell & Brown, 2006; Saunders et al., 2013). There are variations of the TD that do not include a zero-second delay during intervention (e.g., Halle et al., 1979) and the original application of TD used a variable delay that would increase and decrease the delay to participant's correct or incorrect responses (e.g., Touchette, 1971).

TD can support individuals with ID as they learn to complete algebra related skills. For example, Jimenez et al. (2008) documented techniques to teach high school individuals with ID to solve one-step equations. Baker et al. (2015) replicated the study and three of their participants showed improvement over baseline with the intervention. Creech-Galloway et al. (2013) used a simultaneous TD procedure to teach individuals to solve the Pythagorean Theorem. Other studies have included individuals finding points on the Cartesian plane (e.g., Browder et al., 2010; Browder et al., 2012). However, current research does not show individuals with ID using TD to create equations when given graphs. Creating equations from graphical representations is a key element to the encoding and decoding of functions in mathematics (Kilpatrick et al., 2001).

Purpose of the Study

The purpose of the study was to show a method for teaching high school-aged individuals with ID the algebra skill of creating an equation from a line using a time-delay strategy and equation template.

Method

Research Design

We employed a non-concurrent multiple probe across participants design to evaluate the effectiveness of a combination of TD and equation template when teaching. This design effectively evaluates an intervention using a population with specific characteristics in real-world environments without exposing participants to excessive baseline trials (Gast et al., 2014; Horner et al., 2005), and the non-concurrent designed allowed for flexibility with the student's schedules. Before beginning the study, the University Institutional Review Board and the school district reviewed and approved the study. Additionally, participants' parents supplied permission, and individuals assented to take part in the study.

Setting

This study took place at a high school with 1,900 students in a southern U.S. state. The school served as a regional center to provide community-based instruction to participants with ID. Participants engaged in academic instruction within a general education, computer literacy class taught by a dual-certified special education and general education teacher. The ten-person class met every other school day for 90 minutes in the late morning before lunch. The classroom had a workstation devoted to prerequisite mathematics-related instruction (e.g., creating formulas). The class included individual desks for lectures and a small table for station/lab work. The table was large enough for two individual workstations and one paraprofessional member. All individuals rotated to the station once for 10-minute practice sessions during the 90-minute class. When not engaged in the rotation, participants engaged in computer literacy activities with the larger class group. The station included a wheelchair accessible table, necessary supplies, outlets for laptop computers, and communication tools (e.g., whiteboards, calculators, three-dimensional shapes, manipulatives, graph paper, and pencils). Two participants rotated to a paraprofessional-supervised station devoted to the mathematics activities, and at the station, individuals worked on other individualized mathematics assignments.

Although a teacher could instruct individuals at the workstation, **a** paraprofessional (assistant teacher) delivered the mathematics interventions related to the study. The paraprofessional was 54 years old and had 18 years of experience collaborating with individuals with ID. She had less than two years of college and she took part in regular professional development in the areas of (a) positive behavioral supports, (b) prompting strategies, (c) data collection, and (d) systematic instruction.

Prior to participating in the study, the paraprofessional engaged in training which included five, 30-minute training sessions delivered by a general education math teacher and a behavioral specialist. Content instruction delivered by the math teacher included a direct demonstration with the task analysis for creating equations from graphs, as well as alternate procedures for creating the equation (e.g., using two points). The paraprofessional was able to solve a random selection of the problems with 100% accuracy, in which the number of correct steps divided by the total number of steps is multiplied by 100. In a separate training session, a behavior specialist reviewed prompting strategies and procedures. During role playing activities she demonstrated the ability to set up the activity, deliver the intervention, and record the data with 100% accuracy. Finally, the classroom teacher and the paraprofessional practiced recording data on the task analysis until the interobserver agreement reached a minimum of 90% agreement by using the point-by-point agreement ratio (agreements/[agreements + disagreements] x 100).

Participants

The participants in this study were (1) enrolled in high school, (2) eligible for participation in the statewide alternative assessment (see Every Student Succeeds Act of 2015), (3) under the age of 18, and (4) had not completed the state high school mathematics alternative assessment. The school distributed a letter of interest to the ten parents of qualifying individuals. Four of the ten parents supplied consent for participation.

Gagarin

Gagarin (pseudonym) immigrated to the United States at the age of seven. School records showed that he received special education services under the ID label. For state testing, the school classified him as white. Records reported a full-scale intellectual quotient (IQ) of 40 on the Universal Nonverbal Intelligence Test-Second Edition (Bracken & McCallum, 2016) and a score between 17 and 40 on the Scale of Independent Behavior-Revised Adaptive Behavior subtest (Bruininks et al., 1996). At the time of the study, he was a 17-year-old male enrolled in his third year of high school. He communicated with verbal communications, gestures, and Picture Exchange Communication Symbols®. This was supplemented with a dynamic display voice output communication aid. Gagarin took part in general education classes, including piano, physical education, computer literacy, and art. His individual education program (IEP) mentioned a single mathematics goal designed to promote number identification implemented during cooking activities.

Shepard

At the time of the study, Shepard (pseudonym) was a 16-year-old high school female who received services under the ID disability category. She was classified as white on standardized tests. School records selectively presented cognitive scores from the Wechsler-Intelligence Scale for Children Fourth Edition (WISC-IV; Wechsler, 2003) with Working Memory Index and Processing Speed Index, showing a standard score of 65. School records also showed adaptive scores of 41-47 on the Scales of Independent Behavior-Revised (SIB-R: AB). Shepard attended general education classes devoted to health, chorus, computer literacy, and culinary arts, with less than half of her time devoted to community-based activities. During verbal communication exchanges, the paraprofessional asked clarifying questions to support Shepard with expressive communication. Her IEP goal said she would apply mathematical skills to practical situations, and the IEP noted she had a low tolerance for academic activities. Her math activities included running a cash register, buying items in restaurants or stores, and counting inventory items. Outside of the computer literacy class and this study, Shepard did not engage in mathematics related activities.

Grissom

Grissom (pseudonym) was a 17-year-old male attending his second year of high school. On state tests, the school reported his race as “other”. The IEP described multiple health issues with ID as his primary disability. School records highlighted scores from the Woodcock-Johnson Tests of Cognitive Abilities-Third Edition (Woodcock et al., 2001) listing a Brief Intelligence Ability score of 40 and a Verbal Comprehension Index of 61. The school also reported a standard score of 73 on the Vineland Adaptive Behavioral Scales-Second Edition (Sparrow & Cicchetti, 2005). Grissom took part in elective general education classes, including chorus, physical education, drama, and a computer literacy class. A paraprofessional supported his receptive communication with written directions. Grissom took part in regular mathematics activities, including measuring solids and liquids in a kitchen, changing to the nearest quarter, counting inventory, and running a register. His IEP said that Grissom would learn to solve one-step equations.

Titov

Titov (pseudonym) was a 15-year-old female participant attending her first year in high school. On state tests, the school classified Titov as "White" under the race category. School records confirmed individual education eligibility under the category of ID with a full-scale intelligence score of 69 (WISC-IV) and adaptive scores of 37-58 (SIB-R: AB). The teachers reported that Titov did not need communication support. She took part in general education for art, computer literacy, and physical education. Her IEP mathematics goal called for an increase in computational and functional mathematics skills but did not supply math skills examples. Her teacher reported that Titov participated in mathematics activities, including running a cash register, counting money, making change, taking inventory, and buying items by rounding up to the nearest dollar.

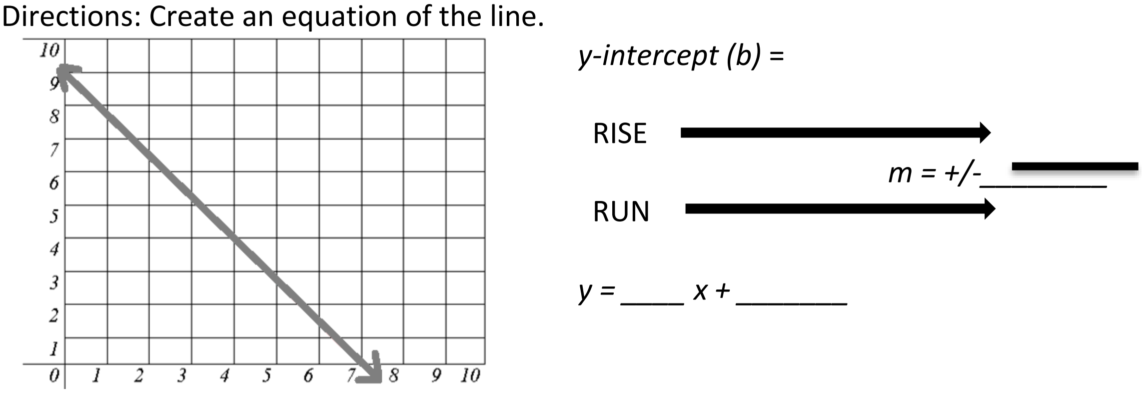
Materials

The paraprofessional accessed the materials needed to check, record data, and supply the intervention. Items included answer keys and a computer-generated equation of a line to match the following parameters: a line in the first quadrant with whole number x-intercepts and y-intercepts ranging between one and ten. The paraprofessional presented the formula in the slope-intercept form (*y = mx + b*), a laminated communication board with numbers 1 to 10 (for Gagarin), pencils, paper, a four-function calculator, and a graphic having the formula template and a graph of a line (Figure 1).

Figure 1.

Sample Problem with Template

Directions: Create an equation of the line.



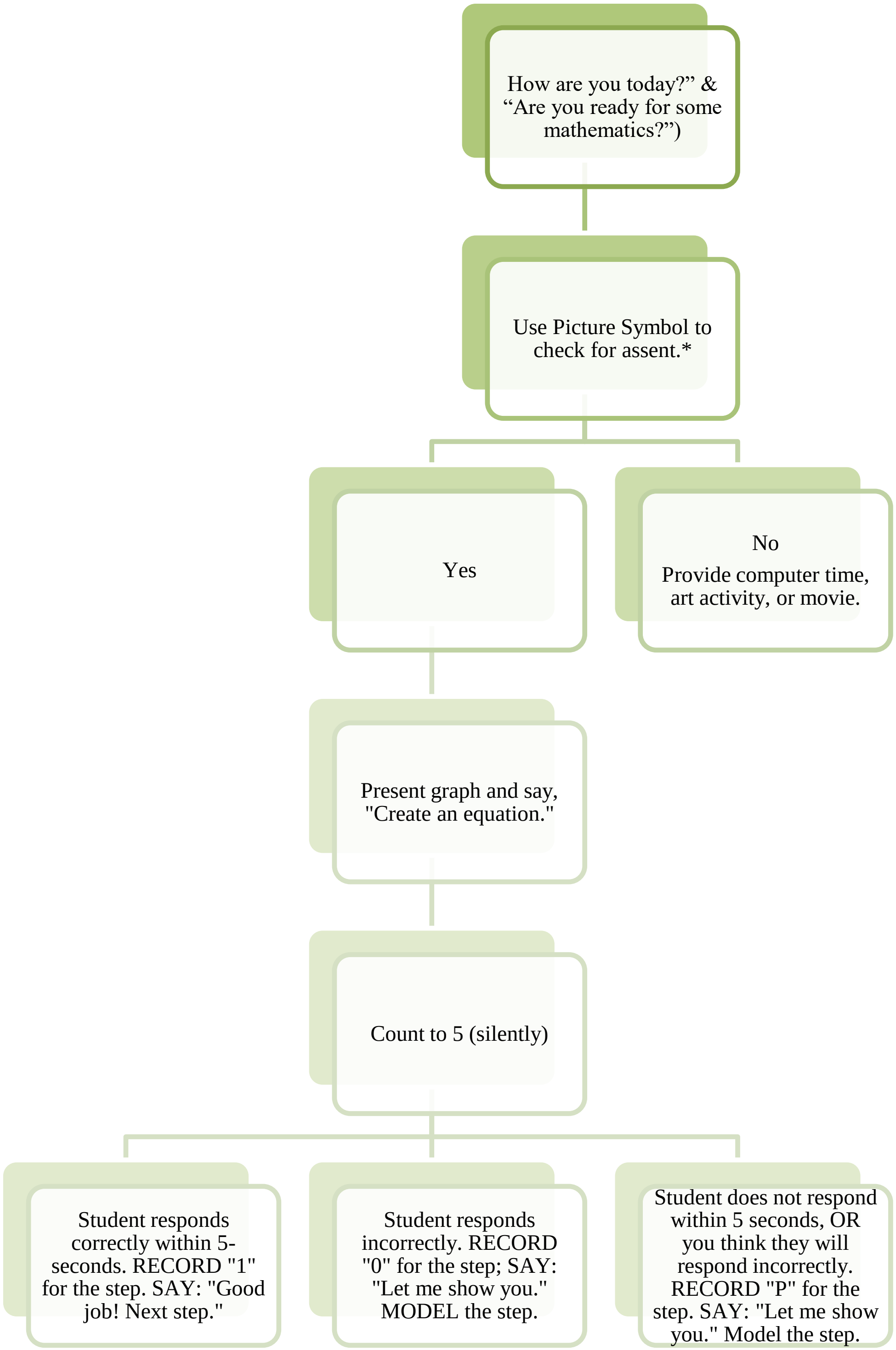
Note. For each trial, participants received a computer-generated line with whole number intercepts between 1 and 10. The arrows have been added for clarity.

Procedures

Pairs of participants rotated to the in-class stations devoted to mathematics activities. The school grouped participants into pairs for the study based on activity schedule alignment which was loosely based on student interest and ability levels. A pair worked at the same workstation (with a divider between them) during the study. Gagarin and Titov made up the first pair and Grissom and Shepard formed the second pair. Although it should be noted that Titov was often unavailable because she was selling coffee as part of a class fundraising activity. One participant engaged in unrelated mathematics independent practice work (e.g., using a calculator, counting money, ranking values, or finding shapes); the independent practice used a structured teaching method based on the Treatment and Education of Autistic and related Communications Handicapped Children (TEACCH) system (See Collins, 2012; Virues-Ortega et al., 2013). Then, the paraprofessional began the intervention with the second student before rotating to the first student. Initial baseline probes occurred on different days due to the availability of the participants. Borders surrounded the students to prevent direct observation of the intervention asked the participant if they wanted to take part in an algebra activity. Consistent with the IRB protocol, participants assented with a verbal acknowledgment or nod. If the participant did not assent, the staff was prepared to offer an alternate activity (art, watching a movie, or a computer game). Procedurally, the paraprofessional followed a semi-structured script. The script included the following an introduction, an assent to take part check, the algebra activity with a time delay procedure (See figure 2). To keep track of the five-seconds, the paraprofessional silently counted and tapped a finger on the table for each second.

Figure 2.

Semi-Structured Script Used by the Paraprofessional



Measurement

The researchers measured the dependent variable by calculating the independently completed steps for each trial recorded by a paraprofessional using the 11-step task analysis (Table 1). The paraprofessional recorded participant performance during baseline and intervention phases using codes described in the procedures. It should be noted that the measurement described in the script differed slightly for each phase of the study. When gathering baseline, the paraprofessional did not model the steps; she recorded "1" for correct responses, and "0" for incorrect responses. She would remove the work from the student complete the step out of the field of view from the student, and then present the task again saying, "next step." The generalization phase occurred as part of the participants alternate assessment testing, and once the individual failed to answer a step within five seconds or after answering any step incorrectly, the trial was stopped, and all remaining steps were recorded with a "0."

Table 1.

Task Analysis for Creating an Equation from a Graph

Step in the Task	Description of the behavior
1. Identify the *y-axis*	Participant touches or points to the y-axis
2. Identify the *y-intercept*	Participant touches the point where the line passes through the y-axis.
3. Place the *y-intercept* in the formula.	Participant writes number into the equation of a line *y = mx +* ***b***.
4. Trace the triangle	Participant touches the y-intercept traces across the line to the x-intercept & from the x-intercept to the origin
5. Count rise	Participant counts from the origin to the y-intercept.
6. Put rise into the formula	Participant writes number into the slope formula *(m = +/-* ***rise****/run)*
7. Negative or positive slope?	Participant selects a negative or positive sign in the slope formula *(m =* ***+/-*** *rise/run)*
8. Place sign into the formula.	Participant writes sign into the equation of a line. *y=* ***+/-*** *mx + b*
9. Count run.	Participant counts from origin to the *x-intercept.*
10. Place run into the formula	Participant writes run into the slope formula. *m=+/- rise/* ***run***
11. Place slope into the line formula.	Participant writes slope into equation of a line *Y= +/-* ***m****x + b*

Note. Gagarin placed communication cards into the formula instead of "writing"

Of the 88 individual trials, the researchers observed and coded 48% of the trials for fidelity and accuracy with the measurement. The 43 observations included: (a) 14 scheduled trials, (b) all 20 state testing trials, and (c) 9 unscheduled observations of convenience.

Fidelity

A fidelity checklist was used to measure fidelity. The checklist verified the materials used, the counting of 5 seconds (by tapping on the table), delivery of the prompt, and accuracy of data recording. The researcher who used the checklist during observations of the intervention and coded a session as not meeting the fidelity criteria if any item was not checked on the trial checklist. Of the 21 observed intervention and baseline trials, in 2 trials the paraprofessional recorded an incorrect response with a "P" instead of a "0." Although important, the error would not change the graphed results because "P" did not count as an independently completed step. More concerning, during the generalization phase, the paraprofessional was observed delivering an inadvertent prompt on 3 out of 20 of the trials. The protocol for the state testing required the trial cease when a prompt was delivered, so the estimates of generalization for three trials might appear lower than what the student could have achieved without the error.

Baseline

The paraprofessional asked which participant wanted to start the activities. The paraprofessional provided one participant with an alternate math task unrelated to the study (e.g., using a calculator, counting money, ranking values, or finding shapes) at one workstation. Then, the paraprofessional provided the other participant adjacent workstation with the study-related materials, including a graph of the line and a verbal instruction, "Create the equation." Participants were provided with five minutes to complete all the steps in the task analysis. The paraprofessional recorded a "0" for incorrect steps and a "1" for an independent step. A participant needed to complete a minimum of five baseline trials across a minimum of five days. The paraprofessional then provided the participant with alternate math work and repeated the process with the second participant.

Intervention

Working with one participant at a time, the paraprofessional supplied the materials, the computer-generated math problem, and an instruction “Create the equation.” For each step of the task, the paraprofessional would say, “What is the first (or next) step?” The paraprofessional would silently and discretely tap on the table five times at one-second intervals. If the participant completed the task independently within the five-second delay, the paraprofessional would record a “1” and they would supply verbal feedback (e.g., good job, nice work, yes, that is correct). If the participant tried the problem but completed the step incorrectly, the paraprofessional recorded a “0.” The paraprofessional would also say, “Let me help you out.” The paraprofessional would supply verbal feedback (e.g., the y-intercept is this line). More commonly, the paraprofessional would say, “Let me show you,” before modeling the step. Similarly, if the participant did not engage in the step, the paraprofessional would record a “P” and model the step after saying, “Let me help.” If the prompts did not elicit a correct response, the paraprofessional would complete the step and state, “What is next?”

Analysis

To prepare the data for visual analysis, the team reviewed recommended literature for conducting a visual analysis (see Gast et al., 2014; Horner et al., 2005; Kubina et al, 2017; Kubina et al, 2021). First, researchers entered the raw data from the task analysis into an Excel spreadsheet for each day of the trial. On six occasions, the intervention took place in the morning and the afternoon (school schedule) and the separate trials were coded as afternoon trials by adding 0.5 to the calendar day. The software summed the steps with “1” entered (independently completed step) and ignored the “0” and “P” in the sums. Then the researchers displayed graphically with the total number of steps completed on the ***y**-axis* and the calendar day on the ***x**-axis.* displaying the number of steps completed independently by each participant across A-baseline, B- intervention, and C-generalization conditions.

During visual analysis the researchers examined performance trends before and after condition lines as well as changes the graphs were used to conduct a visual analysis with particular attention paid to the level of achievement before and after each condition line, overall trends, variability (see Horner et al., 2005). Particular attention was paid to the change in participant performance occurring before and after the condition lines (Gast et al., 2014; Horner et al., 2005).

Interobserver Agreement

For the same observed trials both the paraprofessional and the researcher coded data on the task analysis form. The percentage of agreement between observers was calculated using the formula described by Chaturvedi & Shweta (2015) where Percent Agreement = 100 x number of concurrent agreements/ total number of concurrent observations.

Results

The skill of creating an equation required participants to convert an equation in standard form into a graph of the equation using an 11-step process for creating a graph from an equation. Figure 3 presents a line graph of the participant performance.

All four participants showed zero steps completed during the baseline phase, and all four participants showed an increase in performance after the intervention began. Overall positive trends were noted for all participants during the intervention phase with the effects noticed immediately for Gagarin, after one trial for Shepard and Titov, and after two trials for Grissom. Variability was high for Shepard and Grissom with decreases in performance occurring after intervention interruptions related to breaks in the intervention (school breaks or weekends). The levels of achievement depended on the students. Three participants (Shepard, Grissom, & Titov) completed at least one trial with 100% of the steps completed, but Gagarin's performance only increased to 45%. His intervention ended early related to family initiated, planned absences. Shepard and Grissom showed variability during the intervention, with scores ranging between zero and ten steps completed.

During the generalization phase of the study, participants took the state assessment, and the same task analysis was used to measure performance; however, if staff inadvertently administered a prompt, the trial stopped, and the remaining steps were coded as a "0." All participants exhibited a decrease in performance during the generalization phase, although all generalization performances were higher than baseline. Variability also increased during the generalization phase with Gagarin completing; Shepard 37 % to 81%, Grissom 45% to 82%, and Titov 5% to 66% of steps.

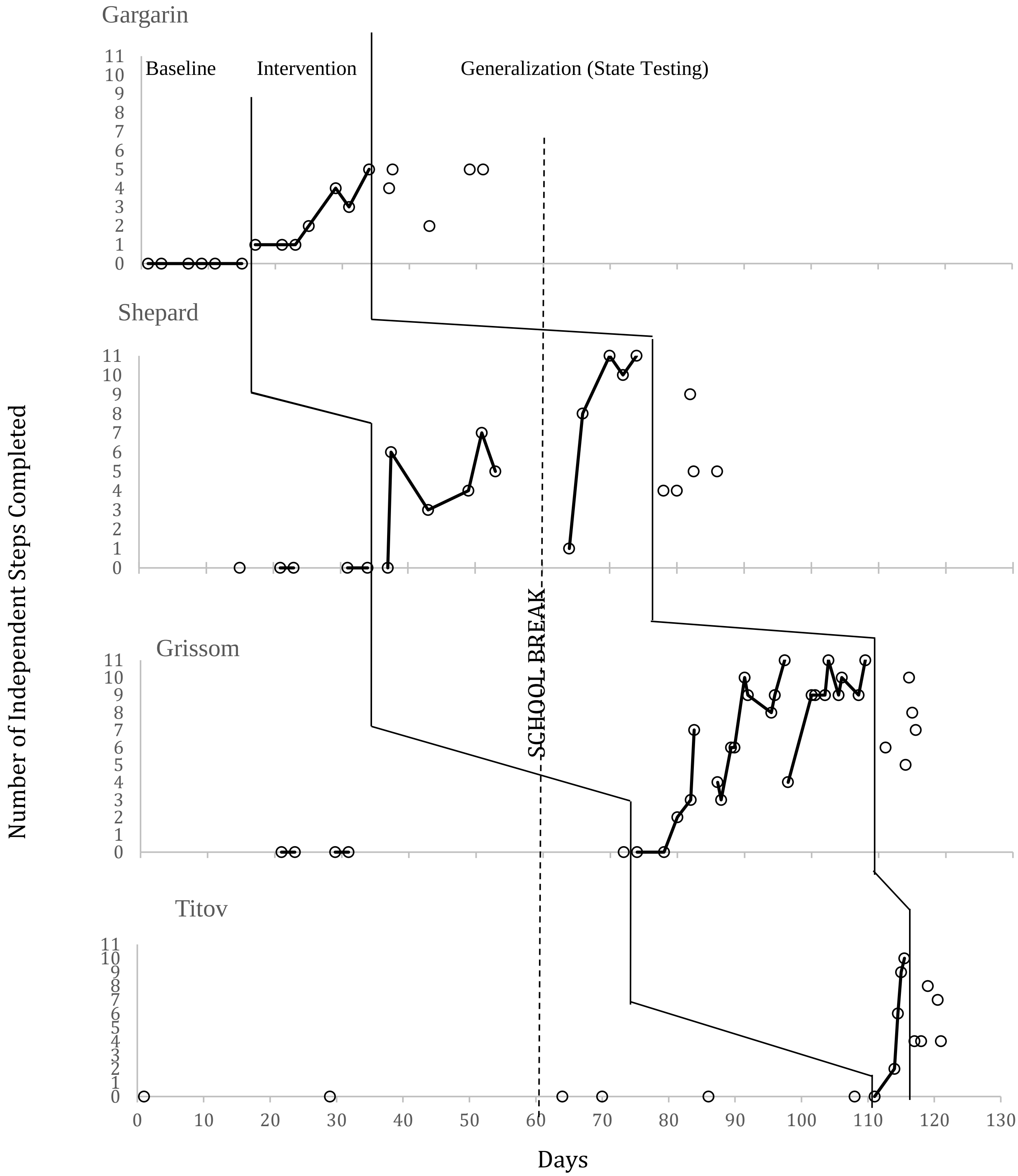
All participants showed a decrease in performance during the generalization phase, although all generalization performances were higher than baseline. Variability also increased during the generalization phase with Gagarin's scores ranging between 18% and 45%; Shepard's scores fell and rebounded from 37% to 82%. Grissom's scores also fell and rebounded from 45% to 89%, and Titov's scores ranged between 36% and 45% to 55% of steps. between 18% and 73%.

Effect-Sizes

Effect-sizes can be used to estimate the effect of interventions in single case study designs, and the researchers used Tarlow and Penland's (2016a) Nonoverlapping Data (PND) calculator (online) to estimate the PND effect-size. The researchers choose this method because the data was non-parametric, and the Percentage of Nonoverlapping Data (PND) is the relatively easy to interpret (Tarlow & Penland, 2016b). The change in performance between baseline and intervention resulted in a percentage of nonoverlapping data (PND) calculator to estimate the PND effect-size of 86.84% ($p<0.001$). Rakap (2015) noted that this would show an effective intervention. Similarly, the PND between the baseline and generalization phases was 100% (effective), with the PND between the intervention and generalization stage 34%.

Figure 3.

Independent Steps Completed to Make and Equation from a Graph



Social Validity

At the end of the study, researchers interviewed participants and asked the individuals about math activity. All four participants expressed interest in continuing algebra activities, and all four of the participants agreed that the training helped them learn math. Shepard commented that the “sheet” (template) made the work easier, and two participants, Grissom and Titov, stressed that algebra was “fun.”

Discussion

The purpose of the study was to evaluate the effectiveness of a TD method for including high school-aged individuals with ID within the abstract grade-level academic mathematics standards. The four participants successfully converted a picture of a line into the slope-intercept form of an equation and increased performance with the skill. Given the results and the fact that only the use of TD changed between baseline and intervention phases, it appears that TD can improve performance for individuals with ID when they learn abstract algebra skills. However, our conclusion rests on the assumption that the flexible script with the modeling prompts did not impact participant performance. Flexible and adaptive instruction tailored to the individual’s responses constitutes a form of individualized feedback. It is possible that the variations, or the flexibility in the modeling prompting, contributed to participant improvements. The prompting methods used in the study were not a factor in the student’s lower scores. We hypothesize that the generalization phase might require a longer period for the intervention. However, the study’s procedures account for the lower generalization scores. During the generalization phase of the study, participants took the state assessment, and the same task analysis was used to measure performance; however, if staff inadvertently administered a prompt, the trial stopped, and the remaining steps were coded as a “0.” Because the trials were prematurely stopped, the participant would not have had the opportunity to demonstrate mastery of subsequent steps in the task analysis.

The non-concurrent design was selected to maximize the school’s ability to adjust participant schedules, and the school did take advantage of the flexibility. For instance, Titov was rarely assigned to work with her partner and was often assigned to sell coffee outside of the classroom. Gagarin’s participation was scheduled to complete the project first, because his family planned a long vacation, and his transition to the state-testing phase occurred prematurely. The school's desire to use the training to prepare students for the state assessment also influenced their decision to keep Grissom in the intervention for a longer period, and the school's decision to end participation after five trials (related to the state testing).

Behaviorists will notice another limitation. The study used an unorthodox version of the TD procedure. Genuinely, the researchers erred when developing the intervention. We had intended to use the constant time delay method, but our intervention package did not include trials with zero-second introduction trials associated with the procedure. We kept fidelity to the intervention and the TD procedure described in the intervention protocol, but the definition of TD differed from the constant time delay intervention as defined by Collins (2012) or employed by Jimenez et al. (2008). Sometimes research mistakes can help researchers to develop new questions. After the mistake was found, the researchers reviewed the historical literature and found historical inconsistencies with the TD and constant time delay procedure. Wolery et al. (1992) said as much when they noted the number of zero-second delays during intervention trials used and reported ranged widely with researchers at the time describing the use of a zero-second delay but not documenting the trial in the results.

Our error raises some questions about the overall TD procedure. (1) Where did the practice of including a zero-second time delay during a constant time delay intervention come from? The historical record shows the TD practice sometimes included a zero-second delay to introduce procedures (See Snell & Gast, 1981; Touchette, 1971), but not always. Halle et al. (1979) describes a constant 15s intervention without mention of a zero-second time delay. (2) Does it matter if we use a zero-second TD when initially introducing a skill? Probably not, Worley (1992) suggested the zero-second delay may be redundant. If participants wait zero or five seconds and the initial intervention trials would reflect 0% of the steps completed. Graphically, the data would appear to show a delay in the effects after the intervention phase began. Halle and colleagues' (1979) study was the only study that did not explicitly describe a zero-second time delay, and the pattern of our results are similar.

On the other hand, one of our participants, Gagarin, did show an increase in performance immediately after baseline. His score increased from 0 to 9% which would account for 1-step. This may have been luck. He may have inferred a step after seeing a preceding step modeled, or an unknown variable may account for the improvement. For example, the semi-structured script may have contributed to the participant's performance variability.

Although the paraprofessional modeled each step, she sometimes provided a verbal explanation tailored to each participant, the step of the task, and if necessary, the error. As we did not record the variations in the script, we were unable to analyze the data to see if it might have influenced student performance. Looking back at the existing literature, none of the existing structured intervention studies involving TD procedures described the use of scripts (see Browder et al., 2010; Creech-Galloway et al., 2013; Jimenez et al., 2008; Root & Browder, 2019; Root et al., 2017). It could be that the structure allows educators to provide feedback in a predictable but adaptable format. If so, interactive feedback appears to be a common element across most of the studies involving students with ID and algebra (e.g., Göransson et al., 2013; Monari Martinez & Neodo, 2020; Rodriguez, 2016a/b).

Finally, we do recognize the current study only presents a small sample of the type of algebra that general education students learn. The current study may lack credibility among constructivist educators who stress the importance of building conceptual understanding (e.g., Greenstein & Baglieri, 2018; Göransson, et al., 2016), or among practitioners who desire clear pragmatic applications as a prerequisite to instruction (see Greenstein & Baglieri, 2018). Theoretically, the conceptual understanding is intertwined with procedural fluency (Kilpatrick et al., 2001), and although outside of the scope of the current study, modifications may help to prove the development of mathematical communication skills while learning a procedural skill. In our study participants were exposed to new vocabulary like slope, *x*-intercept, *y*-intercept, origin, rise, run, positive, or negative, and the use of symbols (e.g., *m, b*).

Conclusion

Despite the limitations, the study effectively shows that students *can* learn *some* parts of the grade-level High-school level Algebra course curriculum using a structured teaching pedagogy to improve procedural fluency. Previously, scholars guessed that exclusion in academics occurs because teachers lack research-based methods for including students in a class (Agran et al., 2020; Creech-Galloway et al., 2013; Jimenez et al., 2008; Johnson et al., 2013). Hopkins and Dymond, (2020) showed that teacher perceptions related to a student's perceived abilities can influence the prioritization of transitional activities. A similar phenomenon may be occurring in algebra. The findings from the present add to a growing number of studies showing individuals with ID can learn abstract mathematical procedures (e.g., Browder et al., 2010; Browder et al., 2012, Creech-Galloway et al., 2013: Jimenez et al., 2008; Monari Martinez & Neodo, 2020; Monari Martinez & Pellegrini, 2010; Rodriguez et al., 2016a). Are practicing special educators aware of the research showing individuals with ID learning skills like algebra? Will our study help to convince special educators that students with ID can benefit from algebra? In both cases, the authors would hope the answer is yes, but we suspect the answer is no. We suspect, special educators, or other team members may believe the skill is too abstract to be practical or meaningful (see Agran et al., 2020; Greenstein & Baglieri, 2018; Kleinert et al., 2015).

We acknowledge that the definition of educational benefit for students with ID is evolving (see Yell & Bateman, 2020), and when reasonably calculating ambitious academic goals, IEP teams might consider TD procedures to support students in algebra. At a minimum this study does show students with ID can access the procedural elements of the general education, algebra curriculum. We assert that teaching algebra, even learning an isolated skill like converting a graph into an equation format constitutes a *meaningful benefit* because algebra skill development increases employment, recreational, and educational opportunities (Kress, 2005; Matthes & Drakopoulos, 2019; Monari Martinez & Benedetti, 2010; Taylor, 2018).

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