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TEACHING AN ALGEBRAIC EQUATION TO HIGH SCHOOL STUDENTS WITH MODERATE TO SEVERE INTELLECTUAL DISABILITY

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TEACHING AN ALGEBRAIC EQUATION TO HIGH SCHOOL STUDENTS WITH MODERATE TO SEVERE INTELLECTUAL DISABILITY

THESIS

A thesis submitted in partial fulfillment of the
requirements for the degree of Master of Science in the
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By

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ABSTRACT OF THESIS

TEACHING AN ALGEBRAIC EQUATION TO HIGH SCHOOL STUDENTS WITH MODERATE TO SEVERE INTELLECTUAL DISABILITY

The purpose of this study was to examine the effectiveness of using the system of least prompts and concrete representations to teach students with moderate and severe disabilities (MSD) to solve simple linear equations. A multiple-probe (days) across participants, single case research design was used to evaluate the effectiveness of task analytic instruction along with concrete representation on teaching students with MSD to solve algebraic equations. The results showed the system of least prompts and concrete representations were effective in teaching students with MSD to solve simple linear equations.

KEYWORDS: Moderate and severe disabilities, system of least prompts, concrete representations, academics, algebra

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April 8, 2016

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Section 1: Introduction

Systematic instruction is an important and core characteristic of programming for students with moderate and severe disabilities (MSD). Three main systematic instructional strategies have been used to teach academic skills to students with MSD (Browder & Spooner, 2014; Browder & Spooner, 2011). These strategies include the system of least prompts (Ault & Griffen, 2013; Manley, Collins, Stenhoff, & Kleinert, 2008), time delay (Hughes & Fredrick, 2006; Riesen, McDonnell, Polychronis, & Jameson, 2007), and simultaneous prompting (Riesen et al.).

The system of least prompts is an instructional strategy that provides prompts for producing a desired behavior and then gradually fades the prompts until a student can perform the behaviors independently. The system of least prompts defines a prompt hierarchy and then delivers those prompts from the least to the most amount of assistance required to elicit the desired behavior until the student can perform the behavior independently. In a typical sequence, the teacher delivers a task direction and waits a specified amount of time (e.g., 3-5 s) for the student to respond independently. If the student does not respond or makes an error, the teacher delivers the first prompt in the hierarchy and waits the specified response interval for the student to respond. If the student makes an error or does not respond again, the teacher delivers the next prompt from the hierarchy giving the student more assistance. This sequence continues until the student responds correctly or the teacher delivers all of the prompts specified in the prompt hierarchy, ending with a controlling prompt. The teacher reinforces the student for correct responding and records the independent response or the prompt level that resulted in the correct response (Ault & Griffen, 2013; Collins, 2012; Westling & Fox, 2009; Wolery, Ault, & Doyle, 1992).

Several studies have examined the effects of using systematic instruction to teach functional and vocational skills such as opening a locker (Fetko, Schuster, Harley, & Collins, 1999), cooking (Graves, Collins, Schuster, & Kleinert, 2005; Mechling, Gast, & Fields, 2008), constructing shipping boxes (Maciag, Schuster, Collins, & Cooper, 2000), using a telephone (Manley et al., 2008), and shopping for groceries (Morse & Schuster, 2000) to students with MSD. The system of least prompts procedure has a strong research base and a history of success in teaching individuals with disabilities a variety of skills (e.g., Ault & Griffen, 20013; Doyle, Wolery, Ault, & Gast, 1988; Snell & Brown, 2011). Traditionally, the system of least prompts has been used to teach functional skills encompassing daily living tasks (Yakubova & Taber-Doughty, 2013), pretend play to preschoolers (Barton & Wolery, 2010), telephone skills to elementary students (Manley, Collins, Stenhoff, & Kleinert, 2008), iPod use to aid elementary students with transition between activities (Cihak, Fahrenkrog, Ayres, & Smith, 2010), and portable DVD player use to demonstrate cooking tasks (Mechling, Gast, & Fields, 2008) to students with MSD.

Recently, teachers have placed more importance on teaching grade appropriate academic skills to students with MSD including the next dollar strategy (Colyer & Collins, 1996), accessing grade-appropriate literature (Browder, Trela, & Jimenez, 2007), listening comprehension (Hudson & Browder, 2014), reading comprehension skills (Browder, Lee, & Mims, 2011), and inquiry-based science skills (Courtade, Browder, Spooner, & DiBiase, 2010). These findings suggest that use of the system of least prompts combined with task analysis is an effective strategy for teaching students with MSD a wide variety of skills.

Previous research suggests that students with MSD can learn to problem solve with highly structured, teacher-directed instruction (Butler, Miller, Lee, & Pierce, 2001). Although the system of least prompts and other systematic instructional strategies have been used to teach a variety of academic skills including mathematical skills, few studies have attempted to teach higher order problem solving skills like algebra to students with MSD (Browder, Spooner, Ahlgrim-Delzell, Harris & Wakeman, 2008). Rather, most of the mathematics skills included in individual education programs and in previous literature for persons with MSD are basic numeracy and computation skills like adding and subtracting. Mathematics instruction for students with MSD typically focuses on functional skills including money management, telling time, or basic number identification (Jimenez, Browder, & Courtade, 2008). Instruction of functional mathematics skills for students with MSD is well documented in the research (Jimenez et al., 2008; Browder & Grasso, 1999). However, few studies have examined whether students with MSD can acquire higher order problem solving skills of the type found in the general curriculum (Jimenez et al., 2008).

Much of the literature in the area of MSD focuses on either academic skills or functional skills, but few have studied the effects of embedding core content skills in the context of teaching functional tasks (Collins, Hager, & Galloway, 2011; Collins, Karl, Riggs, Galloway, & Hager 2010; Karl, Collins, Hager, & Ault, 2013). What few studies there are on this topic have found the practice of teaching academic skills combined with functional skills to be effective and beneficial for students. For example, Collins et al.

(2011) studied the effects of adding functional content during language arts, science, and math classes. Teachers used constant time delay to teach functional skills such as cooking, appropriate dressing, reading the news, and computing sales tax as well as core content skills of academic vocabulary, properties of elements in the periodic table, and mathematic computation. The study found that students could learn, maintain, and generalize both types of content presented within the same lesson.

A 2008 study by Jimenez, Browder, and Courtade used the system of least prompts in combination with a concrete representation to teach students with moderate developmental disabilities to solve simple linear algebraic equations. In this study, participants ranged in age from 15-17 years and communicated verbally. The participants could count and identify numbers one through nine, which were requirements for participating in the study. The students were taught to solve linear equations such as $3 + x = 5$ using a multi-component intervention that included (a) a concrete representation of solving a simple linear equation, (b) task analytic instruction on the steps to solve the equation, (c) multiple trials for learning, and (d) systematic prompting with fading to promote errorless learning. The process for solving this type of equation was task analyzed, and the system of least prompts was used to teach the participants the process. The concrete representations allowed students to work with materials in a hands-on manner in order to solve the given algebraic equations.

A multiple-probe across participants design was used to evaluate the effectiveness of the task-analytic instruction with the concrete representation on the acquisition of an algebra skill. Results of the study indicated the participants mastered the concrete representation of the equations they were asked to solve. All three participants also generalized the skill to the general education setting and were able to perform the skill with a peer.

The purpose of this study was to extend the research of the Jimenez et al. study to high school students with MSD. The main objective of the study was to determine whether the students could generalize the skill to functional tasks (Karl et al., 2013) of a future job. In addition, it examined the effectiveness of using a treatment package that included the use of a story to introduce each task, a graphic organizer featuring the linear equation, a number line, concrete representations of the equation, the system of least prompts, and task analysis to teach students with MSD to solve simple linear equations. More research is needed to determine if strategies such as concrete representations and systematic instruction could make it possible for students with MSD to learn mathematics skills that would enable them to fully access the general curriculum.

Section 2: Research Questions

The specific research questions that will be addressed in this study are:

1. Is there a functional relation between the use of a treatment package and a change in level and trend of correct independent completion of a task analysis for solving linear equations in high school students with MSD?
2. If the answer to Question 1 is affirmative, can students generalize these skills?

Section 3: Method

Participants

Students. Three students ranging from 14 to 15 years old were selected to participate in this study. All three students could communicate verbally using complete sentences and were classified as having a moderate or severe intellectual disability. The students were receiving instruction concurrently in mathematics skills including reading numbers; using money; figuring place value; solving algebraic equations; and adding, subtracting, and multiplying numbers.

One of the participants was a male named Dylan. He was 14 years 10 months old and was classified as having multiple disabilities of autism and epilepsy. Dylan spent most of his day (80%) in the resource classroom and received the related service of transportation. According to the *Wechsler Intelligence Scale for Children – Fourth Edition* (*WISC IV*; Wechsler, 2003) Dylan's IQ was 40. His adaptive behavior composite score on the *Vineland Adaptive Behavior Scales* was 58 (Sparrow, Balla, Cicchetti, & Doll, 20505). Dylan had goals on his IEP in the areas of reading (comprehension and fluency), mathematics (addition and subtraction), daily living skills, and social skills. His strengths included improved handwriting skills, persistence to task, social skills, number identification, counting, following directions, and sight word identification. Dylan's areas of weakness included written expression, reading comprehension, money skills, problem solving, and non-compliance to math activities.

The second participant was Isaac, a 15 year 9 month male, whose primary disability was intellectual disability. Isaac received instruction in the resource setting for reading, mathematics, language arts, and physical education. He received special education services in a general education collaboration setting for history and science. Isaac received the related service of transportation. According to the *WISC IV* (Wechsler, 2003) Isaac's IQ was 52. His adaptive behavior composite score on the *Vineland Adaptive Behavior Scales* was 55 (Sparrow et al., 2005). Isaac had goals on his IEP in the areas of reading (comprehension and fluency), mathematics (addition, subtraction, and fractions), and answering questions. His strengths included answering questions about visual stimuli, completing of hands-on tasks, using a calculator, using social skills, and having a good attitude and desire to succeed. Areas of weakness for Isaac included generalizing familiar tasks to new settings, following verbal and written directions, retaining new information learned, processing stimuli visually, and remaining focused in the presence of peers.

The third student participant, Gabe, was a 14 years 0 months of age male classified as having an intellectual disability. Gabe spent most of his day (80%) in the resource classroom and received the related services of speech therapy and transportation. According to the *Wechsler Intelligence Scale for Children – Fourth Edition* (WISC IV) Gabe's IQ was 44. His adaptive behavior composite score was 61 on the *Vineland Adaptive Behavior Scales* (Sparrow et al., 2005). Gabe had goals on his IEP in the areas of speech and language, reading, money skills, and mathematics (addition and subtraction). His strengths included sight word recognition, attending to stories read aloud to him, counting, telling time, and cursive handwriting. Areas of weakness for Gabe included reading fluency and comprehension, abstract mathematics concepts, written expression, and grammar.

Other participants. The investigator was a third year graduate student in the Teacher Leader Master's program with an emphasis in moderate and severe disabilities. She was a certified teacher in the area of MSD and had 3 years of experience in teaching students with MSD. She was completing this study as a part of her coursework, served as the primary investigator, and coordinated instruction for all baseline, intervention, maintenance, and generalization sessions. The participants' classroom teacher collected reliability data (inter-rater and procedural fidelity). She was a full-time resource teacher for students with MSD and had agreed to collect reliability data. The classroom teacher was a certified MSD teacher who also held a certification to teach middle grades English and Social Studies. She had 17 years of experience teaching students with MSD. She had previous experience in data collection and was trained in reliability data collection procedures for the purposes of this study.

Inclusion Criteria

To be included in this study, students had to be of high school age and have moderate and severe disabilities. The students had to demonstrate the ability to rote count to nine, identify numbers through nine in their printed numerical form, and demonstrate one-to-one correspondence. Additionally, students had to demonstrate an ability to listen, comprehend, and follow one-step verbal directions; follow gestural and physical prompts; imitate models given by teachers; write with a writing utensil; and write numbers 1-9 in numerical form.

To determine if students had the prerequisite skills to participate in this study, the investigator reviewed their goals in the area of mathematics on their IEP. If the students' IEPs contained mathematic goals in the areas of addition, subtraction, multiplication, division, and algebraic skills, they were coded as an eligible participant for the study. Following a review of the students' IEPs, the investigator observed the students during classroom activities to determine if they could demonstrate the prerequisite skills necessary to participate in the study. If students did not have the prerequisite skills necessary to participate, they were excluded from the study. Prior to baseline sessions, the students were screened to ensure they could not already perform the skills being taught in the study. If a student could solve a linear equation independently during screening sessions, they were excluded from participating in the study.

Precautions

There were no precautions for this study aside from those associated with normal classroom activities.

Setting and Arrangement

This study was conducted in a public high school in a rural setting in a resource room for students with MSD. The classroom included a restroom, one table with chairs, and six student desks. The dimensions of the room were 8.5 m by 7.6 m. Additionally, the classroom contained two desktop computers, a dry-erase board, a Smart Board, a projector, and a document camera. All sessions were conducted at a kidney-shaped table in a one-to-one format, with the students' backs to the rest of the class. The teacher and the student sat facing each other on opposite sides of the table. During all sessions, the other students in the classroom were working with the classroom teacher, a paraprofessional, or on their own on other mathematics skills. Generalization sessions were conducted at various locations in the school including the cafeteria, library, and front office. When performing the tasks in these settings, other individuals were present but were engaged in other tasks not related to the study.

Materials and Equipment

The materials included both teacher-made and commercially produced materials. Materials included a number strip, a graphic organizer (22 cm x 28 cm) printed with an algebraic equation without numbers (____ + x = _____), a green object to use as a place marker, a red object to use as a place marker, dry erase markers, materials to use for counting (bags of chips, plates, newspapers), and data collection sheets. The number strip included the numbers 1-9. It was laminated and contained Velcro so the students could remove the numbers from the strip. The graphic organizer containing the equation was laminated and featured Velcro so numbers could be affixed to the surface. An example of the graphic organizer and number line is shown in Figures 1 and 2 respectively.

Instructional Objective/ Dependent Variable

The dependent variable was the percentage of task-analyzed steps completed independently in solving linear equations. The specific instructional objective for this study was: Given a simple linear equation (e. g., 3 + x = 5) and concrete manipulatives, the student will solve for x while correctly and independently completing the steps of the task analysis with 100% accuracy across three consecutive sessions. The steps of the task analysis were: (1) student points to sum on equation (e.g., *How many spoons do you need?),* (2) moves red marker to sum on chart, (3) counts number of items in container and finds this known number on equation (e.g., *How many spoons do you already have?),* (4) moves the green marker to known number on chart, (5) counts to the sum with materials (e.g., *How many spoons will you need to get?),* (6) selects the number counted,

(7) puts in the correct number in for x, (8*)* places the correct number needed in container, and (9) solves for x (writes number).

$$\underline{\qquad\qquad\qquad} + x = \underline{\qquad\qquad\qquad}$$

Figure 1. This figure depicts the graphic organizer used to aid students in solving linear equations.

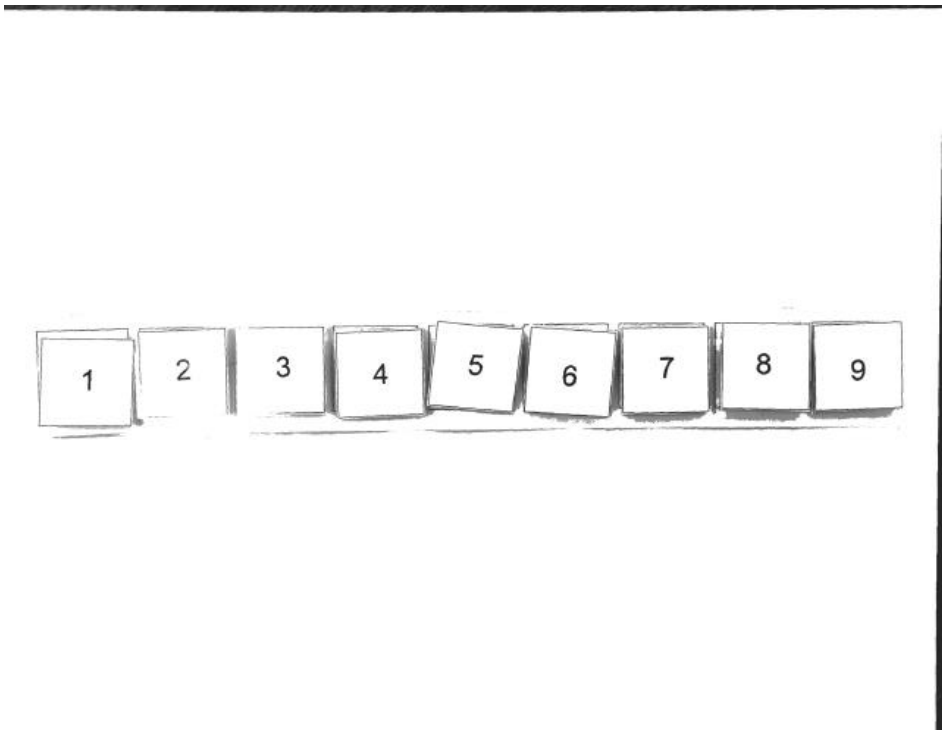

Figure 2. This figure shows the number line with Velcro removable numbers that students used to fill in numbers in the equation on the student graphic organizer.

Experimental Design

A multiple-probe (days) across participants single case research design was used to evaluate the effectiveness of a treatment package on teaching students with MSD to solve algebraic equations (Gast, Lloyd, & Ledford 2014). All students were first given a baseline probe. When the first participant received at least three baseline sessions and showed a stable baseline level and trend, the first student began receiving intervention. Probes were conducted periodically (every third session) for the other participants during the first student's intervention phase to ensure covariation had not taken place. When the first student performed 5/9 steps of the task analysis independently during intervention, the investigator began collecting consecutive baseline data for the second student. When the second student demonstrated a stable baseline trend, the second participant began intervention. Periodic probes were conducted to ensure covariation had not occurred for the third participant not yet receiving instruction. When the second student performed 5/9 steps of the task analysis independently, the investigator began conducting consecutive baseline data for the third student. The investigator collected baseline data for a minimum of two sessions or until the data displayed a stable trend. The third student then began the intervention phase. Using a multiple probe design prevented repeated exposure to skills the students had not yet been taught, thus minimizing testing effects.

Using a multiple probe design, experimental control is demonstrated when, upon introduction of the independent variable, there is a change in level and trend of correct independent responding and non-intervened tiers remaining at baseline levels. In the current study, experimental control was demonstrated when the students had an increase in independent completion of the task analysis for solving linear equations.

General Procedures

A treatment package was used as the independent variable and included (a) the use of a short story to introduce each task, (b) a graphic organizer featuring the linear equation to be solved, (c) a number line, (d) concrete representations of the numbers in the equation, (e) the system of least prompts, and (f) total task analytic sequence of instruction. The students learned to solve the algebraic equation using a graphic organizer with the equation, manipulatives to represent the numbers in the equation, markers to keep their place, and a number line to help them count out the solution to the equations (Jimenez, et al. 2008). During generalization pre-test and post-test probes, the problem was presented like a job task with various new manipulatives. The generalization pre-test was conducted first, followed by baseline sessions. Baseline sessions were conducted for all students. Once a stable baseline level had been achieved for the first student, the first student entered the intervention phase. Students not in intervention had intermittent probe sessions on a weekly basis and at least two probe sessions immediately before entering intervention. When the first student was able to perform five steps of the task analysis independently or improved their performance at least 50% over baseline levels, the second student entered the intervention phase. Following the second student demonstrating the ability to perform five steps of the task analysis independently, student three began intervention. These procedures continued until all students had received intervention. After each student reached criterion, the generalization post-test was administered. Following the generalization post-test, each student entered the maintenance phase.

Screening Procedures

Before conducting formal baseline sessions, the investigator conducted screening sessions to determine if the students could perform the task of solving a linear equation. The investigator began by providing a general attentional cue to focus the participant's attention. An example of an attentional cue was, "Get ready to work on math." The student then joined the investigator at the table for the session. During the screening phase of this study, each participant was presented with a number line, a graphic organizer with an algebraic expression, manipulatives for counting, a green marker, a red marker, and a dry erase marker and was asked to solve for *x*. The students were given no prompts or feedback for their performance. Screening sessions were conducted in a single opportunity probe format. On the first step that was incorrect or if the student did not respond, all remaining steps were scored as incorrect and the session was stopped. If a student initiated the first step correctly, but not the subsequent steps, the first step was scored correct and the rest were scored incorrect.

Three types of student responses could be recorded during screening sessions. *Correct* responses were defined as the student initiating a step of the task analysis within 5 s of the task direction or of completing the previous step and completing the step correctly within 5 s of the initiation. *Incorrect* responses were defined as the student initiating a step within 5 s of the task direction and completing the step incorrectly, out of sequence, or not completing the step within 5 s of the initiation. *No responses* were defined as the student failing to initiate any type of response within 5 s of the task direction. The investigator gave no feedback following student responses during screening sessions. Participants were given reinforcement in the form of descriptive verbal praise (e.g. "Thank you for working hard,") at the conclusion of each screening session.

Generalization Pre/Post-Test Procedures

The investigator also conducted a generalization pre-test prior to collecting baseline data and a generalization post-test following the students mastering the skill. Each student was given one task to complete that was selected from stocking the snack cart in the cafeteria, setting the table for a pre-determined number of people, or pulling pre-determined numbers of library books from shelves. The students were given each of the stories during the generalization pre and post-test conditions and were presented with a different story during each session conducted. The investigator provided the student with a verbal prompt asking the student to solve a problem. The student was asked to obtain a certain number of items based on how many items were already in place and how many items they needed to have at the conclusion of the task. The student was presented with a number line, a graphic organizer with an algebraic expression and the numbers from the story filled in by the investigator, items for counting, a green place marker, a red place marker, and a dry erase marker and was asked to solve for *x*. The problems were presented like a job task using manipulatives (e.g., spoons, bottled beverages, snacks, cups, and plates). For example, the investigator said, "I need you to stock this shelf. There are three bags of chips on the shelf already, but I need 10 bags total on the shelf. How many more bags of chips do you need? Solve for *x* and put the correct number of bags on the shelf." The student was given no prompts or feedback for his/her performance. The generalization pre-test was conducted using a multiple opportunity probe format once and a single opportunity probe format twice. If a student completed a step incorrectly during the multiple opportunity probe format, the investigator completed the step for the student without allowing the student to see her complete it, and gave the student the opportunity to complete the remainder of the steps. If a student did not initiate the first step correctly during the single opportunity probe format, all steps were scored as incorrect. If at anytime the student gave an incorrect response, the remaining steps also were scored as incorrect. Participants were given reinforcement in the form of verbal praise (e.g., "Thank you for working hard,") at the conclusion of each generalization pre and post-test. The number of correct responses for solving the expression by following the task analysis was recorded on a data sheet. (Appendix A).

Baseline/Probe Procedures

Baseline sessions were conducted using the same trial sequence as was described in the generalization pre and post-test section. A multiple opportunity probe format was used for the first baseline session followed by single opportunity probe formats for the remainder of the baseline sessions. Three types of student responses could be recorded during baseline sessions. *Correct* responses were defined as the student initiating a step within 5 s of the task direction and completing the step correctly within 5 s of the initiation. *Incorrect* responses were defined as student initiating a step within 5 s of the task direction and completing the step incorrectly, out of sequence, or not completing the step within 5 s of the initiation. *No student response* was defined as the student failing to initiate any type of response within 5 s of the task direction. The investigator gave no feedback following student responses during baseline sessions. Participants were given reinforcement in the form of verbal praise (e.g. "Thank you for working hard,") at the end of each baseline session. The number of correct steps for solving the equation was recorded on a data sheet (Appendix B). Baseline sessions were conducted with the first student for a minimum of 3 sessions or until responding was stable. Baseline sessions for students 2 and 3 were conducted on a weekly basis and for a minimum of 2 consecutive sessions immediately before entering intervention. Baseline data were recorded by the investigator on the baseline data sheet (Appendix B).

Instructional Procedures

In the intervention phase of the study, the investigator began by providing a general attentional cue designed to gain and keep the participant's attention. An example of the attentional cue was, "Get ready to work on math." The student then joined the investigator at the table for the intervention session. The investigator verbally presented a personally relevant short story that featured a student being required to complete a realistic task demanding them to gather a specified number of materials (bags of chips, newspapers, plates). An example of each short story used can be found in Appendices C, D, and E. These three stories were presented to the students in a rotating sequence, with the investigator changing the numbers in the problem from session to session.

The student was then presented with materials for solving the equation (a number line, a graphic organizer with an algebraic equation and numbers corresponding to the story filled in by the investigator, manipulatives for counting, a green place marker, a red place marker, and a dry erase marker) and given the direction, "Solve for *x*." Manipulatives for solving the equations corresponded to the materials used in the story. For example, if the student in the story was asked to gather a certain number of plates, the participant solving the equation also used plates as manipulatives for solving the equation.

A system of least prompts procedure was used to teach the skill. The prompt hierarchy included an independent level, a verbal prompt, a gesture plus verbal prompt, and a model plus verbal prompt. A verbal prompt included a verbal description of the step the student was to perform (e.g., “Point to the sum on the equation.”). A gesture plus verbal prompt was the investigator pointing to the materials needed or portion of the equation the student was solving while also verbally describing the step that needed to be completed. A model plus verbal prompt included the investigator using the student’s materials to model the step for the student while also verbally describing what she was doing. For each step of the task analysis, the investigator waited 5 s before delivering the first prompt to provide an opportunity for the student to respond independently. If a student did not independently initiate the step or emitted an incorrect response, the investigator gave a verbal prompt and then waited 5 s for the student to perform the step. If the student was incorrect or did not perform the step after 5 s, the investigator provided a verbal prompt along with a gesture and waited 5 s for the student to respond. If the student did not perform the step following the verbal and gesture prompt, the investigator issued a verbal prompt, modeled the step for the student, and asked the student to imitate the model. This procedure was followed until each step of the task analysis was completed. If the student began to make an error, the investigator interrupted the student’s response and gave the next prompt in the prompt hierarchy. At any time in the prompt sequence that a correct response occurred, the student was reinforced with descriptive verbal praise (e.g. “Great job using the green marker”). Once the student reached 100% independent responding for 1 day, descriptive verbal praise was faded to a fixed ratio reinforcement schedule for every third correct response until the student reached 100% independent responding for 1 day. Praise was then faded to a fixed ratio reinforcement schedule for nine correct responses, which was praise delivered only at the end of a session. During intervention sessions, the investigator recorded the prompt level required for the student to complete each step of the task analysis on the data sheet (Appendix F). Five types of student responses were recorded during intervention sessions. *Correct independent* responses were defined as the student initiating a step independently within 5 s of the task direction of previous step and completing the step correctly within 5 s of the initiation. *Correct with verbal prompt* responses were defined as a student initiating an incorrect step or a step out of order within 5 s of the task direction, but correctly completing the step following a verbal prompt from the investigator within 5 s of the prompt being delivered. *Correct with gesture prompt* and *correct with model prompt* responses were recorded in the same manner as correct with verbal prompt. *No student response* was defined as the student failing to initiate any type of response within 5 s of the task direction or given prompt. Correct responses resulted in the investigator saying, "Good," and describing the step the student performed correctly (e.g., "Good, you pointed to the sum on the equation"). Incorrect responses resulted in the investigator interrupting the response, saying, "Wait," and delivering the verbal, gesture, or model prompt. Each student continued in the intervention phase until he or she reached the criterion level of 100% for three consecutive sessions.

Maintenance Procedures

Maintenance sessions were conducted using the same procedures as baseline sessions in one multiple opportunity session followed by two single opportunity probe sessions. The number of correct responses for solving the expression was recorded on a data sheet

(Appendix G). Maintenance sessions were conducted weekly for three weeks following each participant reaching criterion levels during the intervention phase.

Reliability

The classroom teacher collected reliability data for both interobserver agreement (IOA) and procedural fidelity. An example of the IOA and procedural fidelity data sheet is found in Appendix H. The investigator trained the classroom teacher on instructional procedures and student response definitions. The classroom teacher was given an opportunity to practice collecting reliability data through role-play using the data sheet before collecting data on the investigator conducting sessions. The classroom teacher was required to have 100% IOA and procedural fidelity before she began collecting data during baseline or intervention sessions. IOA and procedural fidelity were collected on 38% of all baseline sessions and 22% of all intervention sessions. IOA and procedural fidelity had to be at least 80% or higher to be considered at acceptable levels. If the data fell below 80%, the investigator would retrain the classroom teacher collecting the reliability data for another practice session.

Dependent variable reliability. IOA was determined using the point-by-point agreement formula: number of agreements divided by number of agreements plus disagreements times 100 (Ayres & Ledford, 2014).

Independent variable reliability. Procedural fidelity during baseline was assessed by scoring the accuracy of the following teacher behaviors: securing student attention, introducing the context of the task, providing materials necessary for completing the task, giving the task direction, stopping the session following incorrect student responses, and giving reinforcement at the conclusion of the session. Procedural fidelity was assessed by scoring the following teacher behaviors during intervention: securing student attention, introducing the context of the task, providing materials necessary for completing task, giving the task direction, providing a 5 s response interval, correctly providing prompts following incorrect student responses, and providing reinforcement following correct responses. It was computed as the percentage of investigator behaviors observed divided by the planned investigator behaviors times 100 (Gast, 2014).

Social Validity

The researcher collected social validity data at the conclusion of the study. Appendices I and J show the surveys given to the classroom teacher and students respectfully. The investigator measured social-validity using 5-point Likert-type scale surveys using the anchors of strongly agree, agree, undecided, disagree, and strongly disagree. The teacher survey had five questions that included: (1) The skills addressed in this study are valuable for my students to learn, (2) The skills addressed in this study are skills that will help my students with future job tasks, (3) The skills addressed in this study are part of the academic curriculum my students are required to learn, (4) The intervention used to teach the skills was effective, and (5) I will use this intervention in the future when teaching similar skills. The student survey consisted of four questions including: (1) The skill I learned in this study was important, (2) Learning how to solve these problems will help me in the future when I get a job, (3) The way the teacher taught me this skill was easy to learn, and (4) I will use this method to solve problems in the future. The investigator read the survey questions and answer choices aloud to each student and each student recorded their own responses.

Section 4: Results

The results indicated that the use of a treatment package was effective in increasing the level and trend of correct independent completion of a task analysis for solving linear equations in high school students with MSD. Figure 3 shows the student responding data for baseline, intervention, and maintenance conditions. Data during the baseline condition shows that all three students were at zero levels of independent completion of the task analysis for solving linear equations. During the intervention condition, levels of independent completion of the task analysis increased to criterion for each student.

Dylan was able to perform 9 steps of the task analysis independently in 16 intervention sessions. He reached criterion during intervention session 16 and performed 9 steps of the task analysis independently for three consecutive sessions. Dylan maintained the skill for three additional sessions. Isaac performed 9 steps of the task analysis independently in 8 intervention sessions and reached criterion of performing 9 steps of the task analysis independently for three consecutive sessions during session number 10. Isaac demonstrated a decrease in steps of the task analysis completed independently during the first maintenance session, but he was able to complete 9 steps independently during subsequent maintenance sessions. Gabe performed 9 steps of the task analysis independently in 15 intervention sessions and reached criterion of performing 9 steps of the task analysis independently for three consecutive sessions during intervention session number 17. Gabe was only able to perform 5 steps of the task analysis independently during the first maintenance session, but he performed 8 and 9 steps independently during subsequent maintenance sessions.

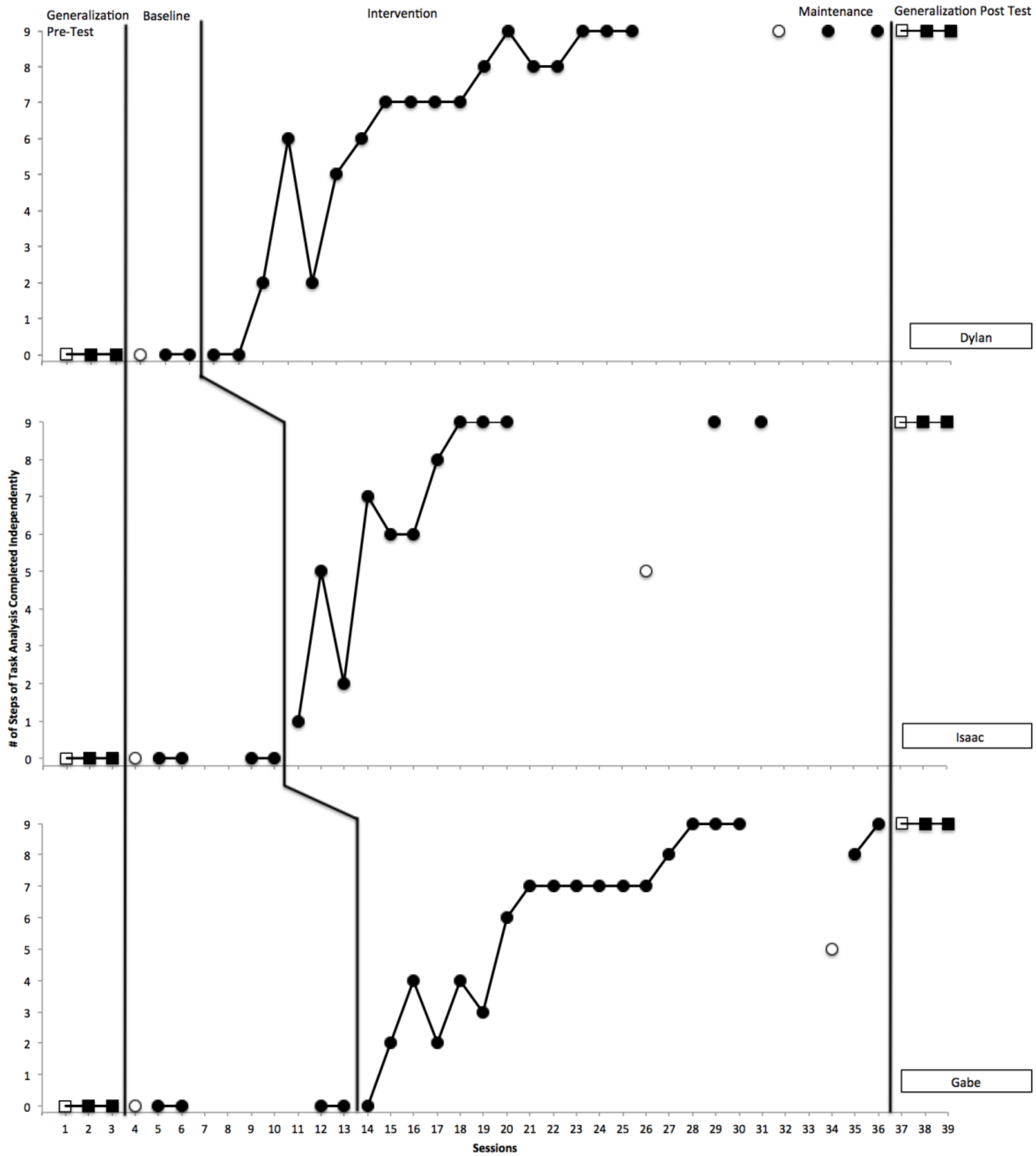

Figure 3. Number of steps of task analysis completed independently. This figure shows how many steps the task analysis each student completed correctly for generalization pre-test (square), baseline, intervention, generalization post-test (square), and maintenance sessions. Open shapes indicate multiple opportunity probe sessions.

Generalization pre-test data were collected during the first three sessions for all students and in the three sessions immediately following each student meeting criterion in the intervention phase. None of the students were able to complete any of the steps of the task analysis independently during generalization pre-test sessions, but they were able to complete all steps independently in the generalization post-test sessions. All students were successful in generalizing the skill to job tasks with untrained materials and settings in the school. Each student completed 9 steps of the task analysis independently when they were asked to solve an equation as a part of a job task.

Reliability

Interobserver agreement data were 100% for all baseline and intervention sessions. During observed baseline sessions, procedural fidelity data ranged from 92% to 100% with a mean of 97.6%. For observed intervention sessions, procedural fidelity data ranged from 92% to 100% with a mean of 97.3%. Procedural reliability data were within the acceptable range for all sessions observed. Teacher behaviors observed included providing attentional cue, ensuring attentional response, providing task direction, providing materials for completing the task, giving context for task, providing reinforcement according to schedule, providing a 5 s response interval for each step of the task analysis, and providing the correct consequence following student response for each step of the task analysis. Teacher errors observed were in providing a 5 s response interval and providing the correct consequence following student responses. For providing a 5 s response interval, procedural fidelity ranged from 88% to 100% with a mean of 95%. For the teacher behavior of providing the correct consequence the data ranged from 88% to 100% with a mean of 98%.

Social Validity

The classroom teacher completed a survey using a 5-point Likert-type scale on the intervention and behaviors targeted by the study. The classroom teacher *strongly agreed* that the skills taught in this study were valuable for her students to learn. She *agreed* that the skills the students learned as a result of the study would help them with future job tasks, were a part of the academic curriculum they are required to learn, and that the intervention used to teach the skills was effective. She was *undecided* on whether she would use this intervention in the future to teach similar skills.

The students also completed a survey using a 5-point Likert-type scale on the intervention and behaviors targeted by the study. Dylan and Gabe *strongly agreed* that the skill they learned from the study was important. Isaac agreed that the skill he learned was important. All three students *agreed* that the skill they learned will help them in the future with job tasks. Dylan and Isaac *agreed* that the way the investigator taught the skill was easy to learn, while Gabe was *undecided*. Gabe and Isaac *agreed* that they would use this method in the future to solve problems and Dylan was *undecided*.

Section 5: Discussion

The purpose of this study was to examine the effectiveness of using a treatment package to teach students with MSD to solve simple linear equations. Results indicated that a functional relation was established between the use of a treatment package and criterion responding on the number of steps of a task analysis that students could complete to solve linear equations. The results of the study also provided evidence that this method of teaching aided the students in generalizing the skill to job tasks within the school building. Prior to the study, the students had little to no experience solving linear equations using a task analysis and concrete representations. The study not only provided the students with an opportunity to learn to solve linear equations, it also provided the students with an opportunity to learn using a new strategy—the system of least prompts. The three students who participated in the study all reached criterion levels of completing the task analysis for solving linear equations and generalized the skill to job tasks. In addition to reaching criterion levels of responding during the intervention condition of the study, the students also maintained the skill during subsequent maintenance sessions. However, during maintenance sessions Isaac and Gabe both had lower levels of independent responding during the multiple opportunity probes but returned to criterion levels of responding during single opportunity probes. The students may have had higher levels of independent responding during single opportunity probes because the multiple opportunity probes served as a prompt for them.

Considering they had little to no prior experience with solving linear equations and learning using the system of least prompts, the students made significant gains; and their progress provides evidence that the treatment package used in the study is effective in teaching students to solve algebraic equations. This study replicated others' findings and demonstrated that students with MSD can learn grade-appropriate math content and generalize it to a functional task.

Limitations and Conclusions

One limitation to this study was the limited diversity of the participants. All of the participants in the study were male and were in the same grade. The participants were also similar in their strengths, weaknesses, and cultural backgrounds, which limits external validity. A second limitation of the study was that the investigator also served as the instructor and primary data collector instead of the classroom teacher. A third limitation was that the skill was taught in a special education setting and generalized to a job task. Generalization to other settings like the general education setting was not examined.

Future research including a more diverse pool of participants is needed to determine if the intervention is effective when used with students of varying academic strengths, ages, grades, and cultural backgrounds. It would also be beneficial if, in future replications of this study, the classroom teacher was trained to deliver instruction rather than the investigator delivering instruction so that instruction occurs more naturally for the students. This would be especially important because the teacher from the current study was unsure if she would use a similar intervention in the future. The generalization of the skill to other settings such as the general education setting should also be considered in future research in order to determine if students can also learn to do linear equations found in a textbook format typical of general education when given task analytic instruction with systematic prompting. Future research is needed not only to determine if the skills taught in this study could be generalized to more settings, but also to determine if utilizing the method used in this study could be effective in teaching other advanced level mathematics skills.

In summary, this study is one of few studies that have taught algebra skills to students with MSD. The students who participated in this study were successful at learning how to solve an algebraic equation through the use of systematic instruction with a concrete representation of the problems being solved. The students all showed mastery with generalization across materials and settings. This study contributes to the literature in that it addressed access to grade-level standards in mathematics for high school students with MSD. It also extends the literature through the use of a functional application and the use of contextual stories prior to delivering instruction. However, continued research is still necessary to help students gain more access to grade-level standards and the application of these skills to real-life situations.

Appendix A: Generalization Pre and Post-Test

Investigator:									
Student:				**Task:** Student will complete simple algebraic addition equation. Example: 3 + x = 7					
Steps:	Session: Task:	Session: Task:	Session: Task:	Session: Task:	Session: Task:	Session: Task:	Session: Task:	Session: Task:	Session: Task #:
1. Student points to sum on equation. *How many spoons do you need*									
2. Moves red marker to sum on chart									
3. Counts number of items in container and finds this known number on equation. *How many spoons do you already have?*									
4. Moves the green marker to known number on chart.									
5. Count to the sum with materials. *How many spoons will you need to get?*									
6. Selects the number counted.									
7. Puts correct number in for x									

in formula.									
8. Puts correct number needed in appropriate place									
9. Solves for x (writes number)									
Total Number Completed Correctly:									
Percent (%) of Steps Completed Independnetly:									
Key: + correct –incorrect 0 no response									

Appendix B: Baseline Data Sheet

Investigator:									
Student: **Academic Component:**				**Task:** Student will complete simple algebraic addition equation. Example: 3 + x = 7					
Steps:	Session: Task #:	Session: Task #:	Session: Task #:	Session: Task #:	Session: Task #:	Session: Task #:	Session: Task #:	Session: Task #:	Session: Task #:
1. Student points to sum on equation. *How many spoons do you need*									
2. Moves red marker to sum on chart									
3. Counts number of items in container and finds this known number on equation. *How many spoons do you already have?*									
4. Moves the green marker to known number on chart.									
5. Count to the sum with materials. *How many*									

spoons will you need to get?									
6. Selects the number counted.									
7. Puts correct number in for x in formula.									
8. Puts correct number needed in container.									
9. Solves for x (writes number)									
Total Number Completed Correctly:									
Percent (%) of Steps Completed Independently:									
Key: + correct –incorrect 0 no response									

Appendix C: Short Story 1

John works at Dollar General stocking shelves. Today he is stocking chips on the shelves. His manager gave him a box with bags of chips and asked him to make sure there are 10 bags of chips on the shelf. Before John started stocking the shelf, there were already 5 bags of chips on the shelf. John needs to figure out how many more bags of chips he needs to put on the shelf.

Appendix D: Short Story 2

Sally works at a restaurant and it is her responsibility to set the tables. The hostess asked her to set a table with enough plates for 10 people. There are 5 plates on the table. She needs to figure out how many more plates she needs to finish setting the table.

Appendix E: Short Story 3

Mike delivers newspapers. He has to deliver newspapers to 7 people. He has 3 newspapers in his bag. Mike needs to figure out how many more newspapers he needs to put in his bag before setting out to deliver them.

Appendix F: Intervention Data Sheet

Investigator:									
Student: **Academic Component:**				**Task:** Student will complete simple algebraic addition equation. Example: 3 + x = 7					
Steps:	Session: Task #:	Session: Task #:	Session: Task #:	Session: Task #:	Session: Task #:	Session: Task #:	Session: Task #:	Session: Task #:	Session: Task #:
1. Student points to sum on equation. *How many spoons do you need*									
2. Moves red marker to sum on chart									
3. Counts number of items in container and finds this known number on equation. *How many spoons do you already have?*									
4. Moves the green marker to known number on chart.									
5. Count to the sum with materials.									

How many spoons will you need to get?									
6. Selects the number counted.									
7. Puts correct number in for x in formula.									
8. Puts correct number needed in container.									
9. Solves for x (writes number)									
#/ % Completed Independn etly:									
#/ % Verbal Prompt:									
#/ % Gesture Prompt:									
#/ % Model Prompt:									
Key: I- Independent V- verbal prompt G-gesture prompt M-model									

Appendix G: Maintenance Data Sheet

Investigator:									
Student: **Academic Component:**				**Task:** Student will complete simple algebraic addition equation. Example: 3 + x = 7					
Steps:	Date:	Date:	Date:	Date:	Date:	Date:	Date:	Date:	Date:
1. Student points to sum on equation. *How many spoons do you need*									
2. Moves red marker to sum on chart									
3. Counts number of items in container and finds this known number on equation. *How many spoons do you already have?*									
4. Moves the green marker to known number on chart.									
5. Count to the sum with materials. *How many spoons will you need to*									

get?									
6. Selects the number counted.									
7. Puts correct number in for x in formula.									
8. Puts correct number needed in appropriate place									
9. Solves for x (writes number)									
Total Number Completed Correctly:									
Key: + correct -incorrect									

Appendix H: Procedural Fidelity and Interobserver Agreement Data Sheet

Session #: _______ **Task #: ______** **Student: _____________**

Investigator Behaviors:

Provides Attentional Cue: Yes No Ensures Attentional Response: Yes No
Provides Task Direction: Yes No Provides Materials for Completing Task: Yes No
Provides Context for Task: Yes No Provides Reinforcement: Yes No

	Investigator Behaviors:		**Interobserver Agreement of Student Responses**			
Task Analysis	Provides 5 s response interval:	Provides correct consequence:	Independent	Verbal	Gesture	Model
1. Point to sum on equation						
2. Moves red marker to sum on chart						
3. Counts # of items and finds known # on equation						
4. Moves green marker to known # on chart						
5. Count to sum with materials						
6. Selects # counted						
7. Puts correct # in for x in formula						
8. Puts correct # needed in						

container						
9. Solves for x (writes #)						

Procedural Fidelity: # observed______/ total planned______ = _______%

IOA: # of agreements ______ / # of agreements ____ + # of disagreements x 100 = _______%

Appendix I: 5-Point Likert Scale Survey- Teachers

Question (Mark “X” in the appropriate box)	Strongly Agree	Agree	Undecided/Neutral	Disagree	Strongly Disagree
1. The skills addressed in this study were valuable for my students to learn.					
2. The skills addressed in this study are skills will help my students with future job tasks.					
3. The skills addressed in this study are part of the academic curriculum my students are required to learn					
4. The intervention used to teach the skills was effective.					
5. I will use this intervention in the future when teaching similar skills.					
Comments:					

Appendix J: 5-Point Likert Scale Survey- Students

Question (Mark "X" in the appropriate box)	Strongly Agree 5	Agree 4	Undecided/Neutral 3	Disagree 2	Strongly Disagree 1
1. The skill I learned in this study was important.					
2. Learning how to solve these problems will help me in the future when I get a job.					
3. The way the teacher taught me this skill was easy to learn.					
4. I will use this method to solve problems in the future.					
Comments:					

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