



Brief Report

Effects of explicit instruction on acquisition and generalization of mathematical concepts for a student with autism spectrum disorder



Jenny R. Root

Florida State University, United States

ARTICLE INFO

No. of reviews completed is 3

Keywords:

Autism
Intellectual disability
Direct instruction
Explicit instruction
Mathematics
Generalization
Single-case design

ABSTRACT

Background: This study investigated the effects of explicit instruction on acquisition and generalization of mathematical concepts (more, different, long) by an elementary student with autism and co-morbid intellectual disability.

Method: This study used a single-case multiple probe across behaviors design to measure the acquisition and generalization of concepts across four categories of stimuli: (a) far distractor objects, (b) near distractor objects, (c) near distractor pictures, and (d) environmental objects.

Results: A functional relation was found between explicit instruction and independent identification of mathematical concepts. Data indicate the intervention was effective and treatment effects were maintained across concepts. Variable generalization patterns were observed across concepts.

Conclusions: Explicit instruction is an effective instructional strategy for teaching mathematical concepts to learners with autism and co-morbid intellectual disability. Future research should measure the efficacy of explicit instruction for more advanced generalization of concepts and application to functional tasks.

1. Introduction

Early number sense is the broad term used to describe an individual's ability to understand numbers and operations and use mathematical concepts to make judgments (McIntosh, Reys, & Reys, 1992). Also called "early numeracy", number sense is fundamental for advanced knowledge in mathematics. Without a firm foundation of number sense, learners will struggle with both acquiring and generalizing future mathematical learning (Jordan, Kaplan, Ramineni, & Locuniak, 2009). Early measurement concepts, including more/less, same/different, longer/shorter are important components of number sense. Learners with disabilities who struggle with foundational number sense are likely to have persistent difficulty throughout their educational careers (Carlson, Jenkins, Bitterman, & Keller, 2011).

Understanding of mathematical concepts and symbols are essential components of mathematical knowledge (Skemp, 1987). Expanded vocabularies allow learners to understand commonalities and differences between items by describing their attributes (Sandhofer & Smith, 1999). Preschool students with developmental delays, including autism spectrum disorder (ASD) and intellectual disability (ID) have been found to have lower math skills than peers with more high incidence disabilities such as speech language impairments (Carlson et al., 2011). Learners with ASD/ID need high quality intensive intervention using evidence-based practices in order to demonstrate both acquisition and generalization of math concepts.

A recent review of the literature found Explicit Instruction (EI) to be an evidence-based practice for teaching mathematics to learners with ASD/ID (Spoonster et al., 2017). When teachers use EI, they employ a series of supports and scaffolds to guide students

E-mail address: jroot@fsu.edu.

<https://doi.org/10.1016/j.rasd.2018.09.005>

Received 30 March 2018; Received in revised form 29 August 2018; Accepted 23 September 2018

Available online 03 October 2018

1750-9467/ © 2018 Elsevier Ltd. All rights reserved.

through the learning process in small steps with clear explanations and demonstrations of the targeted skill, providing practice with feedback until mastery is achieved (Archer & Hughes, 2011). Several instructional strategies fall under the EI “umbrella”, including direct instruction and multiple exemplar training. Multiple exemplar training is designed to promote generalization by teaching multiple examples of desired responses (Chadsey-Rusch, Drasgow, Reinoehl, Halle, & Collet-Klingenberg, 1993; Horner, Sprague, & Wilcox, 1982; Stokes & Baer, 1977).

Spooner et al. (2017) found eight studies published between 2005–2016 used EI to teach mathematics to learners with ASD/ID. Targeted skills included addition (Cihak & Foust, 2008; Cihak & Grim, 2008; Fletcher, Boone, & Cihak, 2010), telling time (Thompson et al., 2012), purchasing skills (Hansen & Morgan, 2008; Hsu, Tang, & Hwang, 2014), and problem solving (Root, Browder, Saunders, & Lo, 2016). One study used EI to teach mathematical concepts related to number sense to learners with developmental disability. Celik and Vuran (2014) compared the effects of direct instruction and simultaneous prompting on identification of mathematical concepts (few, old, long, thick) by four elementary students with moderate ID who did not have ASD. Results of the single-case parallel treatments design found DI effective for all four participants whereas simultaneous prompting was only effective for three participants.

Although there is limited empirical research specifically on teaching mathematics concepts to students with ASD using EI, research supports its efficacy for teaching other basic concepts and vocabulary terms. For example, Hicks, Bethune, Wood, Cooke, and Mims (2011) measured the effects of direct instruction on acquisition of prepositions. Results indicated a functional relation between DI and the students’ use of and response to prepositions. Given the positive findings of explicit instruction to teach concepts to students with moderate ID, research on its utility for teaching mathematical concepts to students with ASD and co-morbid ID is warranted. Therefore, the purpose of this study was to investigate the effects of explicit instruction (i.e., a model, lead, test procedure with multiple exemplars) on the acquisition and generalization of three mathematical concepts (more, different, long) for a student with ASD and co-morbid ID.

2. Method

2.1. Participant and setting

Approval from the institutional review board, written parental consent, and verbal student assent were obtained prior to beginning the study. Teacher nomination was used to recruit a participant based on the following inclusion criteria: (a) an educational or medical diagnosis of ASD, (2) ability to indicate choices between two items using gestures or words, and (3) satisfactory performance on a prescreening measure. The prescreening measure was administered by the author in a one-on-one setting and assessed receptive and expressive identification of pictures and objects as well as the three targeted mathematics concepts (more, different, long). Performance on the prescreening measure was considered satisfactory if the participant was able to expressively and receptively identify pictures and objects of common items (i.e., iPad, pizza, tree) but unable to identify the targeted mathematics concepts.

One female student participated in the pilot study. Ruth was a 10-year-old Black female in the 4th grade and had a medical diagnosis of ASD and ID. She attended a private school for students with ASD where she received individualized instruction from Registered Behavior Technicians (RBTs) on basic academic skills, although the primary emphasis of instruction was on communication, language, and self-help skills. The majority of her instruction throughout the school day was conducted in a one-on-one format. Typical math instruction focused on numeral recognition and making sets up to five. Ruth communicated using one-word utterances. A graduate student completing a Master’s degree in special education who was trained in systematic instruction techniques conducted all sessions. Sessions lasted approximately ten minutes and took place one-on-one in the afternoons at Ruth’s desk.

2.2. Materials

Four example sets (far distractor objects, near distractor objects, near distractor pictures, and environmental objects) were developed by the researcher for each concept based on the guidelines outlined by Engelmann and Carnine (1982) for selecting examples for teaching concepts. See Table 1 for the positive and negative materials for each category and concept. The first example set (far distractor objects) included objects that had a high degree of similarity in irrelevant dimensions and only differed in the quality related to the concept (e.g., length). The second example set (near distractor objects) included objects with a lower degree of similarity in irrelevant dimensions and differed in more than one quality in addition to the quality related to the concept (e.g., length and color). The third example set (near distractor pictures) included pictures with a lower degree of similarity in irrelevant dimensions similar to the near distractor objects. Finally, the fourth example set (environmental objects) contained items that were common to Ruth’s school environment that represented the concepts.

2.3. Experimental design

We used a multiple probe across behaviors design (Horner & Baer, 1978; Kratochwill et al., 2013) to evaluate the effects of explicit instruction on acquisition and generalization of mathematical concepts. The dependent variable was acquisition and generalization of math concepts, measured by the number of correct identifications of concepts out of six opportunities. Responses were considered independently correct if Ruth touched the correct stimuli (i.e., object/picture depicting the targeted concept) within 4 s of the instructional cue (i.e., “touch long”). There were three experimental conditions: baseline, intervention, and probe. Intervention consisted of up to four phases for each concept: (a) EI with far distractor objects, (b) EI with near distractor objects, (c) EI with near

Table 1
Positive and Negative Materials Across Four Categories of Stimuli for Each Targeted Concept.

Concept	Far Distractor - Objects		Near Distractors - Objects-		Near Distractors - Pictures		Environmental Generalization	
	Positive	Negative	Positive	Negative	Positive	Negative	Positive	Negative
More	Pile of more than five 1 inch cubes	Single 1-inch cube	Pile of more than five 1 inch yellow foam shapes (circles, squares, and triangles)	Single 1 inch yellow foam shape	Picture of a ten frame with 3 dots	Picture of a ten frame with 10 stars	(a) Box full of 8 markers (b) Sticker book page with 15 stickers	(a) Box with 2 markers (b) Sticker book page with 3 stickers
Different	1 inch purple foam cube and 1 inch green foam cube	Two 1 inch green foam cubes	3 inch red toy plane and toy car	3 inch yellow toy plane and 3 inch green toy plane	Picture of an apple and a banana	Picture of two oranges	(a) Green marker and purple marker (b) Pizza memory game card and hot dog memory game card	(b) Two black markers (b) Two star memory game cards
Long	4 inch purple straw	1 inch purple straw	8 inch stack of multicolored cubes	2 inch stack of multicolored unifix cubes	6 inch picture of ruler	3 inch picture of measuring tape	(a) 7 inch silver pencil (a) 5 inch red fraction rod	(b) 1 inch yellow pencil (b) 1 inch blue fraction rod

distractor pictures, and (d) EI with environmental objects. Once the participant demonstrated mastery for all four categories of stimuli during a probe, instruction ceased. Prior to introduction of the intervention (explicit instruction) three baseline probes were taken on the far distractors objects across the three concepts and one probe was taken across the other stimuli sets. Concepts were randomly assigned to order of intervention. After a clear accelerating trend in identification of the far distractor objects in the first concept (more) as evidenced by at least two sessions with increasing number of independent correct identifications of concepts, instruction began on the second concept (different), with the third concept (long) following the same rules systematic introduction to intervention. Following mastery in each instructional phase (5/6 independent correct identifications for two sessions), the participant was probed to measure maintenance of treatment effects for trained stimuli and generalization of effects to other untrained stimuli.

A trained observer (first author) calculated interobserver agreement (IOA) and procedural fidelity (PF) by viewing video recordings for 40% of baseline sessions for all three concepts, with mean agreement of 100% and mean fidelity of 100%. IOA and PF were collected for 30% of intervention sessions across all three concepts, with a mean agreement of 100% across all concepts and a mean fidelity of 92% for more, 98% for different, and 100% for long.

2.4. Procedures

2.4.1. Baseline and probe sessions

For each example set (i.e., far distractor objects, near distractor objects, near distractor pictures and environmental objects) the interventionist presented a positive and negative example sets (see Table 1) at least five inches apart on the table and the instructional cue “Touch *concept*”. For example, in baseline trials for *more* using far distractors, the interventionist presented a pile of at least 5 red 1 inch cubes and a single red 1 inch cube that and said “Touch *more*”. The interventionist randomized the location of the correct answer (i.e., left or right) in between each trial for each category of stimuli. At the end of each baseline and probe session Ruth was given access to YouTube videos on an iPad to reinforce task completion.

2.4.2. Intervention sessions

Instruction consisted of up to four phases for each concept using Engelmann and Carnine’s (1982) instructional sequence for teaching concepts and a script developed by current authors. The EI procedure remained the same across the four phases, the only difference being the stimuli example sets. In intervention sessions, the interventionist used a model-lead-test procedure, which consisted of: (a) modeling six trials (i.e., “This is *long*. This is *not long*.”); (b) guided practice for six trials (i.e., “Touch *long*”) with error correction and behavior specific praise; and (c) six trials of a test (i.e., “Touch *long*”) with no error correction or feedback. Error correction included modeling the correct answer and retesting (e.g., “This is *long*. Touch *long*”). Behavior specific praise included statements such as “Yes, *long*”. At the end of each intervention session Ruth was given access to YouTube videos on an iPad to reinforce task completion.

3. Results

The number of independent correct identifications across concepts for Ruth is shown in Fig. 1. These data show a functional relation between EI and acquisition and generalization of math concepts. Ruth demonstrated a stable pattern of low responding across the three concepts in a baseline of 0 independent correct responses. A basic effect was seen for each concept, as demonstrated by an immediate jump in level of independent correct identifications of the far distractor objects for each concept following introduction to the intervention. Visual analyses reveals a functional relation, in that there are three demonstrations of effect across the three targeted concepts at three different points in time with no overlap between baseline and intervention data points.

Ruth was able to reach mastery criteria for far distractor objects in three sessions for *more* and two sessions for both *different* and *long*. On Probe 1 she demonstrated maintenance of treatment effects for far distractor objects across all three concepts and demonstrated some generalization to untrained stimuli for *different* and *long*. Ruth reached mastery criteria for the near distractor objects in four sessions for *more*, two sessions for *different*, and three sessions for *long*. On the Probe 2 she demonstrated maintenance for trained stimuli across all three concepts and reached mastery criteria for trained and untrained stimuli for *different*; as a result, instruction for *different* ceased. Ruth reached mastery criteria for near distractor pictures in two sessions for both *more* and *long*. On Probe 3, Ruth demonstrated maintenance for all taught stimuli for *more* and *long* and all four stimuli example sets (taught and untaught) for *different*. She met mastery for environmental objects for *more* and *long* following two sessions. On the first session of Probe 4 for *more*, Ruth had irregular responding that may have been due to an impending illness. A follow-up session indicated some maintenance across all four stimuli example sets for *more*. On Probe 4 for *long* and *different* she demonstrated maintenance on all four stimuli example sets.

4. Discussion

The results of the current study add to the body of literature on the effectiveness of DI on concept learning for students with ASD/ID. While DI is an established evidence-based practice for teaching mathematics to these students (Spooner et al., 2017), this study was the first to evaluate the procedure for teaching mathematics concepts for students with ASD/ID. These findings support those of Celik and Vuran (2014) and Hicks et al. (2011). Similar to Hicks et al. (2011), the current investigation evaluated the degree to which the participant could generalize responding with untaught stimuli. Ruth was able to generalize learning of one concept (*different*) to untaught stimuli example sets (near picture distractors and environmental objects) and demonstrate maintenance. For the other two

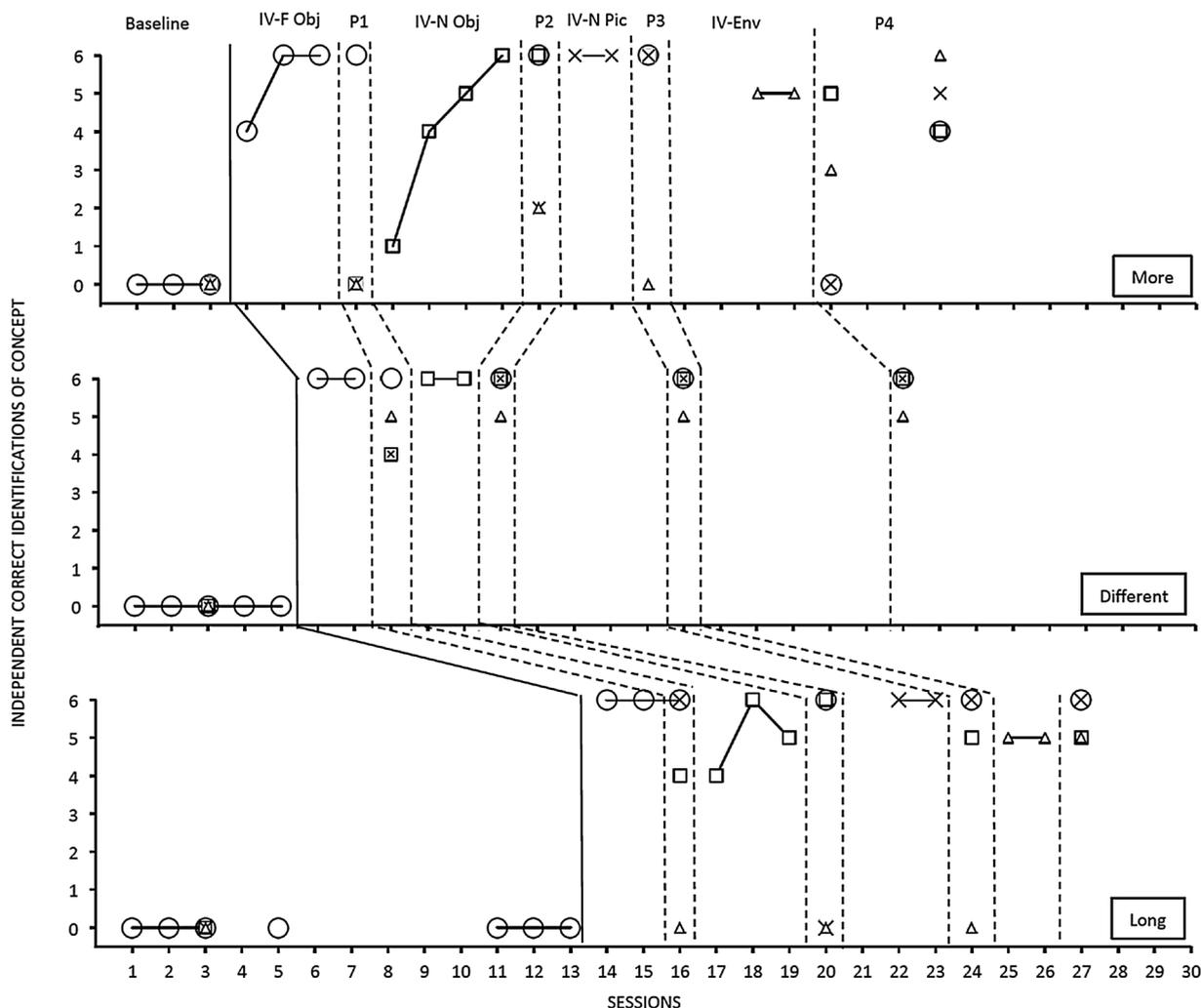


Fig. 1. Graph of independent correct identifications of concepts across experimental conditions. Note. Circles = far distractor objects, squares = near distractor objects, cross hash = near picture distractors, triangle = environmental distractors.

concepts (*more* and *long*) Ruth required intervention on all stimuli example sets in order to reach mastery. This differential pattern of responding highlights some possible limitations of the current study, namely boundaries on generalization; it cannot be assumed based on the given data that Ruth had acquired generalized responding to untrained stimuli. In other words. While the study did not include a formal measure of social validity, it does meet four of the social validity quality indicators for research with individuals with ASD outlined by Reichow et al. (2008), including: (a) socially important dependent variables, (b) time-and cost-effective intervention, (c) behavioral change that is large enough for clinical value, and (d) a natural context.

4.1. Limitations and suggestions for practice and future research

These preliminary findings have important implications for instruction of students with ASD/ID and future research in this area. These learners have lower mathematical and vocabulary abilities than typically developing peers (Carlson et al., 2011) which negatively impacts their ability to access the general education curriculum as well as generalize mathematics skills to everyday life. Practitioners should consider the conceptual and vocabulary knowledge required by their students to fully participate in both the general education curriculum as well as for increased independence in functional skills and provide DI on these prioritized learning targets using DI. While Ruth did learn to identify concepts across all four stimuli sets, it was not without intervention. Rather than employ the “train and hope” (Stokes & Baer, 1977) method of the current study, future research could employ the principles of juxtaposition (Engelmann & Carnine, 1982) to present multiple example sets that fall within the same category (i.e., far distractors that only differ in one quality) in an effort to train loosely (Stokes & Baer, 1977). Finally, the current preliminary study only measured receptive understanding of concepts, or the ability to label or tact. Functional applications of concept learning will likely require more advanced knowledge of concepts, such as selecting from a larger array of stimuli or altering a stimulus to give it the quality of the

concept. Future research into the efficacy of EI for more advanced generalization of concepts is warranted. Finally, this study did not meet three of Reichow et al.'s (2008) social validity indicators. Future research should include formal social validity measures to provide data on the satisfaction of consumers, as well as consider use of a peer-comparison group and implementation by natural intervention agents (i.e., teachers, behavior therapists).

Conflict of interest

Authors declare they have no conflict of interest.

References

- Archer, A. L., & Hughes, C. A. (2011). *Explicit instruction: Effective and efficient teaching*. New York, NY: Guilford.
- Carlson, E., Jenkins, F., Bitterman, A., & Keller, B. (2011). *A longitudinal view of the receptive vocabulary and math achievement of young children with disabilities*. Washington, DC: National Center for Special Education Research.
- Celik, S., & Vuran, S. (2014). Comparison of direct instruction and simultaneous prompting procedure on teaching concepts to individuals with intellectual disability. *Education and Training in Autism and Developmental Disabilities, 49*, 127–144.
- Chadsey-Rusch, J., Drasgow, E., Reinhoehl, B., Halle, J., & Collet-Klingenberg, L. (1993). Using general-case instruction to teach spontaneous and generalized requests for assistance to learners with severe disabilities. *Journal of the Association for Persons with Severe Handicaps, 18*, 177–187.
- Cihak, D. F., & Foust, J. L. (2008). Comparing number lines and touch points to teach addition facts to students with autism. *Focus on Autism and Other Developmental Disabilities, 23*, 131–137. <https://doi.org/10.1177/1088357608318950>.
- Cihak, D. F., & Grim, J. (2008). Teaching students with autism spectrum disorder and moderate intellectual disabilities to use counting-on strategies to enhance independent purchasing skills. *Research in Autism Spectrum Disorders, 2*, 716–727. <https://doi.org/10.1016/j.rasd.2008.02.006>.
- Engelmann, S., & Carnine, D. (1982). *Theory of instruction: Principles and applications*. New York: Irvington Publishers.
- Fletcher, D., Boone, R. T., & Cihak, D. F. (2010). Effects of the "TOUCHMATH" program compared to a number line strategy to teach addition facts to middle school students with moderate intellectual disabilities. *Education and Training in Autism and Developmental Disabilities, 45*, 449–458.
- Hansen, D. L., & Morgan, R. L. (2008). Teaching grocery store purchasing skills to students with intellectual disabilities using a computer-based instruction program. *Education and Training in Developmental Disabilities, 43*, 431–442.
- Hicks, S. C., Bethune, K. S., Wood, C. L., Cooke, N. L., & Mims, P. J. (2011). Effects of direct instruction on the acquisition of prepositions by students with intellectual disabilities. *Journal of Applied Behavior Analysis, 44*, 675–679.
- Horner, R. D., & Baer, D. M. (1978). Multiple-probe technique: A variation of the multiple baseline. *Journal of Applied Behavior Analysis, 11*, 189–196.
- Horner, R. H., Sprague, J., & Wilcox, B. (1982). General case programming for community activities. In B. W. In, & G. T. Bellamy (Eds.). *Design of high school programs for severely handicapped students* (pp. 61–98). Baltimore, MD: Brookes.
- Hsu, G., Tang, J., & Hwang, W. (2014). Effects of extending the one-more-than technique with the support of a mobile purchasing assistance system. *Research in Developmental Disabilities, 35*, 1809–1827. <https://doi.org/10.1016/j.ridd.2014.04.004>.
- Jordan, N. C., Kaplan, K., Ramineni, C., & Locuniak, M. N. (2009). Early math matters: Kindergarten number competence and later mathematics outcomes. *Developmental Psychology, 45*, 850–867.
- Kratochwill, T. R., Hitchcock, J. H., Horner, R. H., Levin, J. R., Odom, S. L., Rindskopf, D. M., et al. (2013). Single-case intervention research design standards. *Remedial and Special Education, 34*, 26–38.
- McIntosh, A., Reys, B. J., & Reys, R. E. (1992). A proposed framework for examining basic number sense. *For the Learning of Mathematics, 12*, 2–8.
- Reichow, B., Volkmar, F. R., & Cicchetti, D. V. (2008). Development of the evaluative method for evaluating and determining evidence-based practices in autism. *Journal of Autism and Developmental Disorders, 38*, 1311–1319.
- Root, J. R., Browder, D. M., Saunders, A. F., & Lo, Y-y. (2016). Schema-based instruction with concrete and virtual manipulatives to teach problem solving to students with autism. *Remedial and Special Education, 38*, 42–52. <https://doi.org/10.1177/0741932516643592>.
- Skemp, R. (1987). *The psychology of learning mathematics*. Mahwah, NJ: Lawrence Erlbaum.
- Spooner, F., Saunders, A., Root, J., & Brosh, C. (2017). Promoting access to common core mathematics for students with severe disabilities through mathematical problem solving. *Research and Practice for Persons with Severe Disabilities, 42*, 171–186.
- Stokes, T. F., & Baer, D. M. (1977). An implicit technology of generalization. *Journal of Applied Behavior Analysis, 10*, 349–367.