The Effects of CRA/CSA Explicit Instruction for Students with and without Disabilities Taught in an Inclusive Setting

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Abstract

Children with cognitive delays or developmental disabilities are at elevated risk of having a persistent mathematics disability. Students who have difficulty in mathematics display trouble with awareness of numbers and numeric concepts. This is alarming because students who display lower mathematics performance early on in school make smaller gains in mathematics throughout their school years. Researchers show that explicit instruction is effective in teaching students with disabilities mathematics. More research needs to be conducted on brief explicit mathematic interventions using the concrete-representational-abstract sequence which is also referred to as the concrete semi-concrete abstract sequence in mathematics literature that target the skill of counting for students with and without developmental disabilities taught in inclusive settings. In this study, researchers examine the effects of using explicit instruction coupled with the concrete-representational-abstract sequence to teach counting skills to students who received special education services for disabilities in an inclusive setting along with their peers not identified as receiving special education. Implications of these findings are also discussed.

Keywords: counting, explicit instruction, mathematics

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At least six percent of students in school struggle with a mathematics learning disability (Powell, Fuchs, & Fuchs, 2013; Shalev, Auerbach, & Manor, 2000). There are many more students who struggle with mathematics even though a formal diagnosis of a mathematics learning disability is not established (Powell et al., 2013). Children with cognitive delays or developmental disabilities are at elevated risk of having a persistent mathematics disability (Morgan, Farkas, Hillemeier, & Maczuga, 2016). Most students who have difficulty in mathematics have trouble with awareness of numbers and numeric concepts (Powell et al., 2013). Students who display lower mathematics performance early in their school experience make smaller gains in mathematics throughout their school years (Jordan, Kaplan, Locuniak, & Ramineni, 2007). Gersten and Chard (1999) liken the importance of students' awareness of numbers in mathematics to the importance of students' phonemic awareness abilities in reading. Skills that students struggle with are counting, cardinality, magnitude, fluency, and basic combinations of numbers (Mazzocco & Thompson, 2005; Powell, et. al., 2013). Each of these skills is tied to understanding numbers. Teachers who provide instruction in inclusive classrooms must address a wide variety of academic and functional needs. Instruction then must reach diverse groups of students and include foundational skills that build meaningful and useful knowledge for each child. Kroesbergen, van't Noordende, and Kolkman (2014) explain the most important components of understanding numbers are counting and quantity knowledge. Therefore, students must have frequent experiences that give them time and opportunity in which they manipulate quantities, create mental images of those quantities, and organize quantities using the symbols of mathematics (Clements, 1999; Fusion, Clements, & Sarama, 2015).

Counting helps students create mental images of quantities and verbally assign symbols (e.g., five) to those quantities (Kroesbergen et al., 2014). Students need to count in a flexible manner so that they can develop a deep awareness of numeric representations and apprehend that numbers can be represented in many different ways (Clements & Sarama, 2015). Counting is the most basic and important skill of building an awareness of numbers (Kroesbergen et al., 2014). It is also the most common number activity in preschool (Ramani & Siegler, 2011). Activities that teach counting can be found in formal curriculum or informal classroom undertakings such as board games and can be student led instruction or more explicit and structured (Mononen, Koponen, & Mikko, 2014; Ramani & Siegler, 2011; Toll & Van Luit, 2014; Van De Rijt & Van Luit, 1998). This study examines the effects of explicit instruction that focuses on teaching children with developmental disabilities and their peers without disabilities in an inclusive setting to count in flexible ways.

Developmental Stages of Counting and Learning Trajectories

There are developmental stages for counting as well as learning trajectories for counting skills. Van De Rijt and Van Luit (1998) outline the developmental process for counting and Clements and Sarama (2010) delineate the counting trajectories that classify skills teachers observed to guide instruction. Both developmental stages and learning trajectories encompass Gelman and Gallistel's (1978) five fundamental principles of counting. The stages and learning trajectories are discussed within the context of the five principles of counting in the next paragraphs. Students demonstrate acoustic counting around the age of three. Acoustic counting is when students speak numbers but do not connect numbers with quantities (Van De Rijt & Van Luit, 1998). Clements and Sarama (2010) refer to students who demonstrate acoustic counting as chanters because they count through simple songs or rhymes. Even though students speak numbers when counting acoustically, they are not employing any of the five counting principles outlined by Gelman and Gallistel (1978).

After acoustic counting, students count asynchronously (Van De Rijt & Van Luit, 1998). Counting asynchronously is when students connect numbers to quantities of objects. Even though a connection is made between objects and numbers, students are not able to point to one object while enumerating one number. Students who count asynchronously are referred to by Clements and Sarama (2010) as reciters because they repeat number words, but can miss an object or point to the same object twice while counting. When students count asynchronously, they are still not employing any of the five counting principles outlined by Gelman and Gallistel.

The next stage is synchronous counting (Van De Rijt & Van Luit, 1998). Students who demonstrate synchronous counting are also referred to as corresponder counters by Clements and Sarama because students count and enumerate the number at the same time. Students count synchronously around the age of four or five. When counting synchronously students make a one to one relation which is the application of the counting principle of one to one correspondence (Gelman & Gallistel, 1978). Even though students who count synchronously demonstrate one to one correspondence, they can still identify an incorrect amount as the total because they have not learned the counting principle of cardinality.

After synchronous counting, students demonstrate resultative counting which is also known as seriation (Van De Rijt & Van Luit, 1998). When resultative counting, students begin with the number one, every object is counted once, and students say the last number name when enumerating the number as the total number of objects. In resultative counting students demonstrate the principles of stable order and cardinality (Gelman & Gallistel, 1978). Therefore, students who count resultatively are called counters because they accurately count objects or pictures and can accurately answer how many (Clements & Sarama, 2010).

Students who understand that counting is relevant to circumstances in which a certain number must be created are referred to as producers (Clements & Sarama, 2010). This denotes the last stage of counting which is shortened counting (Van De Rijt & Van Luit, 1998). Shortened counting requires the application of the principle of irrelevance because students view numbers in a flexible way (Gelman & Gallistel, 1978). In order to see numbers in a flexible manner, students must recognize the representation of a number. Therefore when employing shortened counting, students count on from a representation of a number they see. For example, looking at a domino, the student would see two dots on one piece and three dots on another piece. Instead of having to touch each dot starting with one, the student would say two and continue to count the remaining dots on the other piece.

Counting Instruction

Promising research exists about effective curricula and building children's understanding of numbers. Toll and Van Luit (2014) investigate two kindergarten remedial programs to build number sense. Both programs have children work with numbers, and perform simple number operations. However, the second program was an accelerated version of the systematic comprehensive program. Students who were identified as at-risk for mathematics difficulties and received the remedial interventions made greater gains for both remedial programs investigated. Although the study addresses the need for intensive remedial numeracy instruction, more research should be conducted on interventions that specifically target counting skills and includes students with autism spectrum disorder or other developmental disabilities.

Mononen, Aunio, and Koponen (2014) examine the effects of early numeracy instruction for students in kindergarten with specific language impairments (SLI). The numeracy instruction incorporates guided instruction that encourages students to subtilize numbers and find groupings of numbers within larger quantities. For example seven can be taught as two and five, and students use manipulatives to see two and five make up the amount of seven. Findings indicate students with SLI improved their counting abilities to the level of their peers, performed similarly to their peers in addition and subtraction, but also showed weaker skills in arithmetic reasoning and in matching spoken and printed multi-digit numbers.

The *Additional Early Mathematics* (AEM) program (Van De Rijt & Van Luit, 1998) is another program shown to improve children's understanding of numbers. AEM includes guided or structured instruction and teachers chose the materials and activities that fit with the abilities of the student. Guided instruction involves the teacher observing students solving problems and providing them feedback. Throughout instruction, the teacher makes suggestions and models solving problems. Results suggest children receiving AEM instruction made significant gains compared to the children receiving instruction in the control groups.

In a different study, Ramani and Siegler (2011) investigate the effects of playing an informal linear board game to build number line estimation, magnitude comparison, numerical identification and arithmetic learning for preschoolers from low socio-economic backgrounds (Ramani & Siegler, 2011). Findings show that the linear board game improved children's knowledge of numeral identification, and the ability to solve novel arithmetic problems. Results also indicate students with low socioeconomic backgrounds made more gains than students with upper socioeconomic backgrounds.

Explicit Instruction and CRA/CSA as a Counting Intervention

Explicit instruction is shown as an effective intervention in teaching students with disabilities mathematical concepts (Adams & Engelmann, 1996; Engelmann & Carnine, 1982; Miller, 2009; National Mathematics Advisory Panel, 2008; Peterson, Mercer, & O'Shea, 1988). Authors (2015) examine the effects of explicit instruction using the concrete-representational-abstract sequence (CRA). CRA is also referred to as a concrete semi-concrete abstract (CSA) sequence in research literature. CRA/CSA involves three phases. They are a concrete phase that includes objects that are manipulated to show the mathematical concept, a representation phase that includes pictures to show the mathematical concept, and an abstract phase that involves the symbols used in mathematics such as numbers and number names.

The study employed a multiple baseline design in which students with mathematic difficulties receive counting instruction using objects for the concrete phase of instruction, pictures of objects for the representational phase of instruction, and pictures of objects with an emphasis of verbal identification of the quantity for the abstract phase of instruction. Steps in the provision of explicit instruction include: a) provide an advance organizer, b) demonstrate and model the skill, c) provide guided practice, d) provide independent practice, and e) provide a post organizer. In implementation of the advance organizer, the teacher makes sure students have the prerequisite knowledge to learn the skill, tells students what they are going to learn and builds relevance for the students. In the modeling phase of instruction, the instructor demonstrates the new mathematical concept or how to perform a skill. During guided practice, the instructor and students together perform the skill. After guided practice students perform the skill without teacher assistance, which is the independent practice phase of instruction. Even though students demonstrate the concept on their own during independent practice, the teacher does provide students with feedback on their performance, and will give assistance if it is required. In the last step, which is the post organizer, students and the teacher reflect and review what they learned.

To summarize, effective instruction can improve counting skills and number knowledge for students with mathematical difficulties. Instruction can range from informal games in preschool to more structured instruction in kindergarten. To date, there needs to be more research that targets counting and includes brief supplemental counting instruction using the CRA/CSA sequence provided for children with developmental disabilities who have mathematical difficulties and their peers. One way of providing mathematics intervention is through explicit instruction coupled with CRA/CSA. The purpose of this study is to examine the effects of CRA/CSA explicit instruction that focuses on improving counting skills for young children with developmental disabilities in an inclusive setting. The research question is to what extent are the effects of explicit instruction that is implemented using the CRA/CSA sequence on the shortened counting skills of students with and without developmental disabilities taught in an inclusive setting?

Method

Setting

This study was done in a three-week summer camp held in a large research university in the Southeast region of the United States. The purpose of the camp was to offer inclusive academic and social opportunities for children with and without disabilities. The camp included mathematic activity sessions, which incorporated instruction to build fluency in numerical operations. Mathematic activity sessions involved stations through which students rotated. Each station was approximately 15 minutes in length. Students played games at the stations to reinforce skills such as counting and operation knowledge with one station implementing the CRA/CSA counting instruction. The CRA/CSA instruction station was led by the researchers and certified teachers who were also graduate students.

Participants

Participants consisted of 24 boys and girls with and without a developmental disability. Thirteen students were identified as having a disability based on the local school district Individualized Educational Programs (IEP) provided by parents, and eleven students were reported to not receive special education services. Participants' ages ranged from age four through age eight. Five students were African American, two students were Asian, four students were Latino/a, and thirteen students were White. Data were also collected on students' completed grade level during the previous school year, mathematical ability, cognitive ability, and disability information based on students' IEPs (see Table 1).

Table 1
Demographic information of participants

Age	Grade Level	Mathematical Ability *a*	Cognitive Ability *b*	Disability Reported *c*
8.6	Kindergarten	<55	40	ASD
5.2	Pre-Kindergarten	90	109	None
5.4	Pre-Kindergarten	85	93	ID
7.9	Kindergarten	<55	58	ID
6.8	Kindergarten	71	77	DD
5.7	Pre-Kindergarten	95	100	SLD
8.0	First Grade	59	53	OHI
5.8	Pre-Kindergarten	104	99	None
6.2	Kindergarten	110	106	None
5.5	Pre-Kindergarten	64	82	OHI

5.6	Pre-Kindergarten	117	107	None
9.1	Second Grade	100	81	OHI
5.2	Pre-Kindergarten	99	88	None

(table continues)

a. Standard Score Test of Early Mathematics Ability (3rd Edition) (Ginsburg & Baroody, 2003).
b. Standard Score Kaufman Brief Intelligence Test (2nd Edition) (Kaufman & Kaufman, 2004).
c. Eligibility categories reported ASD is autism spectrum disorder, SLD is specific learning disability, ID is intellectual disability, SI is speech impairment, and OHI is other health impairment.

Table 1 (continued)
Demographic information of participants

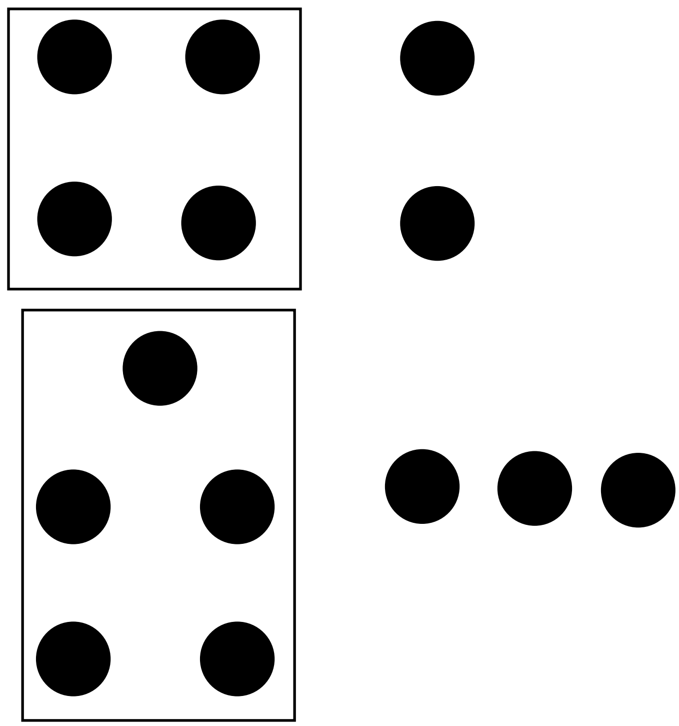
Age	Grade Level	Mathematical Ability *a*	Intellectual Functioning *b*	Disability Reported *c*
7.0	Kindergarten	<55	69	ID
6.5	Kindergarten	95	89	None
5.5	Pre-Kindergarten	109	97	None
6.3	Pre-Kindergarten	75	83	SI
5.3	Pre-Kindergarten	84	102	None
6.7	Kindergarten	70	71	ASD
6.5	Kindergarten	99	107	OHI
5.4	Kindergarten	117	104	None
6.3	Kindergarten	112	116	None
8.5	Kindergarten	<55	55	ID
7.2	Kindergarten	100	90	None

a. Standard Score Test of Early Mathematics Ability (3rd Edition) (Ginsburg & Baroody, 2003).
b. Standard Score Kaufman Brief Intelligence Test (2nd Edition) (Kaufman & Kaufman, 2004).
c. Eligibility categories reported ASD is autism spectrum disorder, SLD is specific learning disability, ID is intellectual disability, SI is speech impairment, and OHI is other health impairment.

Materials

Lesson materials included work mats, plates, counting objects such as bears and cubes, and lesson sheets that had drawings of circles students could count. Work mats consisted of construction paper or a blank sheet of paper the researchers and students placed objects on to count. The plates helped students organize the objects they were counting and see the numeric amounts. Lesson sheets included numeric pictorial representations of circles which ranged from numerical representations of one to ten. The first three lessons for each counting skill involved objects students counted using work mats and plates. Flash cards were used at the beginning of the lessons in which each card had a specific number of circles that represented a certain number. Students would count the amount of circles on the cards without touching.

Figure 1. Example of Counting Probes Sets



Procedures

There were a total of four mathematics stations in which one of the four stations included CRA/CSA counting instruction. Three stations involved activities such as reading a book and incorporating mathematics problem solving, identifying quantities using dominos, and identifying numbers using dice games. Students rotated to each station every 15 minutes. Each station was led by a certified teacher. Teachers who led the CRA/CSA counting station were trained during orientation. Researchers modeled each step of explicit instruction for each phase of instruction. After modeling teachers and researchers practiced each step of instruction together. Finally, teachers were required to independently implement the steps of explicit instruction for each phase of CRA/CSA until fidelity was at 100 percent.

The independent variable was the CRA/CSA instruction. CRA/CSA counting instruction comprised explicit instruction. Each phase of instruction consisted of an advanced organizer in which the teacher reviewed counting using one to one correspondence, and explained to students that they were going to learn flexible ways of counting. After the advanced organizer the teacher modeled counting on for each phase of instruction. Once the teacher modeled counting on, students were invited to count on with the teacher. Then after counting with teacher assistance, students were directed to count on independently. When students counted on independently the teacher provided feedback. In the concrete phase students counted using colored bears. In the representational phase students counted using flashcards with dots and tens frames. For the abstract phase students counted on quantities that were represented by worksheets. In the abstract phase students were expected to state the number that symbolized the total quantity that was counted.

The dependent variable was students' performance on a curriculum based probe that measured shortened counting. The assessment consisted of dots outlined in a box and dots that were not outlined (see Figure 1). Students were directed to count the dots and state how many in all. They were told that they could say the amount inside the box and continue counting. Pre and posttests were administered to gather information on students' ability to count using shortened counting.

Procedural Integrity and Interrater Reliability

Procedural integrity data were collected throughout the study. The procedural checklist included the following: (a) administration of assessment prior to lesson implementation; (b) application of advanced organizer; (c) execution of modeling and demonstration of shortened counting using objects, drawings, or numbers only; (d) use of guided practice in shortened counting using objects, drawings, or numbers only; (e) inviting students to count independently with teacher feedback on student responses; and provision of a post organizer. A teacher completed the checklist during instructional lessons. The primary or second author observed lessons every day. A checklist was completed while observing instructional lessons at least once a week by the second author for a total of 25 percent of lessons for each instructional phase. The observers' checklists indicated 100 percent integrity. The two checklists (observer and teacher) with corresponding dates were compared to compute interobserver agreement. Interobserver agreement was calculated at 100 percent. All pre and posttest assessments were observed and checked for accuracy by the first and second authors. Interobserver agreement was computed by adding the agreements and dividing the number of agreements and disagreements. Interobserver agreement was calculated at 100 percent.

Results

A paired samples *t*- test was conducted to evaluate differences in pre and posttest measures of children's counting skills. The results indicated a significant difference in pre and posttest scores ($M = 5.64$, $SD = 3.50$, $t(23) = -8.06$, $p = 0.00$). Effect size was calculated using Cohen's *d*. Cohen's *d* was calculated as 1.6 which indicates a large effect size. The mean and standard deviation for pre and posttest measures are presented in Table 2.

Descriptive statistics were examined. There were statistically significant differences among mathematics achievement scores of students identified as having a developmental disability versus not identified as having a developmental disability. Students receiving special education services and identified as having a developmental disability scored significantly lower with an average standard score of 74 compared to their peers who were not identified as having a disability demonstrated an average standard score of 104.

Before receiving instruction on counting there were no significant differences in the participants' ability to count using shortened counting. This means that students whether identified as having a developmental disability or not only counted using resultative counting instead of the more flexible shortened counting. As a total group, all participants averaged one set counted correctly before instruction began. After receiving instruction the average score for all participants was six sets counted correctly.

Table 2
Mean and standard deviation for pretest and posttest scores

Condition	*N*	Mean	*SD*
Pretest Students with Disabilities	13	0.36	1.35
Pretest Students without Disabilities	11	0.72	1.68
Pretest Total	25	0.52	0.30
Posttest Students with Disabilities	13	5.21	4.21
Posttest Students without Disabilities	11	6.27	4.36
Posttest Total	24	5.68	4.22

Discussion

The purpose of this study was to examine the effectiveness of explicit instruction using CRA/CSA in improving the counting skills for students with developmental disabilities in an inclusive setting. The findings of this study are congruent with previous research in that CRA/CSA and explicit instruction was an effective means to teach students who struggle with mathematical concepts mathematic skills (Miller, 2009; National Mathematics Advisory Panel, 2008). It is important for students to learn how to count in flexible ways because it builds awareness of numbers (Kroesbergen et al., 2014). The awareness of numbers is critical to a good foundation in mathematics and students' mathematical foundation has a lasting impact that is carried throughout their school years (Gersten & Chard, 1999; Jordan et al., 2007). One of the primary ways children build number knowledge is through counting and learning to count in a flexible manner (Clements, 1999; Kroesbergen et al., 2014). Therefore it is essential that students have the opportunity to learn how to count on and manipulate quantities of numbers in flexible ways. This study showed that explicit instruction using CRA/CSA for counting was an effective way to teach children with developmental disabilities in an inclusive setting in which peers without developmental disabilities also gained from the instructional experience. Even though there were significant differences among the groups of children with and without developmental disabilities, all children displayed difficulty in shortened counting which is considered the last stage in the development of counting skills (Van De Rijt & Van Luit, 1998). Teachers often provide instruction in which students' count using one to one correspondence and displaying cardinality. However, more instruction needs to be implemented in which children count quantities in different ways that build higher conceptual understandings in the magnitude and representation of numbers. This intervention provided an explicit way of moving students from basic counting using one to one correspondence to a more fluid manner of identifying quantities using shortened counting.

It is important that teachers help students learn to see numbers in a fluid way because it is required in developing more sophisticated understandings of mathematical concepts (National Council of Teachers of Mathematics, 2000). Perhaps if teachers can deepen students' numeric understandings then it is possible their performance in mathematical operations will improve as a result. Also if students begin their early years with higher counting abilities, then greater gains can be made as they progress through school. Such counting skills are important for all students and explicit instruction is a way of building students' with developmental disabilities knowledge base in an inclusive setting in which they have access to instruction alongside their peers.

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