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Using the concrete-representational-abstract approach to support students with intellectual disability to solve change-making problems

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A B S T R A C T

Background/aims/methods: The Concrete-Representational-Abstract (CRA) instructional approach supports students with disabilities in mathematics. Yet, no research explores the use of the CRA approach to teach functional-based mathematics for this population and limited research explores the CRA approach for students who have a disability different from a learning disability, such as an intellectual disability. This study investigated the effects of using the CRA approach to teach middle school students in a self-contained mathematics class focused on functional-based mathematics to solve making change problems. Researchers used a multiple probe across participants design to determine if a functional relation existed between the CRA strategy and students' ability to solve making change problems.
Procedures/outcomes: The study of consisted of five-to-eight baseline sessions, 9–11 intervention sessions, and two maintenance sessions for each student. Data were collected on percentage of making change problems students solved correctly.
Results/conclusions: The CRA instructional strategy was effective in teaching all four participants to correctly solve the problems; a functional relation between the CRA approach and solving making change with coins problems across all participants was found.
Implications: The CRA instructional approach can be used to support students with mild intellectual disability or severe learning disabilities in learning functional-based mathematics, such as purchasing skills (i.e., making change).
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What this paper adds?

This papers adds to the limited literature examining the CRA approach to support students with disabilities in learning functional-based mathematics, such as purchasing skills. The CRA instructional sequence is an evidence-based approach to teaching students with learning disabilities, but additional research – such as this study – is needed to demonstrate its effectiveness with students with other disabilities, such as intellectual disability, and with more functional-based mathematics as opposed to more academic mathematics (e.g., double-digit subtraction with regrouping).

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1. Introduction

Functional (or life skills) mathematics – the mathematics related to living, working, participating, and accessing services in everyday life – is important for all individuals, but particularly students with disabilities (Burton, Anderson, Prater, & Dyches, 2013). Functional mathematics, like all functional domains (e.g., vocational skills and daily living skills), teaches students to maximize their own independence (Bouck & Joshi, 2012). Additional research, such as this study, is needed to find research-based approaches to teaching functional mathematical content to students with intellectual disability.

One important domain of life skills mathematics is purchasing skills (Alwell & Cobb, 2009; Xin, Grasso, Dipipi-Hoy, & Jitendra, 2005). Purchasing skills refer to the skills related to engaging in financial transactions to obtain services or goods (Browder, Spooner, & Trela, 2011); purchasing skills include such skills as navigating a store, comparing prices, and using money (e.g., making change; Mechling & Gast, 2003). Previous researchers suggested the value in helping students to become more independent with purchasing skills, including making change (c.f., Cihak & Grim, 2008). Cihak and Grim (2008) successfully taught purchasing skills to secondary students with autism and intellectual disability via the counting-on and next-dollar strategies. The students acquired as well as maintained and generalized the skills. In another study, Burton et al. (2013) found video self-modeling as an effective instructional strategy to teach students with autism and intellectual disability to estimate the amount they would need to pay for an item as well as the change they would receive.

As found by Burton et al. (2013), video modeling was an effective strategy for helping students with autism and intellectual disability determine the change they would receive from making a purchase. Video modeling is considered an evidence-based practice (Wong et al., 2014) and is used extensively to provide instruction to students with disabilities, particularly students with autism and intellectual disability (Ayres, Mechling, & Sansosti, 2013; Odom et al., 2015), including in mathematics. For example, Yakubova, Hughes, and Hornberger (2015) successfully used video modeling to teach three high school students with autism to solve mixed fraction word problems. However, video modeling possesses limitations as well as benefits (e.g., effective strategy). For some schools the implementation of video modeling can be cost prohibitive, as they would need to purchase tablets (Weng & Bouck, 2014). Teachers have also expressed concerns that creating video models is both time consuming and challenging (Carnahan, Basham, Christman, & Hollinghead, 2012; Weng, Savage, & Bouck, 2014). This study examined an alternative approach to the effective and evidence-based approach of video modeling with regards to supporting students with intellectual disability in learning functional mathematics content, to provide teachers options to consider when teaching such mathematical content.

Researchers sought to find other effective mathematical strategies for students with disabilities. For example, some researchers explored the Concrete-Representational-Abstract (CRA) approach to teaching mathematics to students with autism and/or intellectual disability (Flores, Hinton, Stroizer, & Terry, 2014; Stroizer, Hinton, Flores, & Terry, 2015; Yakubova, Hughes, & Shinaberry, 2016). The previous studies of the CRA approach involving students with intellectual disability and/or autism suggest the benefit of such approach, with all demonstrating a functional relation between the CRA approach and students' solving mathematical problems. However, the three previous studies examining the CRA approach for students with intellectual disability and/or autism involve basic operations, such as addition, subtraction, and multiplication (Flores et al., 2014; Stroizer et al., 2015; Yakubova et al., 2016). To date, no study examines the CRA approach to support functional mathematical content, such as change-making problems with students with intellectual disability or other disabilities. Hence, this study fills an important niche in the research base for both the CRA instructional strategy and for teaching mathematical content to students with intellectual disability.

The CRA approach is a graduated sequence of instruction, which moves students from solving mathematical problems (e.g., subtraction with regrouping) with concrete manipulatives (e.g., base 10 blocks) to solving the problems with drawings or representations of the objects (e.g., lines and dots). Finally, students learn to solve the problems abstractly, without any support or aids (Agrawal & Morin, 2016). The CRA approach is built upon the instructional strategy in mathematics known as explicit instruction; explicit instruction is considered an effective or recommended instructional approach for students with disabilities (Gersten et al., 2009). When a teacher uses explicit instruction in mathematics s/he models how to solve mathematical problems, such as subtraction with regrouping, through demonstrations and think-alouds. Next, the teacher moves onto providing prompts and cues as needed when students solve the problems themselves (i.e., guided instruction). Last, the students engage in independent practice in solving the mathematical problems (Doabler & Fien, 2013).

The CRA begins with teachers teaching students to solve a type of mathematics problem (e.g., multiplication with regrouping) with concrete manipulatives. To do so, teachers use the principles of explicit instruction to first model (i.e., demonstrate how to solve with the concrete manipulatives and use think-alouds to explain) with a few problems. Next, teachers guide students as they solve a few problems with the concrete manipulatives, meaning they provide prompts and cues as needed. Finally, students solve some mathematical problems independently with the concrete manipulatives. The same procedures are repeated for the representational phase in which students draw pictures or images to represent the concrete manipulatives, and then finally the abstract phase where students solve the problems without additional supports (Agrawal & Morin, 2016; Mancl, Miller, & Kennedy, 2012). Generally, students need to achieve 80% correct or better across three sets of independently solved math problems to move from concrete to representational and then from representational to abstract (Mancl et al., 2012).

The CRA approach has an extensive research base, spawning multiple decades and across different mathematical skill areas (e.g., place value, fractions, subtraction with regrouping, algebra) (Bouck & Park, 2016). Across the multiple studies – both single case design studies and group design studies, researchers found students were able to make gains in their

Table 1
Participants' Demographic Information.

Student	Diagnosis	IQ	Ethnicity	Age	Grade	Math Achievement (STAR)
Carly	Intellectual Disability	68 (WISC-IV)	Caucasian	12	6	2.5
Mark	Learning Disability	92 (RIAS)	Caucasian	13	6	2.1
Joe	Intellectual Disability	56 (WISC-IV)	Caucasian	12	6	2.3
Blake	Learning Disability	74 (WJ-III-Cog)	Caucasian	12	6	1.5

Note: WISC-IV = Wechsler Intelligence Scale for Children-Fourth Edition, RIAS = Reynolds Intellectual Assessment Scale, WJ-III-Cog = Woodcock-Johnson Tests of Cognitive Abilities-Third Edition.

ability to solve the mathematics problems when using the CRA approach (c.f., Butler, Miller, Crehan, Babbitt, & Pierce, 2003; Flores, 2010; Maccini & Hughes, 2000; Mancl et al., 2012; Witzel, Mercer, & Miller, 2003). However, the majority of the research on CRA was conducted with students with learning disabilities. The majority of the research on CRA also focuses on largely academic mathematical concepts, such as place value, basic operations (e.g., subtraction, multiplication), and algebra (Bouck & Park, 2016; Bouck, Satsangi, & Park, 2016). Little-to-no research exists that explores the CRA approach to support students with disabilities in learning more functional-based mathematics, such as purchasing skills, and limited research (n = 3) examines the CRA instructional sequence for students with intellectual disability. Yet, the CRA approach is an evidence-based practice for students with learning disabilities and works to build conceptual understanding – a goal of all mathematics education, including functional mathematics (Bouck et al., 2016; Mancl et al., 2012). This study sought to explore the potential of an evidence-based mathematical approach for students with learning disabilities to educate students with intellectual disability in functional mathematics content.

As a result of the potential CRA instruction to support students in understanding mathematic concepts and solving real-world problems, this study investigated how students with intellectual disability solved word problems involving making change with coins with the CRA approach. The research questions for this study include: (a) To what extent do secondary students with disabilities improve their performance on solving change-making with coins word problems following instruction via the CRA sequence?; (b) To what extent do secondary students with disabilities maintain performance on solving change-making with coins word problems two weeks after instruction ends?; and (c) To what extent do secondary students with disabilities and their teacher find the CRA strategy beneficial?

2. Method

2.1. Participants

Four middle school students participated in the study. The same teacher taught all students in the same pullout special education classroom. The middle school the students attended provided three pullout special education options; the teacher reported her class was the middle option, meaning the students' functioning was deemed between the higher level functioning room in which more academics were taught and the lower functional pullout classroom in which the total focus was on life skills instruction. The focus of this pullout class was a balance between academics and functional life skills, such as money. The participants were selected for the study based on the following criteria: (a) teacher recommendation as a potential good fit for the study given each student's lack of mastery of making change despite repeatedly working on it in class; (b) a goal or focus of their mathematics instruction involved purchasing skills; (c) ability to discriminate coins (i.e., penny, nickel, dime, and quarter); (d) ability to add money without regrouping; (e) having not yet mastered making change with money at the level of coins; and (d) adequate fine motor ability to use concrete manipulatives (e.g., coins). Students who did not meet these criteria were excluded. The target population was students with intellectual disability, but given that by law services are not provided to students based on disability category, the researcher included any student in the self-contained class, regardless of their disability, who met the inclusion criteria (Yell, 2012).

2.1.1. Carly

Carly was a 12-year-old female Caucasian student in sixth grade. Carly was a shy girl who enjoyed math. Her teacher stated that she was a hard worker. Her special education eligibility was in the area of mild intellectual disability. According to the *Wechsler Intelligence Scale for Children-Fourth Edition* (WISC-IV; Wechsler, 2004), Carly's full-scale IQ was 68 (see Table 1). According to subtest of the WISC-IV, her standard score was 64 on the Math Problem Solving subtest and 66 on the Numerical Operations. Her performance on the *STAR Math Assessment* (Renaissance, 2016) suggested a second grade (2.5) grade-equivalent mathematics performance. Carly's IEP goals for math included adding and subtracting money in dollars only, or in cents only, up to and including $10.00.

2.1.2. Mark

Mark was 13-year-old male Caucasian student in sixth grade. Mark was a calm and positive young man who had a lot of patience. His special education eligibility was in the area of specific learning disability for math calculations and math reasoning. According to his performance on the *Reynolds Intellectual Assessment Scale* (RIAS; Reynolds & Kamphaus, 2009), Mark's full-scale IQ was 92. His performance on the mathematics subtests of the *Wechsler Individual Achievement Test-Third Edition* (WIAT-III; Psychological Corporation, 2009) indicated a Math Problem Solving standard score of 64 and Math Calculations score of 64. Mark's math score on the *STAR Math Assessment* (Renaissance, 2016) suggested grade-equivalent mathematics performance at the second grade level (2.1). Mark's IEP goals for math were fluently add and subtract within 100 using strategies based on place value, properties of operations, and/or the relationship between addition and subtraction.

2.1.3. Joe

Joe was 12-year-old male Caucasian student in sixth grade. Joe was pleasant young man who liked talk but was hesitant to engage in math sometimes out of fear of making a mistake. His special education eligibility was in the area of intellectual disability. According to his performance on the *WISC-IV* (Wechsler, 2004), Joe's full-scale IQ was 56, indicating mild intellectual disability. According to subtest of the WISC-IV, his standard score was 75 on the Math Problem Solving subtest and 67 on the Numerical Operations. Joe's score on the *STAR Math Assessment* (Renaissance, 2016) suggested second grade (2.3) grade-equivalent mathematics performance. Joe's IEP goals for math included adding, subtracting, multiplying and dividing whole numbers fluently.

2.1.4. Blake

Blake was 12-year-old male Caucasian student in sixth grade. Blake was a friendly young man who enjoyed playing games. He always had a positive attitude when he worked with the researchers and genuinely enjoyed doing mathematics. His special education eligibility was in the area of specific learning disability for math calculations and math reasoning. According to his performance on the *Woodcock-Johnson Tests of Cognitive Abilities-Third Edition* (WJ-III-Cog; Woodcock, Mather, & McGrew, 2001), Blake's Global Intellectual Ability score was 74. His performance on the *Woodcock Johnson Tests of Achievement-Third Edition* (WJ-III-Ach; Woodcock, Mather, & McGrew, 2001) indicated a Math Calculations standard score of 59, a Math Fluency score of 75, and an Applied Problems score of 78. Blake's score on the *STAR Math Assessment* (Renaissance, 2016) suggested a first grade (1.5) grade-equivalent performance. Blake's IEP goals for math including telling the amount of money, including cents up to and including $1, in dollars up to and including $100.00.

2.2. Setting

The study was conducted in a public middle school within a rural town in a Midwestern state. At the time of data collection, the school enrolled approximately 712 students in sixth through eighth grade. Approximately 86% of the students were Caucasian, 12% Hispanic, 1% Multiracial, and less than 1% were African American and Alaska Native/American Indian. Additionally, approximately 16% of the students were identified as students with disabilities. All sessions – including baseline, intervention, and maintenance sessions – occurred in the hallway just outside the students' special education classroom during the time of the students' designated math class. The hallway was equipped with one table and two chairs. It was generally quiet in the hallway as all students were in classes during that time and many classes operated with their doors closed. All participants worked one-on-one with a researcher throughout the study.

2.3. Materials

The study involved multiple materials, including learning sheets and coin manipulatives. Each learning sheet contained two modeled problems, two guided problems, and five independent practice problems (i.e., the probe). The learning sheets were 8.5- $\times$ 11-inch sheets of paper; all problems on learning sheets were similar, but no problems repeated anytime throughout the study. An example problem is "At the store, John bought a pencil. His total was $0.37. He gave the cashier $1.00. How much change should John get back?" In each problem, students solved to determine how much change an individual should receive with just coins. The manipulative, for the concrete phase, consisted of realistic plastic coins and paper bills. The manipulatives were similar to ones the teacher had available and students used in her class. At each session, students were provided the learning sheets and a pencil.

2.4. Independent and dependent variables

The independent variable was the CRA instructional sequence for solving change-making with coins problems. In the concrete phase, students used plastic coins and paper bills to solve the problems. In the representational phase, students drew images (i.e., circles with numbers [5, 25] or rectangles) to represent coins and bills to solve the problems. Finally, during the abstract phase, students solved the problems without any support. The dependent variable was the percentage of correctly completed change-making with coins problems during the independent portion of the learning sheet. Each sheet consisted of five problems and during each session (e.g., Concrete Session 1 or Abstract Session 2) all students were given the same probe.

2.5. Experimental design

A multiple probe across participants design was used to examine the effectiveness of the CRA instructional sequence in teaching students to solve change-making with coins problems (Gast & Ledford, 2014). A multiple probe across participants design was selected because students demonstrated similar learning challenges relative to the dependent variable examined. Yet, a multiple probe, versus a multiple baseline, was implemented to minimize the number of baselines probes students who received the intervention later would need to take; the multiple probe across participants design allowed researchers to deliver baseline probes intermittently rather than continuously (Gast & Ledford, 2010). This multiple probe across participants design study involved introducing the intervention phase to subsequent participants when the prior participant reached some criteria, which helped to protect against internal validity threats (Gast & Ledford, 2010).

All data collection occurred one-on-one with a member of the research team. Consistent with a multiple probe design, all students began baseline simultaneously. The first student – Carly – moved into intervention (i.e., concrete phase) after demonstrating a stable baseline across five sessions. When Carly achieved 80% or higher on each of three intervention sessions (i.e., mastery criterion) in the concrete phase, the other participants participated in additional baseline session, and then Mark started the first intervention lesson. When Mark reached the mastery criterion on three intervention sessions for the concrete phase, an additional baseline probe was administered to Jay and Blake, and then Jay started the intervention lessons. When Jay reached the 80% mastery criterion on three intervention sessions, the final baseline session was administered to Blake, and then he started the intervention lessons with the concrete manipulatives. A criterion of 80% mastery was established for all intervention sessions, meaning to move from concrete to representational and then from representational to abstract each student must achieve 80% correct on three probes, consistent with the implementation of other CRA researchers; c.f., Mancl et al., 2012; Stroizer et al., 2015). Students who failed to meet the criterion repeated the lesson prior to moving on to the subsequent lesson. Students would, in theory, repeat a lesson until they achieved a score of 80% or higher on said lesson.

2.6. Procedures

All data collection occurred at the classroom instructional table located just outside the room in the hallway. All data collection occurred one-on-one with a member of the research team and occurred during students' mathematics class. The second author, a doctoral student in a special education program and a secondary special education teacher with previous experience conducting research involving secondary students with intellectual disability, provided all the intervention sessions to all students. She was trained by the first author, a special education faculty member well-versed in developing and conducting mathematical interventions for students with intellectual disability. Mastery for delivering the intervention was assured prior to the researcher working with students.

Sessions occurred two days a week for 11 weeks; all sessions during occurred within a single class period of 55 min. Baseline sessions were shorter, generally less than five minutes for each student. Intervention sessions lasted between 10 and 20 min per student. The researcher typically conducted two-to-four intervention sessions in one 55-min period, each with a different student. In other words, students experienced no more than two sessions per day, although that was rare (i.e., the majority of the time each student experienced only one session per day). No intervention session was stopped for time. Note, no student had previous experience being taught with the CRA instructional sequence for any mathematics content and the teacher had not previous, nor did she during the study, provide instruction to the students via the CRA approach.

2.6.1. Pre-assessment

Prior to baseline, the eight students completed a pre-assessment to determine whether the students are eligible for this study. First, researchers gave each student a sheet with discriminating coins problems (e.g., show me the dollar, show me a quarter) and then researchers requested them to show money (e.g., show $1.12). Finally, researchers asked them to solve adding money problems (e.g., $0.32 + $0.55).

2.6.2. Baseline

The baseline phase for each student consisted of a minimum of five sessions; in each session students solved five change-making with coins problems independently on the probe. No manipulatives and prompting were provided to students during baseline. To move from baseline to intervention, in addition to the previous student reaching mastery criterion, each student needed a stable baseline. Researchers defined a stable baseline as 80% of data falling within 20% of the median (Gast & Ledford, 2014).

2.6.3. Intervention

Consistent with CRA administration (cf., Mancl et al., 2012), each student participated in a minimum of nine intervention sessions. In each session, a researcher provided a student with a lesson administrated via explicit instruction. To start, the researcher modeled how to solve two problems. Within the modeling portion of the learning sheet, the researcher demonstrated how to solve while using think-alouds. For example, she would read the problem, model her thinking verbally, and show how she was solving, such as by using manipulative coins, drawings, or abstractly. Next, the researcher provided prompts or cues for students to solve two problems, including asking students what to do next if they were stuck and/or providing immediate corrective feedback. Note, students worked to independently solve the problems; prompts or cues were provided by the researcher only as needed. Finally, students each solved five problems independently, similar to baseline. During the independent portion, which consisted of the probes for the dependent measure, no prompts or feedback were provided. The same procedures occurred regardless of the phase – concrete, representational, abstract. As previously indicated, if the student answered 80% or more correct during the independent phase after three sessions, s/he moved on to the next lesson at his/her next session; if a student failed to achieve 80%, then s/he would repeat the lesson at the next session.

2.6.3.1. Concrete phase. The first three lessons involved concrete manipulatives. As noted, the manipulatives were plastic coins (i.e., pennies, nickels, times, quarters) and paper bills (i.e., $1). The researcher started each concrete lesson by modeling and using think-alouds to solve two problems with the concrete money manipulatives. Next, the researcher provided cues and prompts as each student solved two similar problems with the concrete manipulatives (e.g., what do you do next?; is that that correct coin; what cents did you start at?). Finally, the student solved five problems with the concrete money manipulatives independently. Once a student solved 80% of the independent problems correctly for three sessions, s/he moved onto the representational phase. For any lesson in which a student scored less than 80% correct, s/he repeated the same lesson the next session.

2.6.3.2. Representational phase. The next three lessons involved representing or drawing pictures to aid students in solving the problems. Students were taught to draw a rectangle and write a 1 inside for a dollar bill and draw different size circles and write 1, 5, 10, and 25 inside for the penny, nickel, dime, and quarter, respectively. As noted, the researcher started each representational lesson by modeling and using think-alouds to solve two problems with the drawings to represent the coins and bills. Next, the researcher provided cues and prompts, as needed, as students solved two similar problems with the student drawing the pictures to help him/her solve the problem. Finally, the students solved five problems with representing the money independently. Once a student solved 80% of the independent problems correctly for three sessions, s/he moved onto the abstract phase. As with the concrete phase, for any lesson in which a student scored less than 80% correct, s/he repeated the same lesson the next session.

2.6.3.3. Abstract phase. The final three lessons involved solving the problems abstractly – without concrete manipulatives or drawing to represent the coins. As with the other phases, the researcher demonstrated how to solve the problems abstractly by thinking aloud only during the abstract phase (e.g., "If Bill pays $1 and the ice cream costs $0.91, I need to add up from $0.91 to $1. $0.91 plus 1 penny is $0.92, two pennies $0.93," and so on). Next, within the guided practice, the researcher provided cues and prompts as students solved two similar problems. Then, the students completed the independent practice section of the learning sheet abstractly. Once a student solved 80% of the independent problems correctly for three sessions, s/he was done with the intervention phase. As with the two previous phases, for any lesson in which a student scored less than 80% correct, s/he repeated the same lesson the next session.

2.6.4. Maintenance

Two probes were conducted for each student during maintenance. Each student completed the two maintenance sessions two weeks after his/her last abstract session in which s/he correctly answered 80% or more. As with baseline and all intervention phase sessions, students were given a probe containing five change-making with coins problems. Students were not given any manipulatives or allowed to draw, but solved the problems as they did in the abstract phase – abstractly. The researchers provided no prompting during this phase.

2.7. Inter-observer agreement and treatment fidelity

Inter-observer agreement (IOA) data and treatment fidelity were recorded to assess whether the interventions were being implemented as designed. Two independent scorers recorded IOA data for one-to-two sessions per phase, resulting in at least 33.3% of probes checked for IOA per student. The percent agreement for data collected was calculated by dividing the number of agreements by the total number of agreements plus disagreements and multiplying the quotient by 100. Inter-observer agreement was 100% for all students, across all phases. The first observer was the researcher who acted as the interventionist, a doctoral student who was a former special education teacher. The second observer as a special education professor with experience conducting single case studies, mathematical interventions, and working with students with intellectual disability.

A checklist was used to assess treatment fidelity during the intervention phases. The checklist involved each student receiving the materials, as appropriate; the researcher reading aloud the problems, depending on students' preference; and the researcher implementing the appropriate aspect of explicit instruction (i.e., modeling, prompting, or allowing the student work independently). Treatment fidelity data were collected for a minimum of 33.3% of all intervention sessions for all three students. Treatment fidelity was 100% for all students across all phases and intervention portions.

Table 2
Participant Accuracy Data Across CRA Phases.

		Carly	Mark	Joe	Blake
Baseline	Range	0	0	0	0
	Average	0	0	0	0
	# of sessions	5	6	7	8
Intervention–Concrete	Range	80–80	40–100	80–100	80–80
	Average	80	80	93.3	80
	# lessons repeated	0	1	0	0
Intervention–Representational	Range	80–100	80–100	80–80	80–100
	Average	93.3	86.7	80	93.3
	# lessons repeated	0	0	0	0
Intervention–Abstract	Range	80–80	60–100	60–100	20–100
	Average	80	80	80	72
	# lessons repeated	0	1	1	2
Maintenance	Range	80–80	60–80	60–100	80–80
	Average	70	70	80	80

Note: Average excludes any lesson that were repeated because the student scores less than 80%; range includes the sessions in which scores were less than 80% and lessons were repeated.

2.8. Social validity

Brief interviews were conducted at the end of the study with the teacher and the students. Students were asked questions regarding their perceptions of the CRA instruction, including which phase and instruction (e.g., CRA vs. traditional) they preferred. Specifically, the students were asked if they liked solving the problems best with coins (i.e., concrete), drawing the coins (i.e., representation), or without anything (i.e., abstract). The students were also asked if they liked moving from using plastic coins to drawing to answering the problems without anything as compared to always having to use plastic coins or just solving them without any supports.

The teacher was also interviewed regarding students' learning and her opinion of the benefits and challenges of using the CRA approach to teach students to solve making-change with coins problems. Prior to conducting the social validity interview with the teacher, the researcher demonstrated the CRA approach to the teacher to provide context. The teacher was also provided with copies of the students' assessments and scored responses.

2.9. Data analysis

To analyze the data, the researchers conducted a visual analysis. Researchers calculated level by finding the stability of the data in each phase. For this, researchers first calculated the median for the dependent variable for each phase for each student. If 80% of a student's data fell within 20% of the median, data were deemed stable (Gast & Spriggs, 2010). To determine trend, researchers used the split-middle method (White & Haring, 1980). Researchers determined the middle data point for each phase, calculated the mid-rate and mid-date, and drew a line between mid-rate and mid-date for both baseline and intervention phases to determine whether the line was accelerating, decelerating, or zero-celerating (Gast & Spriggs, 2010).

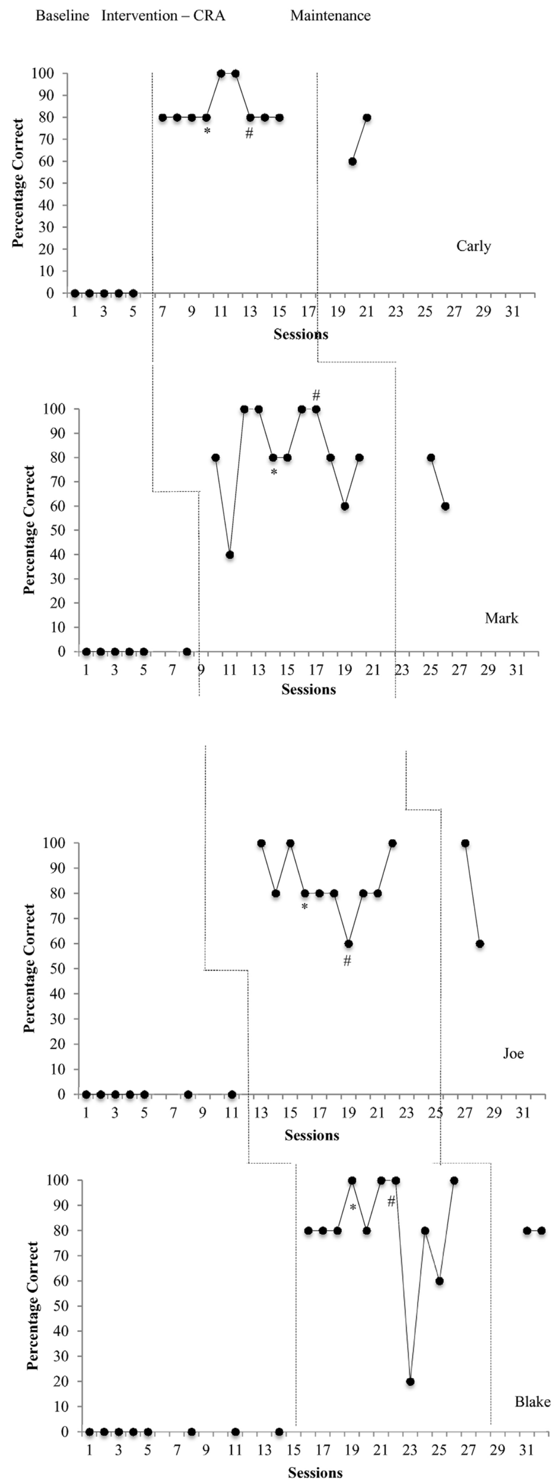
The researchers used Tau-U, which combined non-overlap between phases with trend from within the intervention phase, to determine the effect size for the intervention (Parker, Vannest, Davis, & Sauber, 2011). The researchers used a web-based online calculator (see http://www.singlecaseresearch.org/calculators/tau-u) to calculate Tau-U for the accuracy data. Tau-U scores less than or equal to 65% suggest a small effect, 66–92% a medium effect, and 93% and above a large effect (Parker, Vannest, & Brown, 2009).

3. Results

CRA instruction results showed an increased percentage of accurately solved problems for all four students as compared to their baseline levels (see Fig. 1). In other words, a functional relation existed between students being taught via the CRA instructional strategy and students' accurately solving change-making problems. There was a zero overlap in all students' baseline and intervention data (Tau-U = 100% for all students). All four students maintained solving making change with coins for up to two weeks after finishing the intervention phase, when comparing maintenance performance to that of baseline.

3.1. Baseline

Across all four participants, baseline scores were consistently 0 (see Table 2). In other words, no student answered any change-making with coins problems correct during baseline. Hence, all students had a stable and zero-celerating baseline when they entered the intervention phase with concrete manipulative lessons (see Fig. 1 and Table 3).



* Indicates first representational session (i.e., shift from concrete to representational phase)
# Indicates first abstract session (i.e., shift from representational to abstract phrase)

Fig. 1. Correct Percentage of Problems.

Table 3
Data Analysis Summary Across Participants.

Measure	Baseline	Intervention	Maintenance
Carly			
Range	0	80–100%	60–80%
Mean	0	84.4%	70%
Median	0	80%	70%
Stability	Stable	Variable	Stable
Trend	Zero-celerating	Zero-celerating	Accelerating
Tau-U [a]		100%	
PND		100%	100%
Mark			
Range	0	40–100%	60–80%
Mean	0	81.8%	70%
Median	0	80%	70%
Stability	Stable	Variable	Stable
Trend	Zero-celerating	Decelerating	Decelerating
Tau-U [a]		100%	
PND		100%	100%
Joe			
Range	0	60–100%	60–100%
Mean	0	84%	80%
Median	0	80%	80%
Stability	Stable	Variable	Variable
Trend	Zero-celerating	Decelerating	Decelerating
Tau-U [a]		100%	
PND		100%	100%
Blake			
Range	0	20–100%	80%
Mean	0	80%	80%
Median	0	80%	80%
Stability	Stable	Variable	Stable
Trend	Zero-celerating	Zero-celerating	Zero-celerating
Tau-U [a]		100%	
PND		100%	100%

Note: [a] denotes Tau-U between baseline and intervention.

3.2. Carly

When Carly started intervention with the concrete manipulatives, she experienced an immediate effect. From a last baseline score of 0, Carly's first score with the concrete manipulatives was 80%. Throughout intervention in the concrete, representational, and abstract phases, Carly repeated no lessons (refer to Table 2). In other words, she maintained a percentage score of 80% or greater when solving the change-making with coins problems independently, whether using concrete manipulatives, drawings, or solving abstractly. Visual analysis suggested no overlap in data occurred between the baseline and intervention sessions. Carly's intervention data were variable (i.e., 77.8% fell within 20% of the median [80]) and there was a zero-celerating trend (refer to Table 3). The Tau-U effect size was 100%, suggesting the CRA approach was a highly effective intervention for Carly. During the maintenance phase, Carly scored 60% and 80%, suggestive of a stable but accelerating trend. Her maintenance data also did not overlap with baseline data.

3.3. Mark

Like Carly, when Mark started intervention with the concrete manipulatives, he experienced an immediate effect. From a last baseline score of 0, Mark's first score with the concrete manipulatives was 80%. Throughout intervention in the concrete, representational, and abstract phases, Mark repeated only two lessons – one in the concrete phase and one in the abstract phase, resulting in 11 sessions for Mark (refer to Table 2). Visual analysis suggested no overlap in data between the baseline and intervention sessions. Mark's intervention data were not stable and there was a decelerating trend, which suggested greater performance during the concrete lessons (refer to Table 3). The Tau-U effect size was 100%, suggesting the CRA approach was a highly effective intervention for Mark. During the maintenance phase, Mark scored 80% and 60%; his maintenance data also did not overlap with baseline data.

3.4. Joe

When Joe started intervention with the concrete manipulatives, he also experienced an immediate effect. From a last baseline score of 0, Joe's first score with the concrete manipulatives was 100%. Throughout intervention, Joe repeated one lesson within in abstract phase, resulting in 10 sessions (refer to Table 2). There was no overlap in data between Joe's baseline and intervention sessions. Joe's intervention data were not stable and there was a decelerating trend, which suggested greater performance during the concrete lessons (refer to Table 3). The Tau-U effect size was 100%, suggesting the CRA approach was a highly effective intervention. During the maintenance phase, Joe scored 100% and 60%; his data did not overlap with baseline data.

3.5. Blake

When Blake started intervention with the concrete manipulatives, he experienced an immediate effect. From a last baseline score of 0, Blake's first score with the concrete manipulatives was 80%. Blake repeated two lessons within abstract phase, resulting in 11 sessions (refer to Table 2). There was zero overlap in data between the baseline and intervention sessions for Blake. Blake's intervention data were not stable and there was a zero-celeration trend (refer to Table 3). The Tau-U effect size was 100%, suggesting the CRA approach was a highly effective intervention for Blake. During the maintenance phase, Blake scored 80% on both probes.

3.6. Social validity

All four students responded positively about their perception of learning mathematics via the CRA approach. However, when asked if they would like to solve money problems using concrete, representational, or abstract materials, each student indicated they liked using coins compared to drawing. Joe responded, "I like coins. It is easier to count and grab." Blake explained he liked using coins because, "It helps me to learn faster. I enjoy money shapes." Blake stated, "Every time I draw coins, I get confused!" The students' teacher expressed positive impressions on the impact of the CRA instruction on her students. She thought the CRA sequence benefited her students in learning skills in a short time. She elaborated she would consider using this approach in the future, as she had not previously used it in her teaching. The study gave her a new approach of thinking about how to teach money problems – or even other types of math in which her students struggle. She felt her students really enjoyed solve change-making coins problems with CRA approach.

4. Discussion

This study explored the effectiveness of CRA instruction to teach four middle school students with disabilities to solve change-making with coins problems. Given the repeated demonstrations of the effectiveness of the CRA approach to support students with disabilities in learning different mathematical concepts (c.f., Flores, 2010; Flores et al., 2014; Witzel et al., 2003; Yakubova et al., 2016), the researchers explored the use for more functional-based mathematical content. In this study, the CRA approach was effective in teaching students to solve change-making problems during the intervention phase, although there was some decrease in performance during the maintenance phase. A functional relation was found between the CRA approach and change-making with coins performance across all students.

Consistent with previous research on the CRA approach, students experienced an immediate change from baseline to intervention in their performance of change-making problems (c.f., Flores, 2010; Stroizer et al., 2015). Given the low performance of all students in baseline and the lack of instruction in this area provided to students outside of the intervention sessions, the immediate jump from baseline (0) to all students' first intervention sessions (i.e., 80 or 100) can be attributed to the instructional approach. Further, and consistent with previously published research, students in general needed few lessons repeated (c.f., Mancl et al., 2012). Specifically, Carly needed zero lessons repeated, Joe one, and Mark and Blake each two; all repeated lessons occurred in the abstract phase of the CRA, but one of Mark's. Note, no student needed more no lesson repeated more than once. The data from this study support the effectiveness of the CRA approach across multiple mathematical concepts as well as disability categories. The data also highlight the struggle for these students in solving problems without any supports, to some extent. The abstract phase was the most challenging for students, as expected given the students were used to using concrete manipulatives to solve money problems in their general class instruction (e.g., Witzel et al., 2003). Note, the study occurred in the second semester and the teacher had previously taught students change making problems but identified it as an area of consistent struggle for the students in the study.

Further support for the effectiveness of the CRA, specifically with teaching students to solve the change-making problems in this study, is from the maintenance data, which were collected two weeks after the last intervention session. None of the students' maintenance data overlapped with their baseline data. While the students, with the exception of Blake, performed less than 80% on at least one maintenance probe, their success was still greater than during baseline. During baseline, all students answered zero problems correctly. By students generally maintaining their performance after intervention as well as correctly solving the problems in the abstract sessions, students may be able to continue to solve change-making problems in the longer term without manipulatives. For secondary students, concrete manipulatives can be stigmatizing, given most manipulatives are designed for younger children (Bouck & Park, 2016; Howard, Perry, & Conroy, 1995; Satsangi & Bouck, 2015). The stigmatization can include students using those manipulatives in general education settings in front of their peers or in community settings. While students in this study reported enjoying working with the manipulatives the best, and often were more accurate with the manipulatives (i.e., decelerating trend in intervention for some students), the reality of stigmatization as well as the challenge of using concrete manipulatives in everyday life or natural settings, suggests the benefits of using the CRA instructional strategy to help students solve mathematical problems in the abstract.

Yet, students did generally experience a decrease in accuracy during the maintenance phase (refer to Tables 2 and 3 and Fig. 1). Perhaps the two modeled problems during the abstract portion of intervention primed students to solve the problems independently. During the maintenance phase, the researchers did not model or prompt students prior or during their solving of the five problems. The two problems the researchers demonstrated before each session during intervention may have been the key to students' success in the abstract phase. Yet, as noted above, students were still more successful in the maintenance phase than baseline, suggestive of some degree of maintenance of learning.

As noted, the results of this study support the use of the CRA approach to teach change-making with coins problems with secondary students with disabilities. The CRA approach can and should be evaluated as an alternative to other means of teaching life skills mathematics to students with disabilities, such as video modeling (Burton et al., 2013; Yakubova et al., 2016). Although video modeling and the CRA approach were not compared in this study, the CRA is an efficient approach, at least in terms of change-making problems for secondary students with intellectual disability. The four students in this study completed the CRA sequence in 9–11 lessons; the CRA sequence also requires little preparation from teachers aside from developing the learning sheets and the time to deliver the lessons (i.e., in this study all sessions were completed in less than 20 min). In contrast, video modeling can require extensive time by educators, particularly with regards to developing the video models (Weng & Bouck, 2014). This study can be used to launch further investigations into the use of the CRA approach to support students learning life skills mathematics. However, to fully evaluate the impact on life skills a generalization phase is needed in future research. It is one thing to able to have students perform the functional mathematics skills on paper and another in an actual community setting.

4.1. Implications for practice

This study holds implications for practice as it suggests CRA instruction can successfully support students with intellectual disability with regard to change-making problems. The sequence of CRA helps students make sense of the abstract procedures used to solve making change by counting up with coins. General education teachers and special education teachers can consider implementing the CRA instructional sequence to teach making change. A further benefit to implementing the CRA approach for solving change-making with coins problems is that does not require many resources, but the needed materials (e.g., concrete manipulatives) can be obtained at low cost. In addition, this CRA instruction shows significant progress in a short period (e.g., each intervention session lasted 10–20 min).

4.2. Limitation and future directions

One limitation of this study was the lack of a generalization phase (i.e., solving the problems in vivo). The ultimate purpose of learning life skills is to be able to complete them in natural settings, such as grocery or convenience stores (Cihak & Grim, 2008). In future studies, researchers should include a generalization phase in a natural setting to determine how students can extend their learning within the classroom to actual settings in the community. A related limitation involved that the problems only involved coins, which is limiting in terms of natural experiences and settings. In non-contrived settings, students may need to make change with both coins and bills. Others may also view the multiple disability categories included as participants as a limitation. However, all students were served in the same classroom and had similar mathematical functioning levels (e.g., grade equivalencies). It is important to remember that a disability category does not define a student's educational programming (Yell, 2012).

An additional limitation of this study involved that it was conducted in the hallway. While typically the hallway was quiet, during one intervention and one maintenance sessions, each for a different student, it became noisy and the student was distracted (i.e., Blake's 20% during the abstract portion and Joe's 60% during maintenance). Yet, conducting the sessions one-on-one in the hallways allowed the researchers to minimize the potential effect of multiple probe across participant designs such that students' behavior (i.e., accuracy solving the problems) would not be inferred by observing another student in the study engage with the mathematics (Gast & Ledford, 2010).

Another limitation involved that the intervention was not delivered by the participants' teacher and removed from typical classroom instruction. Future research should explore the impact of teacher delivery of the CRA instructional strategy and delivered within the context of routine classroom instruction, but sensitive to the potential implication of observational learning. A final limitation involved that each probe involved only five problems; hence, phases in which students scored only 80% and 100% would still be considered variable data. Future research should consider probes with more problems.

Researchers should continue to study the CRA approach for a variety of students with disabilities, including students with intellectual disability and also for its use for more functional-based mathematics. This includes a replication and extension of this study to include a generalization phase. Generalization could involve taking the students to a convenience store to make a purchase and accurately determining the change they should receive. Replication of this study should consider other single case designs, as a limitation of multiple probe across participant design studies is that each participant demonstrates the effectiveness of an intervention (i.e., the CRA strategy) once (Gast & Ledford, 2010). The previous research on the CRA approach and students educated more in self-contained programs focused on more academically-oriented mathematics, such as addition and subtraction (e.g., Flores et al., 2014; Stroizer et al., 2015; Yakubova et al., 2016). Yet, this study suggests the potential to expand the CRA instructional sequence to more applied skills as well for students with intellectual disability. However, additional research should also be completed with the CRA for basic operations, such as addition, subtraction, and multiplication. A key to establishing an instructional approach as evidence-based is multiple high-quality studies with multiple participants demonstrating the effectiveness of said intervention (Cook et al., 2014). To determine the CRA status as an evidence-based instructional approach for students with intellectual disability and/or autism, more research is needed.

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