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Interventions to Improve Student Achievement in Mathematics for Middle School Students with Autism

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Abstract

The purpose of this study was to evaluate the effects of using Concrete-Representational-Abstract (CRA) teaching sequence and explicit instruction to improve student achievement in mathematics in middle school aged students with autism and moderate intellectual disabilities. The effects of the CRA teaching sequence and explicit instruction were examined using a Multiple Baseline Design. Although the results in the curriculum-based measurements were inconsistent, all participants showed an increase in the pre-test and post-test scores.

Interventions to Improve Student Achievement in Mathematics for Middle School Students with Autism

Students with autism and intellectual disabilities often struggle with obtaining a conceptual understanding of the math standards. Some students learn the steps to solving mathematical problems or give rote responses, but lack the understanding needed to apply the mathematics to real world situations. The depth of knowledge in mathematics for students with disabilities is often basic recall. Students diagnosed with autism and intellectual disabilities have deficits in their cognitive abilities and working memory. The working memory impacts performance on reading and math skills (Alloway, Rajendran, & Archibald, 2009). Therefore, students with autism and intellectual disabilities have more difficulty solving math problems that are more rigorous and that require real world application.

The purpose of this study was to identify interventions to improve student achievement in mathematics for middle school students with autism and intellectual disabilities. There are a range of interventions that have been researched to evaluate the effects of student achievement in mathematics. This review of literature will discuss interventions that were evaluated and the effects on student achievement in mathematics.

Review of Literature

Autism and Moderate Intellectual Disabilities

According to Huang, Lai, and Rivera (2010), Autism is a neurological disorder that is characterized with impairments with socialization, communication, sensory processing, and repetitive patterns of behaviors. The Centers for Disease Control reported that 1 out of 68 children aged 8 years are diagnosed with autism (Baio, 2014). The data was collected through the Autism and Developmental Disability Monitoring (ADDM) Network that monitors the number of 8 year olds diagnosed with autism in the United States. Based on the report from 2008, there was a 23% estimated increase in the prevalence of autism from 2006 to 2008 (Baio, 2014).

A recent report from the Center for Disease Control Center concluded that there were 31% of children diagnosed with autism who had an IQ less than 70 classifying them in the range of intellectual disability (Center for Disease Control, 2014). There were 23% of children with autism who had an IQ between 70 and 85, in the borderline range. Forty-six percent of the students were classified as having an average to above average IQ (Baio, 2014). Based on the data from seven of eleven sites examined, there were more students diagnosed with autism that had an average to above average IQ. Low-functioning adolescents with autism have been reported to perform below their same age peers (Alloway, Rajendran, & Archibald, 2009). Students with autism and an intellectual disability have deficits with their working memory. Working memory refers to a person's ability to process information over a period of time (Alloway, Rajendran, & Archibald, 2009). According to Alloway et al., deficits in working memory is linked to deficits in verbal and visuospatial memory functioning. This impacts the student's academic performance in reading and math.

The characteristics of autism hugely affects how students with autism perform in mathematics due to deficits in communication and language. According to Donaldson and Zager (2010), students diagnosed with autism have deficits in visuospatial coordination which is required in math skill acquisition. Students with autism also have difficulty with processing abstract concepts. According to Cihak and Foust (2008), using concrete materials can help students develop abstract math concepts. Students with autism in middle school are taught life skills that will help them to survive and coexist in the community with non-disabled individuals (i.e., making purchases, job skills, budgeting, self-help skills, emergency and safety awareness, etc.). Their performance in mathematics significantly impacts their performances with these life skills as it relates to math computation and math reasoning.

One of the characteristics of autism is deficits in language development. Deficits in language skills have a significant impact on the achievement in mathematics of students with autism. Students are expected to be able to make viable arguments to support their understanding of the math standard, and use correct mathematical terminology and vocabulary. These expectations are challenging to meet for students with autism and intellectual disabilities due to language and communication deficits. Students with a diagnosis of autism and that have a moderate intellectual disability have difficulty with understanding the math language. Students with autism struggle with communicating their lack of understanding and needs from the teacher. Also, their deficit in language skills makes it difficult for them to express math language. Math vocabulary and making real world connections are often a challenge due to lack of cognitive deficits.

Interventions to Address Math Challenges

In addition to the research findings that supported the positive effects of using CRA and explicit instruction, there were several studies that investigated the effects of implementing peer-mediated instruction and the effects of computer-assisted interventions to improve student performance in mathematics for students with autism.

Peer mediated instruction

According to Maheady et al. (2001), peer mediated instruction is instruction in which the teacher's role changes from the primary deliverer of instruction to the facilitator and monitor of peer teaching. There are different types of peer-mediated interventions that are used. Harper and Maheady (2001) described Class Wide Student Tutoring Teams (CSTT), Numbered Heads Together (NHT), and Numbered Heads Together with Response Cards as having positive effects on improving student achievement in mathematics. CSTT actively engages students in content-related discussions and review. New instructional content is introduced, reviewed, and discussed initially by the classroom teacher. Students are then given the opportunity to interact with the material during two or more 30-min CSTT sessions per week. Numbered Heads Together (NHT) is a strategy that also serves as an academic pre-correction in that it provides all pupils with access to information necessary to answer teacher questions immediately before they are asked to do so. Response cards are cards, signs, or items that students hold up simultaneously to display their responses to each question or problem presented by the teacher (Harper, G.F. & Maheady, L., 2007).

Maheady et al. (2001) discussed the difficulties students with mild disabilities face in the 21st century classroom. According to the authors, students with mild disabilities have the most difficulties in the following domains: basic academic skills, academic related behaviors, and behavioral and interpersonal interactions. These challenges are often difficult to address by the teachers due to a three-sided instructional challenge. The authors explained that these challenges are an ever-expanding curriculum for a challenging workplace, dwindling instructional resources, and increasing student diversity. The authors explained that teachers can overcome these challenges and improve student achievement with students with disabilities by using evidence based practices. The evidence based practice that the authors suggest are Peer-Mediated Instruction and Interventions. Specifically, the authors discussed the benefits of using CSTT and NHT.

According to Kunsch, Jitendra, & Sheetal (2007), these peer-mediated interventions have proven to be effective for students with disabilities and nondisabled students with math difficulties. Kunsch et al. (2007) conducted a synthesis research on the effectiveness of using peer mediated instruction and interventions to improve student achievement in mathematics with students with learning difficulties and disabilities. The authors selected research studies that included peer mediated instruction for students in elementary and secondary grades. However, there were more studies found including students in the elementary setting. Additionally, the research studies also included students with learning disabilities and students with math difficulties. Based on the findings, the authors concluded that there is a moderate increase in student achievement in mathematics when peer mediated interventions are implemented.

Peer mediated instruction has also been proven to be effective in improving student achievement in mathematics for students with and without disabilities. According to Harper and Maheady (2007), peer mediated instruction works because it gives the students opportunities to receive immediate feedback, increases rate of student responses, and allows students to correct their responses immediately.

Computer-assisted instruction

In comparison, there is extensive research on the effects of using computer-assisted instruction to improve student achievement in mathematics for secondary students with disabilities. Computer assisted instruction (CAI) is instruction that incorporates computer software into instruction (Tienken & Wilson, 2007). Based on the studies reviewed, there is a mixed review on the effects of using computer-assisted instruction. Tienken and Wilson (2007) evaluated the effects of using computer-assisted instruction to improve student achievement in mathematics for 7th grade students with disabilities. The results indicated that there was only a slight increase in the scores. During the following year, Tienken and Maher (2008) conducted a similar study that evaluated the effects of using CAI to improve student achievement in mathematics for 8th grade students with disabilities (Tienken & Maher, 2008). The study yielded the same results, showing that CAI does not have a significant positive effect on improving student achievement in mathematics.

Concrete-Representational-Abstract

Students with disabilities and/or math difficulties struggle with performing on grade level in mathematics and gaining a conceptual understanding of the math concept. Studies have shown that implementing the concrete-representational-abstract (CRA) teaching sequence with explicit instruction has positive effects on improving student achievement in middle school mathematics with students with moderate intellectual disabilities (Morin & Miller, 1998). Therefore, using the concrete-representational-abstract teaching sequence should be beneficial in obtaining a conceptual understanding of the math skill (Donaldson & Zager, 2010).

Although there is often limited use of manipulatives in middle school with students with disabilities during math instruction, research has shown that incorporating manipulatives into math instruction increases student achievement in mathematics with elementary as well as middle school. Studies have also shown that there is greater student achievement with using concrete manipulatives as opposed to using only numerical symbols (abstract) or part of the graduated instructional sequence. Using the concrete-representational-abstract teaching sequence and explicit instruction has proven to be effective as an intervention with improving student achievement in mathematics for students with disabilities in middle school. The results have shown that students with disabilities gain a conceptual understanding of the math skill that is taught, and the results are generalized in an inclusive and special education setting. There were several research studies that supported the use of the concrete-representational-abstract (CRA) teaching sequence and explicit instruction. CRA is a graduated teaching sequence that incorporates using only manipulatives during the concrete sequence first. The representational teaching sequence incorporates using only pictures to teach the math skill. The last component of the teaching sequence is using numerical symbols. During this phase, the instructor teaches the student the math skill using only numbers and math symbols.

Explicit instruction is an instructional approach that includes modeling, guided practice, and independent practice. During the modeling phase, the teacher demonstrates how to complete the math problem and how to meet the success criteria. The guided practice phase includes the teacher assisting the students with completing a math problem. The teacher answers any questions and guides the students when assistance is needed. During this phase, the teacher checks for the student's understanding of the math skill. The independent practice phase allows the students to attempt to complete the math skill without any assistance from the teacher. During this time, the teacher can assess student mastery and areas of improvement. It guides the students in a graduated sequence from most intrusive to least intrusive guidance from the teacher (Witzel, Miller, & Mercer, 2003). Studies have found CRA to be successful when included participants and settings that are similar to those in this study. CRA and explicit instruction has been proven to be effective in inclusive and resource settings, with elementary and secondary students, private and public schools, small and large populations, and with students with disabilities and nondisabled students (Witzel, Miller, & Mercer, 2003).

Effect of CRA on Students with Disabilities

As stated previously, the target population for this study includes individuals in a special education classroom in a middle school setting in an urban public school setting. However, most research on math interventions is conducted in the general education setting. More research is needed to investigate math interventions for students with autism.

Morin and Miller (1998) conducted a study that evaluated the effects of CRA and explicit instruction to improve student performance on multiplication facts with students with intellectual disabilities. The participants in this study included students in middle school who had deficits in mathematics. This single subject study yielded positive results. The results of this study concluded that there was an improvement with performance on multiplication facts.

Another single subject study evaluated the effects of using CRA and explicit instruction to improve student performance on subtraction of integers through word problems (Maccini & Ruhl, 2000). Middle school students with learning disabilities were targeted as participants in this study. Nondisabled students were not included in this study, and this study was also conducted in a special education classroom. The results showed that there was a positive increase in student performance on subtraction of integers after implementing the CRA teaching sequence with explicit instruction. However, the results also showed that the generalization score was below average. Therefore, the researchers implicated that there should be additional research in achieving generalization while using CRA and explicit instruction (Maccini & Ruhl, 2000).

On the other hand, Witzel (2005) conducted a research study that evaluated the effects of CRA and explicit instruction in an inclusive setting for middle school students. This study included a much larger population that included students with disabilities in mathematics and nondisabled students. He measured student performance on linear algebraic functions. Based on the results of the study, CRA and explicit instruction had a greater positive effect on the treatment group than the control group. This study provided further evidence that the CRA teaching sequence and explicit instruction also has a positive effect when used in the general education setting.

Similarly, another study was conducted to evaluate the effects of CRA and explicit instruction to improve student performance on solving complex equations (Witzel, Mercer, & Miller, 2003). This study was also conducted in an inclusive setting for middle school students with and without disabilities. A pre-test and a post-test were given to a treatment and control group. The treatment group received instruction with CRA and explicit instruction, while the control group only received instruction through traditional methodology. The results showed that the students from the treatment group performed better on solving equations than the control group (Witzel, Mercer, & Miller, 2003).

According to Witzel (2008), the concrete-representational-abstract (CRA) teaching sequence with explicit instruction has proven to be effective in improving student achievement in mathematics with secondary students with and without disabilities. He identified CRA as a graduated instructional sequence that incorporates using concrete (manipulatives), semi-concrete (drawings or pictures), and abstract (numerical symbols) to teach solving equations using a CRAMATH method. The CRAMATH method is a method the teacher used that provided steps on how to teach the math skill using CRA. Witzel (2008) also explained that explicit instruction incorporated demonstrating or modeling the solving equations, providing guided practice, and allowing the students to have independent practice.

Butler, Miller, Crehan, Babbitt, and Pierce (2003) conducted a research study that compared the effects of using CRA with explicit instruction to only using RA with explicit instruction. This study evaluated if the graduated instructional sequence would be as effective when only some of the components were used. Similar to some of the other articles, the participants included students in the middle school setting that were diagnosed with disabilities and nondisabled students. The treatment group included students who received CRA and explicit instruction. Another group received only the representational-abstract (RA) sequence with explicit instruction. Pre-tests and post-tests were given to evaluate the students' performance on computing fraction equivalence. The results showed that the students who were taught using the entire CRA sequence with explicit instruction outperformed the students who received only the RA sequence (Butler et al., 2003).

Scheurmann, Deshler, and Schumaker (2009) conducted a research study that evaluated the effects of explicit inquiry routine, concrete-representational-abstract (CRA), and explicit instruction to improve student achievement in solving one-variable equation word problems. The participants selected in this study were identified as having a learning disability from grades 6^{th} through 8^{th}. The results showed that the student performance improved as result of implementing the CRA teaching sequence and explicit instruction. The students maintained mastery after an 11 week period. Also, the results showed that the students were able to generalize the skills they learned.

Riccomini, Witzel, and Robbins (2008) discussed how using evidence based practices can improve student achievement in mathematics with students with emotional and behavior disorders. The authors discussed two instructional approaches that have been proven to be effective. According to the article, peer-mediated instruction and concrete-representational-abstract (CRA) teaching sequence with explicit instruction have been proven to be effective in improving student performance in math. The authors conducted a research study that included 9 secondary students in an urban setting with emotional and behavior disorders. The purpose of the study was to evaluate the effects of using CRA and explicit instruction to improve student achievement in mathematics. The results showed that there was a significant increase in student achievement in mathematics based on the end of grade scores that were collected before and after implementation.

Mancl, Miller, and Kennedy (2012) conducted a single subject study that included five elementary students with a learning disability. The purpose of this study was to evaluate the effects of using the concrete-representational-abstract (CRA) teaching sequence and explicit instruction to improve student performance on subtraction with borrowing and word problems. The results of the study showed that there was an increase in student performance. However, the students were retaught the skill until they mastered the skill. Maintenance probes were not implemented in this study. The authors suggested that future research should include evaluating the use of CRA and explicit instruction in the general education setting.

Flores (2010) conducted a single subject study that evaluated the effects of using concrete-representational-abstract (CRA) teaching sequence to improve student achievement in subtraction with regrouping. The participants selected in this study were not labeled as students with disabilities, but they were identified as at risk for failure. Based on the results of the study, the implementation of CRA increased student performance in subtraction with borrowing. Five out of six students mastered the math skill before completing the entire graduated teaching sequence. Generalization lessons were not included in this study. Therefore, the researchers recommended further research that would evaluate generalization results from implementing CRA.

Based on this literature review, the effects of using the concrete-representational-abstract (CRA) teaching sequence and explicit instruction have yielded positive results in improving student achievement in middle school mathematics. CRA has also shown to be effective with elementary and middle school students as well as students with and without disabilities.

Methods

Setting

This study took place in an urban middle school (grades 6-8) in the Southeast region of the United States. The school's enrollment is a population of approximately 880 students. The demographic profile of the participating school consisted of 99% African American and 1% Hispanic. There are 670 students eligible for free lunch, and there are 61 students eligible for reduced lunch. The student-teacher ratio is 17 students to 1 teacher. The school has a center for students with autism that has two regional classes that are identified as Tier A and Tier BC. The classes are separated by cognitive ability. The Tier A classroom serves students who meet the eligibility for autism and moderate, severe, and profound intellectual disabilities, and students who have significant communication deficits. The students in this class are nonverbal. However, the students use sign language, pointing, gestures, and picture card exchange to communicate their wants and needs. The Tier BC classroom serves students who meet eligibility for autism and have moderate intellectual disabilities. The students in this class verbally communicate their wants and needs. Both classrooms have one special education teacher and one paraprofessional. The research study was conducted in a self-contained setting in the Tier BC classroom.

Participants

Three middle school aged students (3 boys, age range: 10-12 years) participated in the study. Students were selected for this intervention based on their diagnoses of autism from the most recent psychological evaluation and receive special education services under the eligibility of autism. Also, the participants selected have deficits in math calculation and math reasoning that were identified in their most recent Individual Education Plan (IEP) and psychological evaluation. The participants in this study receives special education services in a self-contained autism classroom. Due to the participants' intellectual ability and Individualized Education Plan (IEP), the participants are evaluated under the Georgia Alternative Assessment (GAA) instead of the CRCT (Criterion Referenced Content Test).

"Damien", an African American male, is currently 12 years of age in the 7th grade. He receives special education services in a self-contained classroom for students diagnosed with autism and mild intellectual disability. The student was initially placed in the Tier A classroom during the first few weeks of school. Due to his cognitive ability, he was placed in the Tier BC classroom which serves students that meet eligibility for autism. Damien verbally communicates his wants and needs, but has a speech impairment. His primary exceptionality is autism, but his secondary exceptionality is Speech Language Impairment. Damien's most recent psychological evaluation states that he obtained a full scale IQ score of 85 on the Universal Nonverbal Intelligence Test (UNIT). His overall cognitive and intellectual functioning fell in the low average range. The results from the Woodcock Johnson Test of Achievement –III indicated that Damien scored 46 on math calculation and a score of 63 on math fluency. During the assessment, he was unable to complete basic multiplication and division problems.

"Edward", an African American male, is currently 11 years of age in the 6th grade. He receives special education services in a self-contained classroom for students diagnosed with autism. The student was initially placed in the Tier A classroom during the first few weeks of school. Due to his cognitive ability, he was placed in the Tier BC classroom which serves students that meet eligibility for autism. Edward verbally communicates his wants and needs.

His primary exceptionality is autism, but his secondary exceptionality is Specific Learning Disability. His most recent psychological evaluation states that his intellectual ability falls within the Mild Intellectually Disability to Low Average range. Based on the present levels of academic performance in the IEP, Edward has deficits in math computation and math reasoning.

Caleb, an African American male, is currently 10 years of age in the 6th grade. He receives special education services in a self-contained classroom for students diagnosed with autism and moderate intellectual disability. The student was initially placed in the Tier A classroom during the first few weeks of school. Due to his cognitive ability, he was placed in the Tier BC classroom which serves students that meet eligibility for autism. Caleb verbally communicates his wants and needs. His primary exceptionality is autism, but his secondary exceptionality is Speech/Language Impairment. His most recent psychological evaluation states that he has a Full Scale IQ score of 60 on the Wechsler Intelligence Scale for Children- Fourth Edition (WISC-IV). Based on the present levels of academic performance in the IEP, Caleb has deficits in math calculation and math reasoning.

Interventionist

The researcher in the study served as the Special Education teacher and the monitor of the implementation of the intervention. The researcher holds four degrees, and the highest degree is a Masters degree in Special Education. The researcher is currently pursuing an Educational Specialist degree in Special Education, and is highly qualified as a certified teacher in all subject areas for grades P-8. The teacher has background experience in Applied Behavior Analysis and Verbal Behavior. She has experience as an educator in the public school system for four years, but a total of 8 years with working with children and adults with various disabilities and disorders. The teacher also has experience with delivering instruction using explicit instruction and concrete-representational-abstract (CRA) teaching sequence.

Design

The research study used a Multiple Baseline A-B design Across Participants design as well as a pretest/posttest to evaluate the effects of using the concrete-representational-abstract (CRA) graduated teaching sequence and explicit instruction to improve student achievement for middle school students diagnosed with autism. The Multiple Baseline Design was used to show experimental control and measure the effects of using the concrete-representational-abstract teaching sequence and explicit instruction. The baseline data was staggered across participants with close monitoring of stabilizing the data.

Procedures

Intervention description. The concrete-representational-abstract (CRA) teaching sequence is a three-stage learning process where students learn through physical manipulation of concrete objects, followed by learning through pictorial representations of the concrete manipulations, and ending with solving problems using abstract notation (Witzel, 2005). The concrete component consists of learning through hands on instruction using actual manipulative objects. The representational component is learning through pictorial representations of previously used manipulative objects during concrete instruction, and the abstract component of the sequence is learning through abstract notation such as numbers and operational symbols (Witzel, 2008). Explicit instruction guides the students in a graduated sequence from most intrusive to least intrusive guidance from the teacher by modeling, guided practice, and independent practice (Witzel, Miller, & Mercer, 2003).

Implementation of Intervention. The researcher obtained parental consent and student assent for all three participants prior to taking baseline data. The researcher met with the participants 3 times per week for 30 minutes in a self-contained classroom. There was a total of 27 lessons in a 9 week period in the morning prior to starting school. There were 2 holiday breaks during the study. One holiday break was for a week, and the other holiday break was for 2 consecutive days. The materials needed to conduct the research were student worksheets and manipulatives. The student worksheets will be obtained from Easy CBM (Curriculum Based Measurement) and Aussiechildcarenetwork.com. A pre-test and a post-test obtained from Easy CBM was administered to the participants to measure student performance. Maintenance data were taken to measure the students' retention of the math skill.

The CRAMATH strategy was used in the implementation of the intervention. The CRAMATH strategy is designed to guide teachers' instructional planning to incorporate the components of the CRA instructional approach (Witzel, Riccomini, & Schneider, 2008). First, the researcher chose which math topic to teach. The math topic chosen was multiplication facts (0-100). The researcher taught the student to learn the multiplication facts 0-100, and generalize what they learned through word problems. Secondly, the researcher reviewed the procedures to solve the problem. Next, the researcher adjusted the steps to eliminate notation or calculation. Then match the abstract steps with an appropriate concrete manipulative. The next step includes arranging concrete and representational lessons. Afterwards, the researcher taught the math skill using the concrete, representational, and abstract lesson using explicit instruction to student mastery (Witzel, Riccomini, & Schneider, 2008). The mastery criteria for correctly solving multiplication facts 0-100 was three consecutive scores of 80% accuracy or higher. The students received positive and corrective feedback after each session.

Measures

There were two measures during the study: baseline and intervention probes for multiplication facts 0-100. An assessment from Easy CBM was used as the pre and post-tests. The assessment included 16 questions. The questions also included word problems and non-word problems. During the baseline, there were 16 multiplication problems. The student worksheets included 10 problems. During explicit instruction, there were 6 questions during the model and guided practice. There were 10 questions during the independent practice for the CRA phases.

Data Collection and Data Analysis

Data Collection. Data collection was collected on a data sheet and in a spreadsheet. The researcher graded the pre-tests, student worksheets, and the post-tests using an E-Z Grader. The E-Z grader was used to calculate the score by comparing the number of questions and the number of questions that were incorrect. Scores were documented on a data sheet and in a spreadsheet by recording the percentage correct during each session. Reliability data was taken by the Special Education teacher for each session. The researcher and the teacher scored the pre-tests, baseline probes, student worksheets, and post-tests.

Data Analysis. Data collection was entered into a spreadsheet after each session. Each probe was entered into a line graph to monitor the students' performance on multiplication facts 0-100. The researcher monitored the data closely to analyze the effectiveness of the intervention for each participant. The data was entered into an Excel spreadsheet, and a line graph was created for the data. The graph was measured the percentage correct from 0 to 100 on the y-axis, and the number of sessions was indicated on the x-axis. The mastery criteria was three consecutive scores of 80% accuracy or higher. The mastery criteria was monitored in each phase of the CRA sequence. If the participants score below 80% accuracy, the researcher continued with implementation to monitor the participants' progress without exceeding 5 sessions. If mastery was not met within 5 sessions, the researcher moved the participant to the next phase of the CRA sequence. After completing the CRA graduated teaching sequence, the participants completed a post-test to measure the progress from the pre-test.

Results

The students diagnosed with autism and intellectual disabilities who participated in the CRA and explicit instruction intervention showed an increase in their performance in computing multiplication facts 0-100. Although the results in the curriculum-based measurements were inconsistent, all participants showed an increase in the pre-test and post-test scores. Participant 1 scored 25% on the pre-test and 62% on the post-test, Participant 2 scored 13% on the pre-test and 50% on the post-test, and Participant 3 scored 31% on the pre-test and 44% on the post-test. The difference in the pre-test and post-test scores are 37, 37, and 13 points.

The first participant completed four baseline sessions with a range of 38% to 63% accuracy with a mean of 50.25%. After baseline, participant one completed three sessions in the concrete stage that ranged from 80% to 100 % accuracy. Mastery was met during the concrete stage with three consecutive scores of 80% and above with a mean of 90%. During the representational stage, participant one completed 5 sessions ranging from 50% to 70% accuracy with a mean of 58%. Because the participant showed an increase in scores for the second and third session, the researcher continued with two additional sessions to see if there would be an improvement in his performance. After participant one failed to score at least 80% for all sessions, the researcher began the abstract phase. During the abstract phase, participant one met mastery with a range of 90% to 100% mastery in three consecutive sessions with a mean of 96.66%.

Comparatively, the second participant completed four baseline sessions with a range of 38% to 56% accuracy with a mean of 42.5%. After baseline, participant two completed five sessions during the concrete stage ranging from 30% to 80% accuracy with a mean of 44%. During the representational stage, participant two completed five sessions ranging from 30% to 60% accuracy with a mean of 40%. Participant two met mastery during the abstract phase by scoring 80% to 90% during three consecutive sessions with a mean of 83.33%. The participant was observed applying the strategy of drawing picture representations that was taught from the representational phase during the abstract phase.

Additionally, the third participant completed five sessions during the baseline phase that ranged from 25% to 56% accuracy with a mean of 39.8%. During the concrete phase, participant three completed five sessions ranging from 30% to 60% accuracy with a mean of 40.8%. Participant three did not master the representational phase, the scores ranged from 40% to 60% accuracy with a mean of 44%. During the abstract phase, participant three completed five sessions ranging from 10% to 40% accuracy with a mean of 20%.

Discussion

The purpose of the study was to evaluate the effectiveness of teaching multiplication facts and related word problems using the concrete-representational-abstract (CRA) teaching sequence and explicit instruction to middle school students diagnosed with autism. The results of the study revealed that using the concrete-representational-abstract (CRA) teaching sequence and explicit instruction does improve student achievement in mathematics for middle school students diagnosed with autism. The findings of this study were consistent with the results from Morin &

Miller (1998) that revealed that using CRA improved student achievement in computing multiplication facts 0-81 with students with intellectual disabilities. The results throughout each phase of CRA were inconsistent, but there were improvements in the pre-test and post-test scores for all participants. There were interruptions during the implementation of the intervention due to school breaks during the holiday season. There was a fall break for 3 days, and there was a Thanksgiving break for a week.

A Multiple Baseline A-B Design across participants was used during the study, and implementation of the CRA teaching sequence using explicit instruction was staggered across participants. Once the first participant began the concrete stage, the second participant started baseline. After the first participant met the mastery criteria and started the representational stage, the second participant began the first stage of CRA. Each participant began and continued each phase of CRA as the other participant moved to the next phase. Although the mastery criterion was set at 80% accuracy or higher for 3 consecutive sessions, each participant completed 5 sessions per phase to monitor progress if the mastery criteria was not met after the first 3 sessions.

Furthermore, none of the participants scored above 63% accuracy during the baseline phase. The first participant was the only participant that met the mastery criteria during the concrete phase. However, none of the participants met the mastery criteria during the representational phase. The second participant scored the highest score during the representational phase with 70% accuracy. Although none of the participants met the mastery criteria for the representational phase, two out of the three participants met the mastery criteria during the abstract phase. The first two participants that mastered the abstract phase used the strategy of drawing picture representations to compute the multiplication problems during the abstract phase. The questions the participants answered in the concrete and representational phases included multiple choice answers. However, the abstract phase did not provide multiple choice answers. The third participant was the only participant that did not meet the mastery criteria in any of the phases of CRA. He received his lowest scores during the abstract phase ranging from 10% to 40% accuracy with a mean of 20%.

Limitations

There were several limitations that affected the implementation and results of this study. Prior to conducting the study, the participants were required to sign an assent form. Additionally, the parents of the participants were required to sign a consent form to give permission for the participants to participate in the study. Two out of three participants' parents returned the consent form within one week. However, one participant's parents returned the consent form in one and a half weeks. The length of time it took for all of the participants' parents to return the consent forms prolonged starting the study.

Furthermore, there were time constraints that affected the implementation of the study. The school district's policy states that research cannot be conducted during instructional time. Therefore, the study had to be conducted before or after school. This gave the researcher little time during the day to conduct the study. The study was conducted as soon as the students arrived at school prior to the beginning of the first instructional period. This also affected the participants' motivation to participate in the study. Often, the participants did not want to participate in the study because it was conducted as soon as they arrived at school.

Future Research

Future research should include evaluating the effects of using the CRA teaching sequence and explicit instruction to improve student achievement in mathematics with students with autism in the general education setting. The current study was conducted in a self-contained special education classroom setting. Research needs to be extended to students with autism that receives instruction in the general education setting with nondisabled students in middle school. Another consideration for future research should include considering assessment measures that do not include multiple choice answers. This would allow the teacher to assess the students' ability to compute multiplication problems and eliminates the opportunity for the students to guess the correct answer.

Additionally, future research should include evaluating a different math skill. The results from the study revealed that using CRA and explicit instruction improves student achievement in computing multiplication facts 1-100. Further research is needed in evaluating the effects of CRA and explicit instruction in other math skills (i.e., division, fractions, solving equations). Student performances throughout the CRA phases were inconsistent in this study. Further research should be conducted in comparing student performance using CRA versus RA. This would provide insight on the effects on student performance when partial components of CRA are implemented versus implementing all components of CRA.

Implications for Research

The results of this study will provide further research on instructional strategies that would improve student achievement in mathematics for middle school students with autism. There is little research on evidence based practices that improve student achievement in mathematics with middle school students with autism. There is also little research on the effects of CRA on student achievement in mathematics with students with autism. Although the results from this study were inconsistent, there were improvements in the pre-test and post-test scores for all three participants. This adds to the current body of research on the effects of using CRA to improve student performance in math for students with autism.

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