Using the Concrete-representational-abstract Sequence and the Strategic Instruction Model to Teach Computation to Students with Autism Spectrum Disorders and Developmental Disabilities

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Abstract: There is a need for further investigation of evidence-based practices for students with autism spectrum disorders and developmental disabilities leading to students’ success within the general education curriculum (Cihak & Foust, 2008; Rockwell, Griffin, & Jones, 2011; Schaefer-Whitby, Travers, & Harnik, 2009). The purpose of this study was to investigate the concrete-representational-abstract instructional sequence and the Strategic Instruction Model (CRA-SIM) with regard to mathematics computation performance of students with ASD and DD. Eleven elementary students with ASD and DD participated in four weeks of instruction with regard to basic addition and subtraction using CRA-SIM. A paired samples t-test statistical procedure was conducted to evaluate the differences in student progress across curriculum-based measures over the course of the study. Results indicated that the students made significant progress across three CBMs administered over the course of the study. Measures of effect size also indicated that CRA-SIM had a strong effect on student performance. These results, descriptive performance results, and their implications will be discussed.
prompt fading, prompting hierarchies and error correction. These researchers discussed the need for replication as well as extension of the literature to other potentially effective methods, especially those that previous researchers have shown as effective for students with and without disabilities working within the general education curriculum (Cihak & Foust, 2008; Rockwell, Griffin, Jones, 2011; Schaefer-Whitby, Travers, & Harnik, 2009).

Teaching mathematical operations using touch points has been shown to be effective for students with high incidence disabilities such as mild intellectual disabilities and specific learning disabilities (Calik & Kargin, 2010; Scott, 1993). Cihak and Foust (2008) investigated the effects of touch points on the numerical operations performance of elementary students with ASD. An alternating treatments design showed that the touch-point method of instruction was more effective than the use of the number line. Fletcher, Boon, and Cihak (2012) extended this line of research to include middle school students with ASD and DD, comparing the touch point method to a method involving the use of a number line. Consistent with Cihak and Foust, Fletcher et al. found that the touch point method was more effective than teaching addition using a number line.

With regard to mathematics problem solving, schema-based strategy instruction has been demonstrated as effective for students with specific learning disabilities as well as students at risk for mathematics failure (Jitendra, Star, Rodriguez, Lindell, & Someki, 2011; Jitendra & Star, 2011; Jitendra et al., 2009). Rockwell, Griffin, and Jones (2011) investigated the effectiveness of this word problem strategy for a student with ASD who functioned within the low average range of intellectual ability. Instruction involved explicit teaching strategies regarding procedures for solving word problems. Schema-based instruction also included visual diagrams used to assist the student in demonstrating understanding of word problems as well as making decisions while solving the problem (e.g., choosing the correct operation to solve the problem). The student received explicit and guided instruction in problem solving steps and procedures. Schema-based strategy instruction was successful in teaching the student to solve one-step word problems involving addition and subtraction.

The literature above shares some commonalities which might explain their effectiveness for students with ASD and DD. Each method involves visual aids which have been reported to be a learning preference of students with ASD (Boutot & Miles, 2011; Ganz, Earles-Vollrath, & Cook, 2011). Another shared component of these methods is explicit instruction and graduated guidance which are consistent with recommendations for effective mathematics instruction for students with ASD and DD (Browder et al., 2008; Butler et al., 2001; Schaefer-Whitby et al., 2009). Schema-based instruction provided specific and simple procedures for solving problems in the form of a mnemonic device which helped the student remember the steps (Rockwell et al., 2011). This instructional component is consistent with instructional recommendations for students with ASD (Constable et al., 2013; Donaldson & Zager, 2010; Schaefer-Whitby et al.). Finally, Schema-based instruction has been shown to be effective for students with disabilities as well as students at risk for mathematics failure in the general education setting (Jitendra et al., 2011). Rockwell et al. demonstrated that this intervention, typically used within the general education environment, was effective for a student with ASD.

There is a lack of research that has shown that similar visual and strategic methods may be successful in teaching basic computation to students with ASD and DD. One such method is the combination of the concrete-representational-abstract sequence and the Strategic Instruction Model (CRA-SIM). This method involves an instructional sequence in which the operation is taught using manipulative objects; once mastery is demonstrated using objects, instruction involves the use of drawings and pictures. Once students demonstrate mastery at the representational level, they learn a strategy for solving operations that involve numbers only.

Morin and Miller (1998) conducted research using CRA-SIM with three students with intellectual disabilities. The researchers taught students basic multiplication facts using CRA-SIM using a multiple baseline across behaviors design. A functional relation was demonstrated between CRA-SIM and an in-
crease in the students’ percentage of correct problems. The majority of research regarding mathematics instruction for students with developmental disabilities does not include students with ASD. The studies that do include students with ASD have shown that methods involving visual components, explicit instruction, and procedural strategies have been beneficial. There is a need for more research in this area given rigorous expectations for students’ learning and progress within the general education curriculum. Therefore, the purpose of this study is to investigate the effects of CRA-SIM on the computation performance of elementary students with ASD and DD.

Method

Setting

The study was conducted in a rural region of the Southeastern United States within an extended school year program. The extended school year program was a collaborative partnership between a university and two area school districts. University faculty directed the program which provided four weeks of extended school year services for children with disabilities who attended two rural school districts. The classroom staff members were university students majoring in special education. Each classroom was staffed by a certified special education teacher enrolled in a Master’s program as well as two undergraduate pre-service special education teachers. Classrooms consisted of six to eight children who were placed according to academic and behavioral needs outlined in their individualized educational programs and extended school year service plans written by their teachers during the regular school year. The children attended the program three hours per day, five days per week, for four weeks. Daily instruction included language or reading, mathematics, written expression, and social skills. The children received forty-five minutes of mathematics instruction within homogenous groups that were formed based on instructional needs. Instruction was provided by a certified special education teacher enrolled in a Master’s program who had been provided with nine clock hours of professional development in the mathematics program used for the study.

Participants

Eleven students, enrolled across four classrooms, participated in the study. The students ranged in age from five to twelve years of age and received special education services under the categories of autism spectrum disorders, intellectual disability, and developmental delay. All of the students qualified for services according to state and federal guidelines. With regard to eligibility for students with autism spectrum disorders, appropriate scores on the Autism Diagnostic Observation Schedule (Lord, Rutter, DiLavore, & Risi, 2002) and evaluation by professionals with expertise in autism spectrum disorders were required components of eligibility for students enrolled in the participating districts. The students’ mathematics achievement was significantly below average with the exception of one student, age five, whose achievement was within the average range. The majority of the students’ intellectual functioning was below the average range; two students’ cognitive abilities were within the average range. All of the students’ IEPs indicated needs related to basic computation, either addition or subtraction. Student demographic information is located in Table 1.

Instructional Materials and Procedures

Mathematics CRA-SIM instruction was provided using the Strategic Instruction Math Series: Addition Facts 0–9 (Miller & Mercer, 1998) and Strategic Instruction Math Series: Subtraction Facts 0–9 (Miller & Mercer, 1998). Nine students received instruction in addition facts zero through nine and two students received instruction in subtraction facts zero through nine. Each program consists of twenty-one lessons and the materials include student learning sheets and teacher instructions for each lesson. Instruction is provided explicitly; each lesson consists of an advance organizer, teacher demonstration, guided practice with the teacher, independent practice, and a post organizer. The programs also include the CRA teaching sequence and SIM in which computation instruction is provided using ma-
After students master the operation with objects, instruction is provided using pictures and drawings; this is the representational level (lessons four to six). Lesson seven involves learning a strategy to aid in the procedural process of solving an addition or subtraction problem using the following steps: a) discover the sign, b) read the problem, c) answer or draw and check, and d) write the answer. This strategy is represented by the mnemonic DRAW. Then, instruction is provided using numbers only, the abstract level. The last set of lessons (lessons eleven to twenty-one) is devoted to fluency at the abstract level and completion of word problems written in paragraph form. Instruction proceeds from lesson to lesson based on student mastery; students must achieve eighty percent correct during independent practice in order to move to the next lesson.

The students in this study progressed through the program at different rates. Four students had mastered the operation at the concrete level and were receiving instruction at the representational level at the end of the study. Four students had mastered instruction at the representational level and were receiving instruction at the abstract level at the end of the study. Three students had mastered instruction at the abstract level and at the end of the study, their instruction focused on increasing fluency.

The students received instruction in small groups or one-on-one, based on the instructional groupings in the classroom. For example, in one classroom, three students shared the same instructional needs and progressed at similar rates. However, in another classroom, a student received one-on-one instruction because he was the only student for whom the program was appropriate. Student groupings ranged from one to three across the classrooms.

The procedures for instruction followed the program guidelines. Each lesson included the use of learning sheets provided within the program and began with an advance organizer in which the teacher provided an overview of the lesson. The teacher demonstrated several problems for the students. This demonstration varied depending on the lesson; lessons one to three involved the use of manipulative objects and lessons four to six involved the use of drawings and pictures. Next, the teacher guided the students in solving several problems. Guided practice involved the provision of verbal and/or physical prompts as students completed a set of problems. The third step during instruction was independent practice in which the teacher instructed the students to solve a set of problems without guidance. During independent practice, the teacher monitored student progress and intervened with prompts if the student had difficulty or made an error. The teacher was not to provide the students with answers or complete portions of the problem during independent practice.

Three curriculum based measures (CBM)
were administered to each student throughout the study. One was given prior to instruction, the second was administered after two weeks of instruction and the last CBM was given after instruction ended. The CBMs were Basic Skill Builders precision teaching materials (Beck, Conrad, & Anderson, 1995). The assessments were sheets that were eight by eleven inches with thirty-six problems on each sheet. The procedures for administration were consistent with the precision teaching program guidelines. Students were given the sheets and instructed to complete as many problems as they could before the teacher told them to stop (after one minute). The students were asked to begin working and the teacher started a timer, set to one minute. After one minute, the teacher took the assessments from each student. The CBMs were scored based on the number of correct digits written.

The teachers were provided with professional development in the use of the mathematics program over the course of nine hours. During university coursework, six hours of professional development was provided with regard to the concrete-representational-abstract instructional sequence, the provision of explicit instruction, and the specific use of the Strategic Math Series (Miller & Mercer, 1998). One week prior to the extended school year program, an additional three hours of professional development was provided. This included demonstration, guided practice and independent practice. Independent practice involved implementation of program lessons with the authors. Each teacher was required to implement lesson components with one hundred percent accuracy prior to use of the program in the classroom.

Treatment Integrity and Inter-observer Agreement

Measures of treatment integrity consisted of checklists of nine teacher behaviors related to appropriate implementation of the mathematics program. The checklist listed each behavior and the behavior was rated as either exhibited or not exhibited. Teachers were observed once per week by a faculty member or a doctoral research assistant. If there were two or more behaviors missing, a conference and remediation were conducted; an additional observation was conducted as well in order to assure improvement in implementation. There were three instances of repeated fidelity observations, one in each of the three different classrooms. The most problematic behavior was monitoring students’ independent work without offering answers. Treatment integrity for the study was 92 percent. Classroom instruction was also recorded using video. Inter-observer agreement was calculated for each of the treatment integrity observations by the first author and a doctoral research assistant. Agreement was calculated using the following formula: agreements divided by the total number of agreements and disagreements. Inter-observer agreement was ninety-three percent across all treatment integrity checklists. Inter-observer agreement was also conducted with the curriculum-based measures (CBMs). The classroom teachers and the first author scored the CBMs. Inter-observer agreement was one hundred percent across all of the measures.

Research Design and Analysis

An analysis of co-variance statistical procedure was used with the pre-test score as the covariate to ensure that there were no differences in student performance based on initial skill level. This analysis showed no difference in performance based on initial skill; therefore the data were examined further. A paired samples t-test statistical procedure was conducted to evaluate the differences in student progress across CBMs over the course of the study. This was the most appropriate analysis given the sample size. A one-sample t-test was conducted to examine the students’ performance compared to weekly growth rates established by Fuchs and Fuchs (1993). According to Fuchs and Fuchs, average weekly growth rate for students in first grade was up to 0.5 correct digits per week. This was multiplied by three since the participants received three weeks of instruction to arrive at a test value of 1.5 which was used for comparison. Finally, to evaluate the significance of differences found, effect size was calculated. Descriptive data were also examined in order to further investigate student performance.
Results

A paired samples t-test using repeated measures was conducted to evaluate student progress across the study. The results indicated significant improvement in students’ computation from CBM one to CBM two (\(M = 1.27, SD = 1.10, t(10) = -3.825, p < 0.01\)). Student progress from CBM two to CBM three was statistically significant (\(M = 3.00, SD = 2.72, t(10) = -3.66, p < 0.01\)). Finally, the results indicated significant improvement in student performance from CBM one to CBM three (\(M = 4.27, SD = 2.72, t(10) = 5.20, p < 0.01\)). The means and standard deviations for each pair of CBMs are presented in Table 2.

Comparing students’ growth rates using the rate established by Fuchs and Fuchs (1993), a score of 1.50 correct digits correct, a one sample t-test indicated statistical significance for the students in this study (\(M = 4.45, SD = 2.84, t(10) = 3.45, p < 0.01\)).

Effect size was 0.88 using eta square. Descriptive statistics were examined to further understand student performance. Students were grouped based on the amount of progress made within the program (e.g., those who mastered skills with concrete level instruction, representational level instruction, and abstract level instruction). Students who ended the study at the concrete level had a mean performance of three correct digits. Students who ended the study at the representational level had a mean performance of 4.5 correct digits. Students who ended the study at the abstract level had a mean performance of 6.3 correct digits. Based on descriptive statistics, neither the difference in student pace through the instructional program nor their scores at the end of the study were influenced by IQ. For example, the two students whose IQs were within the average range did not perform differently on the last CBM (four correct digits per minute and seven correct digits per minute) than students whose IQs were below the average range (range of performance from three to nine correct digits per minute).

Discussion

The purpose of this study was to examine the effects of CRA-SIM using the Strategic Math Series on the basic computation performance of students with ASD and DD. The results show that this program made a significant difference in their performance based on statistical significance as well as a moderate effect size. The students who participated in the study made progress at or above the expected rate of progress for students without disabilities (Fuchs & Fuchs, 1993), increasing the number of digits written at a rate of one or more digits per week.

The change in student performance is significant because gains were observed over a short amount of time. In addition, the students received instruction using an evidence-based supplemental mathematics program (using CRA-SIM) more commonly used with students with high incidence disabilities and students without disabilities who struggle with mathematics (Harris, Miller, & Mercer, 1995; Mercer & Miller, 1992; Morin & Miller, 1998; Peterson, Mercer, & O’Shea, 1988; Witzel, Mercer, & Miller, 2003). The Strategic Math Series (which uses CRA-SIM) follows recommendations for computation within the Common Core Standards for Mathematics (National Governors Association Center for Best Practices, Council of Chief State School Officers, 2010) with an emphasis on conceptual understanding of numbers and operations. Student progress within this study confirms the recommendations of McSheehan et al. (2009) and Wagner et al. (2006) for instruction for students with ASD and DD.

Results of this study are significant since CRA-SIM methods are different than those included in the literature for the population of students with ASD and DD which empha-
size declarative knowledge such as prompt fading, prompting hierarchies, and error correction (Browder et al., 2008; Butler et al., 2001; Hord & Bouck, 2012). The students in this study demonstrated conceptual knowledge, expressing understanding of the concepts underpinning computation by manipulating objects and drawing pictures prior to activities related to fluency. Although students progressed through the program at different rates, all students demonstrated the ability to manipulate objects and demonstrate conceptual understanding of addition and subtraction.

Results of this study are consistent with those of other researchers who investigated methods of instruction which emphasized conceptual understanding using touch points (Cihak & Foust, 2008; Fletcher et al., 2010) and using visual schema for solving word problems (Rockwell et al., 2011). All of these strategies had been shown successful with students with high incidence disabilities, but research showed that they were effective with students with ASD and DD. Another commonality among these strategies and CRA-SIM is the use of visual supports for instruction. Research has shown that students with ASD may have a visual learning preference (Boutot & Myles, 2011; Ganz et al., 2011) which may explain students’ improved performance.

Limitations and Future Research

Even though the effect size showed that CRA-SIM was effective, this study is limited by its small sample size. The current study is significant since there is no other published research that addresses CRA-SIM for students with ASD and DD, but additional investigation is necessary to conclude that CRA-SIM is effective for this population. Future research should investigate the effects of CRA-SIM with a larger group of elementary students with ASD and DD. In addition, future research should investigate implementation over a longer period of time. It is unknown how this method might affect performance if all students were able to complete the entire program. Future research should address the effects of multiple programs which would address multiple complimentary areas of numerical operations such as addition, subtraction, and place value.

Conclusions

The current study provides initial evidence that CRA-SIM was effective for a group of students with ASD and DD. CRA-SIM addresses the need for instructional practices that emphasize conceptual understanding of numbers and operations that are included within general education learning standards (National Governors Association Center for Best Practices, Council of Chief State School Officers, 2010). Instructional methods such as CRA-SIM are needed in order for students with ASD and DD to fully participate in the general education curriculum, as mandated in IDEIA (2004).

References

Fletcher, D. Boon, R. T., & Cihak, D. F. (2012). Effects of the TOUCHMATH program compared to a number line strategy to teach addition facts to middle school students with moderate intellec-