Abstract

In the last decade there has been a steady increase in students with disabilities included in general education math classes that use a reform, or standards-based curricula. This has created a need to identify strategies to improve students’ understanding of the prerequisite skills necessary for success in the whole class unit instruction. The purpose of this study is to examine the effects of preteaching using the concrete-to-representational-to-abstract (CRA) sequence as a Tier 2 teaching approach within a response to intervention (RTI) model. Results suggest this strategy is a promising intervention for students with disabilities and those at risk for failure in mathematics.
Supporting Students At-Risk for Math Failure through Preteaching

Over the last decade there has been an increase in mathematics reform in our educational system. No Child Left Behind (2001) and the Reauthorization of the Individuals with Disabilities Act (2004) identifies math as an area in which all students need to reach proficiency. This is no exception for students with disabilities (NCLB, 2001). Aligning closely with the mandates in these legislative acts, the publication of the National Council of Teachers of Mathematics Standards (2000) focuses new math standards on teaching with an emphasis on application rather than skill development, and an increase in “real world” problem solving. These reform acts coincide with the inclusion movement towards increasing the number of students with disabilities receiving core math instruction in the general education classroom (Miller & Mercer, 1997). If all students are expected to be proficient by 2014 (NCLB, 2001), it is essential that effective interventions are researched, developed, and implemented in these core classrooms to support students with disabilities and those at-risk for failure in math.

In response to the new concepts and approaches to math advocated for by the NCTM Standards (2000), many publishing companies have introduced programs that use a standards-based, or reform, curricula. Reform curricula is designed as a spiral curricula, that introduces topics more frequently but does not require the mastery of concepts prior to beginning a new unit. This type of curricula emphasizes more conceptual meaning, and provides more opportunities to apply skills to “real world” situations and involves more group problem solving (Sayeski & Paulsen, 2010). The use of clear models for introducing new concepts, fluency work, and time for extensive practice are not typically found in classrooms using reform curricula. However, research has shown most students who struggle in math have difficulty making connections that develop a strong understanding of the multiple steps needed to solve more
complex problems when these elements are absent from instruction (Bryant, Bryant, & Hammill, 2000, Mercer & Miller, 1992). These same students will have difficulty maintaining those skills over time (Ketterlin-Geller, Chard, & Fien, 2008) and may lose understanding of those prerequisite skills necessary for the second “spiral” of a concept. Creating opportunities for students to develop fluency in solving multi-step problems will promote retention of skills and increase achievement among students with difficulty in math.

Often within a fast-paced curriculum, such as the reform curricula is intended to be, and increasing large class sizes, it becomes difficult for teachers to identify the students who are at-risk and find the time to address their individual student needs. Schools that systematically integrate assessment and instruction through tiered prevention models, such as Response to Intervention (RTI), may find it easier to identify these students and their unique needs (Crawford, Ketterlin-Geller, 2008). Response to Intervention is a 3-tier model. The first tier consists of all students in the school. Tier 2 consists of students who are struggling within the core instruction and require supplemental instruction to be successful. Tier 3 consists of students who require intense, comprehensive instruction and evaluation. This article will address evidence-based practices for providing Tier 2 supplemental support to students at risk for failure in the core math instruction. Few studies addressing quality practices for Tier 2 support have been identified in the area of mathematics (Crawford & Ketterlin-Geller, 2008; Fuchs, Fuchs, & Hollenbeck, 2007).

**Evidence-Based Practices for Struggling Math Students**

Research suggests that many students begin learning more complex math skills before mastering the essential component skills (Carnine, 1980; Kameenui & Carnine, 1986). Without a fluent understanding of the essential prerequisite skills students at risk for math failure often
begin to fall behind as math operations become more complex. This is very common for students who receive instruction through the use of a reform curricula (Sayeski & Paulsen, 2010).

Evidence has supported the use of preteaching as an effective supplemental approach (Wixson, 1986; Carney, Anderson, Blackburn, & Blessing, 1984) for students who need extra support in many content areas. However, very little research has focused on the use of preteaching as an intervention in the area of math (Lalley & Miller, 2006).

The effectiveness of preteaching is impacted by the type of instruction implemented into the instructional sessions. The National Math Panel (2008) identified the use of systematic and explicit instruction to be beneficial for these students. It also addresses the use of concrete models and drawings to support long-term maintenance and generalization of these skills. One intervention that provides direct, explicit instruction and has been shown to support students who struggle in mathematics is a gradual instructional sequence. (Ketterlin-Geller, Chard, & Fien, 2008). The concrete-representational-abstract (CRA) sequence provides students with a conceptual framework of math computations based on the use of connecting concrete, representational, and abstract levels of understanding (Butler, Miller, Crehan, Babbitt, & Pierce, 2003; Witzel, 2005).

There is a large body of research supporting this type of instruction for teaching fractions (Jordan, Miller, & Mercer, 1998; Witzel, 2005; Flores, 2010; Miller & Mercer, 1993; Ketterlin-Gellar, Chard, & Fien, 2008); computation skills (Mercer & Miller, 1993; Maccini & Hughes, 2000); and word problem-solving (Huntington, 1994; Maccini & Ruhl, 2000; Witzel, 2001). Despite a significant amount of research completed on the effectiveness of using the CRA sequence there is no research to support the use of this strategy combined with the preteaching component as an alternative approach to Tier 2 supplemental instruction.
Furthermore, only one study was found that supported the use of this intervention for teaching geometry (Cass, Cates, Smith, & Jackson; 2003). The NCTM standards (2000) identified geometry as one of the crucial building blocks for math success warranting further research in this particular area.

The purpose of this research is to study the effects of preteaching using the CRA sequence as a Tier 2 instructional approach within the RTI model. Two research questions guide the methodology used within this study:

1. What are the effects of preteaching geometry using the CRA sequence for fifth graders who are at-risk for math failure?
2. Will the students receiving treatment be able to generalize the skills learned in the preteaching setting to the whole class unit taught through a reform curriculum?

Method

Participants and Setting

Students (N = 20) in fifth grade identified through a geometry pretest and teacher evaluation were participants in this study. Student criteria for participation include (1) scoring below 40% on the pretest, (2) identification by teacher as having failed previous math units, and (3) discrepancy between individual performance and overall class performance as observed by the teacher. A questionnaire completed by teachers indicated that 5 of the students were identified for special education. Four of the 5 students with IEPs had goals in math and reading; and one student had a behavior-related goal. Twenty-five percent of the students received free and/or reduced lunch. Sixty percent of the participants were Caucasian, 6% African American, 5% Hispanic, and 5% Middle-Eastern. Fifty-five percent were female. Students received their core math instruction in general education
classes. Students with an IEP received special education support, but through the duration of this study did receive instruction relating to the prerequisite skills addressed in treatment groups. One student was absent during post-testing and therefore was not included in the analysis. This left a total of 9 students in the control group and ten students in the treatment group.

Students were enrolled in a large school district in the MidWest. The intervention was conducted in 6 sessions over two weeks during a thirty minute study skills period. This study skills period was a time set aside for all students schoolwide to receive supplemental or extended instruction. A total of two groups, 5 students per group, received the intervention. The teachers for both groups were femal graduate students pursuing a PhD in special education who had previous teaching experience. Both teachers were trained to implement the strategy by reading instructional materials relating to CRA (Witzel & Ricommini, 2008; WWC Intervention Report, 2010) and through webinars related to implementing CRA instructional strategies.

Material

There are few commercial packages that address teaching geometry within the CRA sequence. After training in the implementation of CRA, the first author adapted materials provided in the Differentiation Manual, part of the Everyday Math (EM) curriculum used in general education math classes, to fit within the stages of the CRA model. This material was selected to support further use of this strategy by teachers following the intervention without the need to purchase new curricular materials. The concrete stage of instruction involved the use of geometric shapes, protractors, and geoboards. The representational phase incorporated 2-dimensional pictures and student drawings to represent the concepts. The third phase
incorporated the use of Math Boxes (adapted from EM). These were worksheets that contained 6-8 abstract geometry problems.

Treatment integrity checklists were created that contained the essential components for each instructional phase of the gradual teaching sequence. All lessons were audiotaped to collect this data.

*Design and Procedures*

A treatment and control, single factor pre/post experimental design was used to examine the effect of the intervention on students’ math achievement. Students were randomly assigned to treatment or control by a coin toss (heads = control; tails = experimental). We first blocked on classrooms to ensure that an equal number of students from the two general education math classes were represented in the control and treatment groups. This would help control for confounding effects due to variations in classroom routines and instruction.

*Intervention*

Two weeks prior to the beginning of the EM geometry unit, students in the treatment group received 6 sessions (3 per week for 30 minutes) that addressed three prerequisite identified through the EM Teacher’s Manual, and aligned with Iowa Core Standards, as necessary for success in the upcoming unit. These three skills were (1) describe, analyze, draw, and classify two-dimensional and three-dimensional shapes; (2) measure, draw, and classify angles; and (3) estimate angle measure using a right angle as the benchmark. Two days were spent on each skill respectively. The first day the majority of the time was spent on concrete and representational phases of the CRA sequence. The second day the representational phase was reviewed, and the remainder of the session focused on the abstract phase of the sequence. If a student was not exhibiting a strong understanding of the skills on
day 1, the teacher would review the concrete phase on day 2 as well. See Table 1 for the lessons broken down into instructional phases. During the intervention implementation, students in the control group attended study skills but did not work on activities related to geometry. Following the six preteaching sessions, students in both the treatment and control group participated in the EM geometry unit within the general education setting.

**Dependent Variables**

Students in the control and treatment group were evaluated using a researcher generated post-test consisting of 15 problems, 5 related to each of the 3 identified skill areas. This measure was closely aligned to the pretest, used for identification purposes, which included the same number of items for each skill area. Following whole class unit instruction (4 weeks after the beginning of the intervention phase), students in both treatment and control groups were evaluated using the EM geometry unit assessment. This assessment contained 40 problems, 20 of which related specifically to geometry skills. Given the nature of the reform curriculum, EM unit tests contain items that do not relate specifically to the current unit but act as a generalization measure for previous units. For the purpose of this study only those problems specifically related to geometry were analyzed in the results. This measure was used to evaluate the transfer of skills from the preteaching setting into whole class unit instruction.

**Results**

*Treatment integrity and inter-rater reliability*

Treatment integrity data was collected for all lessons through audio tape and researcher checklists. Audiotapes were reviewed by both researchers following the completion of the study and an overall integrity percentage of 100% was obtained.
Pre-/Post/Unit Test Results

After receiving the preteaching intervention, the independent samples t-test on the posttest for the control group (M = 4.56) and posttest scores (M = 10.50) for the treatment indicated the performance gain was significant, t(17) = -4.316, p < .01. Following the classroom unit instruction on geometry, comparisons of the unit test scores once again indicated similar achievement with the treatment group (M=16.40) scoring slightly higher than the control group (M=15.22). Students’ mean scores and effect size (ES) differences on the pre-test, post-test, and the unit test for the geometry unit are summarized in Table 2.

Discussion

This study investigated the effects of preteaching essential geometry concepts prior to whole class unit instruction that introduced more advance geometry skills. The intervention was designed to provide supplemental, tier 2, support to students at risk for failure in math who received their core math in general education classes using a reform curricula. The use of the CRA sequence within the preteaching intervention provided students who typically did not receive explicit skill instruction with the use of concrete manipulatives the opportunity to gain fluency in essential prerequisite skill areas. It was anticipated that if students were able to master these component skills in the preteaching sessions, then they would be able to apply this knowledge to more abstract and multi-step problems that they encountered in whole class unit instruction.

Prior to the preteaching intervention, students in both the control and treatment group were unable to identify various types of triangles or analyze differences between them. Students were inconsistent with their knowledge of measuring, drawing, or analyzing angles; and students were unable to correctly answer questions involving estimation of angle
measures; thus indicating that these were concepts that they had not retained from previous units that had focused on these objectives. After learning these concepts, the treatment group, compared to the control group, showed significant improvement. Preteaching geometry prerequisite skills using the CRA sequence improved the overall understanding and fluency of the essential components for the upcoming unit. Students in the treatment group, who typically struggle within the core math instruction, were entering the new unit with an increased performance and knowledge of that content compared to the control group.

**Unit instruction scores/discussion**

While the results of the unit test indicated no significant differences between the control and treatment groups; students in the treatment group on average performed higher with less variation in the groups’ scores. There are many factors that may have attributed to these effects. First of all it is important to note that given the small sample size in the treatment (N=10) and control (N=9) there is a high risk for Type II error in the results of this study. Second, the instruction in the preteaching setting did not align with the type of teaching in the whole class instruction. The treatment group received direct, explicit instruction; while classroom instruction was more problem-based involving students to make inquiries about new learning. Research reveals that supplementary interventions are substantially more effective when they align with validated classroom instruction (Fuchs et al., 2008). Despite a small effect on the unit test, teachers indicated through a questionnaire that the students in the control group showed an increase in participation and motivation in the geometry unit compared to that of previous units. Variables including low motivation and poor self-concept greatly affect the math skills of students with LD (Bryant, Bryant, & Hammill, 2000; Mercer & Miller, 1992; Montague & Applegate, 1993). Feeling insecure and unmotivated about learning math skills plays a large role
in the failure of students to achieve basic math standards (Mercer & Miller, 1992). While not analyzed statistically, students in the treatment group had increased opportunities to respond and feel successful in math, which will likely increase future motivation and performance.

Limitations

One limitation of our study relates to using the unit test as our generalization measure. While it did evaluate geometry concepts, EM unit assessments also contain items related to previous math units that may not related directly to the concepts being taught in the geometry unit. Another limitation included the short amount of time allotted for the preteaching intervention based on school activities and scheduling. Another possible limitation related to participant selection. Through the random selection process there was no control for students with disabilities. Following group selection it should be noted that all five students receiving special education services were placed in the treatment group. The ability for students with disabilities to retain and transfer skills is typically more difficult than that of their grade-level peers. This may have resulted in lower unit test scores for the treatment group compared to selection controlling for students on IEPs.

Conclusions

In summary, this study suggests that preteaching students using the CRA sequence is a successful way to increase overall fluency and understanding of essential math skills for students at risk for failure. Additional research supporting this intervention as a way to support classrooms using reform curricula is needed. Future research aligning the preteaching intervention with more cognitive instructional approaches may result in stronger generalization and retention of skills learned through supplemental instruction.
References


Table 1.

<table>
<thead>
<tr>
<th>Prerequisite Skill</th>
<th>Concrete Phase</th>
<th>Representational Phase</th>
<th>Abstract Phase</th>
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<tbody>
<tr>
<td>Describe, analyze, draw, and classify triangles.</td>
<td>Teacher modeled using geometric building blocks the differences between the 3 triangles angles and sides. Students sorted triangles by angles and sides; and used geoboards to create scalene, isosceles, and equilateral triangles.</td>
<td>In a 2 dimensional tessellation including the 3 types of triangles students had to identify and classify the triangles by coloring them each different.</td>
<td>Each Math Box contained the angle and side measurements of a triangle. The students had to identify it as isosceles, scalene, or equilateral and then draw the triangle.</td>
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<tr>
<td>Measure, draw, and classify angles.</td>
<td>Using angles create from two straws and a pipe cleaner students modeled and practiced creating acute, obtuse, and right angles.</td>
<td>Through modeling and practice students drew acute, obtuse, and right triangles on paper.</td>
<td>Each Math Box contained a triangle. Students had to identify each angle in the triangle as right, acute, or obtuse.</td>
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<tr>
<td>Estimate angle measure using a right angle as the benchmark.</td>
<td>Through modeling and practice students were taught to measure their straw angles to the nearest 5\textsuperscript{th} degree using oversized protractors. Students measured angles in the room (doors, desks, etc.) to identify angles that were 90 degrees.</td>
<td>Students measured angles drawn on a paper to the nearest fifth degree. They had to determine if they were obtuse, acute, or right.</td>
<td>Each Math Box contained an angle. Students had to estimate the angle measure to the nearest 5\textsuperscript{th} degree.</td>
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<tr>
<td></td>
<td>Post-test</td>
<td>Unit Test</td>
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<tr>
<td>Treatment Group Mean Scores</td>
<td>10.50(2.80)</td>
<td>16.40(2.22)</td>
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<tr>
<td>Control Group Mean Scores</td>
<td>4.56(3.21)</td>
<td>15.22(3.35)</td>
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<td>Effect Size (Cohen’s d)</td>
<td>2.83</td>
<td>.42</td>
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