The Effects of a Direct Instruction Program on the Fraction Performance of Middle School Students At-risk for Failure in Mathematics

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The current exploratory study investigated the effects of a Direct Instruction program implemented with middle school students identified as at-risk for failure in mathematics. Direct Instruction has typically been implemented with students with disabilities in separate special education settings. However, this study examined the extent to which this kind of instruction could be integrated into a general education setting. The study took place in a rural middle school in which the majority of the students were from culturally and linguistically diverse backgrounds. The participants were seventh grade students who had failed the state-mandated annual assessment at least twice and who were identified as at-risk for failure. The students participated in fourteen lessons of the Direct Instruction fraction program. Student progress was assessed using curriculum-based pre and post-tests and the data were analyzed using a t-test. Participation in the program resulted in significant increases in fraction skills. The students also demonstrated increases in appropriate and on-task behavior during the intervention.

According to the National Council of Teachers of Mathematics (NCTM, 2000), students are expected to be proficient in computation and estimation. According to NCTM standards, middle level students will: (a) work flexibly with fractions, decimals, and percents to solve problems; and (b) compare, order, fractions, decimals, percents efficiently and find their equivalent locations on a number. Students who struggle in mathematics have particular difficulty with fraction concepts (McLeod & Armstrong, 1982; Tourniare & Pulos, 1985). Students have difficulty understanding that numbers and symbols, such as those used in fraction problems, relate to real-world situations (Hiebert, 1985). Other factors may also lead to poorly developed understanding of fraction concepts. According to Kelly, Gersten, and Carnine (1990), student’s poor performance in this area may be due to curriculum design. Traditional basal curricula lack the components of effective curriculum design such as systematic practice in discriminating among problem types; separation of confusing problems and terminology; and use of a wide range of examples to illustrate each problem type.

The research in the area of math regarding specific interventions for students at-risk for math failure is small compared to what is known about other academic areas such as reading (National Research Council, 2002). However, there are several studies in which interventions in the area of fractions were successful for students at-risk for failure in mathematics. These include instruction using strategies and mnemonic devices (Joseph & Hunter, 2000; Test & Ellis, 2005), manipulatives and pictures (Bulter, Miller, Crehan, Babbitt, & Pierce, 2003), and the use of the Direct Instruction model (Scarlato & Burr, 2002).
An effective mathematics intervention for students at risk for failure in mathematics is the use of strategies and mnemonic devices. Joseph and Hunter (2000) provided middle school students with learning disabilities with different strategies for solving addition and subtraction of fractions with like and unlike denominators on a series of cue cards. The use of cue cards fostered independent problem solving rather than reliance on the teacher. The use of the cue cards was faded and the students maintained their performance. Test and Ellis (2005) extended Joseph and Hunter's findings by providing similar fraction solving strategies, but provided students with a mnemonic device that increased the likelihood that students would remember the strategies. Middle school students with high incidence disabilities used the mnemonic device, LAP, which involved the following steps. The first step was "look at the sign and denominator." If the denominator was the same, the students proceeded to solve the problems. The next step was; "Ask yourself the question, 'Will the smallest denominator divide into the largest denominator an even number of times'? If the student's answer was "yes", the student followed specific steps for that type of problem. If the student's answer was "no", the student would follow specific steps for that particular type of problem. All of the students participating in the study made gains in their performance, and five of the six participants mastered addition and subtraction of fractions with like and unlike fractions after six weeks of instruction.

The use of manipulatives and pictures has also been shown to be an effective mathematics intervention for students at risk for failure in mathematics. Jordan, Miller, and Mercer studied the effects of the concrete-representational-abstract (CRA) instruction sequence on fraction performance of elementary students with and without disabilities in general education classrooms. CRA involves three levels of instruction and each includes teacher modeling, guided practice and independent practice. The levels are as follows: (a) the concrete level includes the use of manipulatives to foster understanding of the concept; (b) the representational level involves the use of pictures, fading the students' dependence on manipulatives; and (c) the abstract level involves numbers only. Jordan, Miller, and Mercer found that the use of the CRA sequence resulted in improved performance in fraction problem solving when compared to traditional basal instruction.

Bulte, Miller, Crehan, Babitt, & Pierce, (2003) investigated the need for the concrete level of instruction for teaching fraction equivalency. The researchers compared instruction using the CRA sequence and instruction using only the representational and abstract levels of instruction. Middle school students with disabilities participated in the investigation and the researchers found that although both the CRA and RA sequences resulted in increased understanding, students who participated in the CRA sequence performed at a higher level.

Direct Instruction has also been demonstrated as an effective method of teaching math to students in general education and special education (Hasselbring, et al., 1987; Kelly, Carnine, Gersten, & Grossen, 1986; Kelly, Gersten, & Carnine, 1990; Kitz & Thorpe, 1995; Tarver & Jung, 1995; Woodward, et al., 1986; Hastings, Raymond, & McLaughlin, 1989; Rivera & Smith, 1988; Wilson & Sinde- lar, 1999). The premise of Direct Instruction is that all students can learn with appropriate instructional design and implementation. The efficiency of this methodology is particularly beneficial for students with disabilities, who have many learning needs but little time to address them. Watkins and Slocum (2004) describe the major components of Direct Instruction as follows. Direct Instruction is designed in a way to ensure efficient student learning through: (a) organizing central concepts and strategies in ways that allow application across multiple contexts; (b) providing clear and systematic methods
of teacher communication, decreasing the likelihood of student misunderstanding or confusion; (c) the use of formats involving structured verbal exchanges between students and teachers, allowing for increased student engagement, ongoing progress monitoring, and repeated verbal practice; (d) strategically integrating skills to ensure efficient learning and understanding; and (e) arranging Instructional concepts into tracks in which learning develops across the length of the program while providing ongoing review and generalization.

With regard to fraction instruction, Kelly, Gersten, and Carnine (1990) compared traditional basal instruction and with instruction using a videodisc program based on Direct Instruction methodology. The program was used to teach fractions to high school students enrolled in remedial mathematics classes, half of which were identified as having learning disabilities. The researchers found that students performed at a higher level after participating in the Direct Instruction videodisc instruction compared to students who participated in instruction from a traditional basal curriculum.

Scarlato and Burr (2002) compared traditional instruction in fractions to instruction based on the Direct Instruction model. Students with learning disabilities served in a resource setting participated in twenty weeks of instruction. One group participated in fraction instruction using formats outlined in the book, Designing effective mathematics instruction: A Direct Instruction Approach (Stein, Silbert, & Carnine, 1997). The teacher used modeling, guided practice, and independent practice and cumulative review. Example selection guidelines were followed including the use of varied systematic practice in discriminating among examples; separation of confusing examples and terminology; and use of a wide range of examples to illustrate each problem type. The students received immediate feedback and there were specific mastery criteria for guided and independent practice. The students who participated in Direct Instruction lessons outperformed their peers on informal and formal measures.

Although these investigations demonstrated effective interventions for fraction instruction, the majority of theses studies involved students with disabilities receiving instruction outside of the general education classroom. The studies that involved Direct Instruction used the principles and procedures by modifying instructional procedures or using videodisc program. However, none involved existing published teacher-directed programs. It is not known whether or how such as program could be implemented in a general education setting. The purpose of the current study was to investigate the effects of a Direct Instruction program on the performance of middle school students without disabilities who were at-risk for math failure within the general education setting.

Method
Research Design
This was an exploratory study designed to investigate the following question. What are the effects of a Direct Instruction program on the performance of middle school students without disabilities who were at-risk for math failure within the general education setting? The students’ performance was measured before and after participation in the Direct Instruction intervention and the data were analyzed using a t-test.

Participants
The participants were seventh grade students attending a school in a rural district outside of a large southwestern city. None of the students had been identified as having a disability; however, all students had been identified as being at risk for failure in mathematics. The students had failed the annual state-designated assessment in the area of mathematics two or more times. With regard to fractions, the test from the previous year included the following skills:
(a) modeling of addition and subtraction situations involving fractions with objects, pictures, words, and numbers; (b) equivalent forms of rational numbers including whole numbers and fractions; and (c) the application of addition and subtraction of fractions in word problems. As a result, the students were enrolled in a remedial math course as an elective. Thirty students participated in the study, ranging in age from 12 to 14 years of age, eleven females and nineteen males. Eighteen of the students were Hispanic, six of the students were white, and six of the students were African American. All of the students had demonstrated deficits in the area of basic fractions as demonstrated on district progress assessments. The district designed quarterly assessments to monitor students’ progress through the state curriculum. The assessments are administered during the last 2-weeks of each grading period. Each assessment includes three components: performance assessment, open-ended questions, and multiple-choice items. The performance component requires students to explain their learning in writing. The open-ended component requires a brief written response to a question. With regard to fractions, the quarterly assessment included the following: (a) representation of multiplication and division situations involving fractions with concrete models, pictures, words, and numbers; and (b) usage of addition, subtraction, multiplication, and division to solve problems involving fractions and decimals.

The decisions about the instructional content and procedures were made based on the needs of the individual classroom. The instructional content was chosen based on the students’ needs. The teacher whose classroom was used for this study identified basic fractions as an area of significant need for his students. The teacher had taught and reviewed basic fraction skills with the students earlier in the semester. However, the students’ performance in this area had not changed after instruction as evidenced on recent district progress assessments. The teacher reported concerns about the amount of content that needed to be taught as well as concerns about the lack of achievement demonstrated by the students. The instructional procedures were designed to provide an effective intervention that would not interfere with the existing classroom structure and allow for previously planned instruction to occur without too much disruption. Instruction took place in three sections of a general education remedial math course over a period of seven weeks. The students enrolled in this course as an elective, in addition to their regular seventh grade math course. There were 10-12 students enrolled in each class. Through the course of the study, four students moved away or transferred, so 30 students participated throughout the entire seven-week study.

Pre-test

The pre-test consisted of a curriculum-based assessment that was included in the program. It included the following: (a) translating a whole number into a fraction; (b) translating a fraction into a whole number; (c) multiplication of fractions with like denominators; (d) addition/subtraction of fractions with like denominators; (e) addition/subtraction of mixed numbers with like denominators; and (f) multiplication of whole numbers and fractions. On the first day of the second nine-week grading period, the pre-test was administered at the beginning of each remedial class period. The assessment was administered to students in a whole group format. There was no time limit for completing the assessment.

Materials for Instruction

The instructional materials consisted of a published Direct Instruction program, Corrective mathematics, basic fractions (Engelmann & Steely, 2005). The teacher’s materials included a manual with scripted lessons. Each lesson began with the introduction
of a new skill, demonstrated and modeled by the teacher. The students participated in guided practice of the new skill. The students were actively involved in the lesson through frequent group verbal responses. The teacher provided a signal to ensure responding in unison. The students chose their own signal in which the teacher said, "OK." Incorrect responses were corrected immediately. Correction procedures involved three steps: teacher modeling of the correct response, guided practice with the students responding with the teacher, and independent student response. Students independently practiced skills only after they demonstrated mastery throughout guided practice with the teacher. This decreased the likelihood that students would practice or learn error patterns during independent practice. Instruction was presented systematically, providing a wide range of examples, separated confusing skills and concepts, and provided systematic practice. Instruction facilitated systematic understanding of fraction concepts. Understanding of concepts was developed through the use of pictures and drawings rather than an emphasis on procedures only. Instruction moved at a quick pace to ensure frequent responding and increased engagement. The presentation of skills and concepts allowed for the increased pace because skills were broken down into small units that were mastered quickly and systematically combined to form more complex tasks. The students did not engage in independent practice until they had demonstrated mastery of those skills in previous guided practice with the teacher. This decreased the likelihood of student errors or the practice of error patterns. The program design led to high levels of student success throughout instruction and practice activities. The students’ materials consisted of workbooks, including lesson worksheets with guided practice as well as independent practice problems.

**Instruction**

Prior to the study, each 50-minute class period had been divided, twenty minutes for review of difficult concepts, and thirty minutes of new material. Each class was divided into two groups consisting of 6-7 students. For this study, the first twenty minutes of each class period continued to be devoted to review. However, groups alternated between participation in Direct Instruction, and traditional instruction led by the classroom teacher. For example one group participated in Direct Instruction on Mondays and Wednesdays and traditional instruction on Tuesdays and Thursdays and vice-versa. Teacher-led instruction did not include any of the skills or concepts included in the Direct Instruction program. Traditional instruction involved teacher demonstration of skills and procedures and student practice through remedial skills workbooks tailored to the state-mandated annual assessment. University pre-service teachers were assigned to this classroom to complete a field requirement for a practicum course. The pre-service teachers received professional development in Direct Instruction methodology through a university course and demonstrated proficiency before beginning this field placement. The pre-service teachers led the Direct Instruction groups.

**Procedural Reliability**

Since pre-service teachers led the Direct Instruction groups. It was important to ensure that instruction was carried out with procedural fidelity. The first author checked 50% of the instructional lessons. These checks were conducted through the use of a checklist. The checklist included items such as appropriate pacing of lesson, use of correction procedures, appropriate and engaging use of lesson script, organization of materials, and use of reinforcement for student success. The procedural fidelity was 90% for all lessons across all three classes.
**Posttest**

The post-test consisted of a curriculum based assessment that was included in the program. It included the following: (a) translating a whole number into a fraction; (b) translating a fraction into a whole number; (c) multiplication of fractions with like denominators; (d) addition/subtraction of fractions with like denominators; (e) addition/subtraction of mixed numbers with like denominators; and (f) multiplication of whole numbers and fractions. The post-test was given during the eighth week of the second grading period at the beginning of each remedial class period. The assessment was administered to students in a whole group format. There was no time limit for completing the assessment.

**Results**

**Pre-test Results**

The students were not given feedback on their pre-test performance. The mean performance for the pre-test was 20%, with scores ranging from 0-57%. The students’ performance on the different items on the pre-test are as follows: (a) 4% items correct translating a whole number into a fraction; (b) 22% items correct translating a fraction into a whole number; (c) 30% items correct multiplication of fractions with like denominators; (d) 14% items correct addition/subtraction of fractions with like denominators; (e) 3% items correct addition/subtraction of mixed numbers with like denominators; and (f) 0.02% items correct multiplication of whole numbers and fractions. The most common errors across students were misunderstandings of fractions and their relationship to whole numbers (i.e. \(\frac{2}{4} = 1\)), adding denominators (i.e. \(\frac{7}{6} + \frac{7}{6} = \frac{4}{6}\)), and the incorrect usage of cross multiplication (i.e., \(\frac{1}{3} \times \frac{2}{3} = \frac{3}{6}\)).

**Post-test Results**

The mean performance for the post-test was 77%, with scores ranging from 36-100%. The majority of the students’ post-tests were above 75%; however, there were three students with lower scores. The students’ performance on the different items on the pre-test are as follows: (a) 80% items correct translating a whole number into a fraction; (b) 90% items correct translating a fraction into a whole number; (c) 93% items correct multiplication of fractions with like denominators; (d) 84% items correct addition/subtraction of fractions with like denominators; (e) 57% items correct addition/subtraction of mixed numbers with like denominators; and (f) 67% items correct multiplication of whole numbers and fractions. Common errors across students were errors in multiplication and addition rather than procedural errors, and disregard for the whole number when adding/multiplying mixed numbers (i.e. \(2\frac{1}{4} \times \frac{3}{4} = 2 \frac{3}{16}\)).

**Comparison of Pre-test and Post-test Performance**

A paired samples t-test was performed on the overall performance data. A t-score of 16.224 was obtained, which was significant at the 0.005 level. The probability that this score was obtained by chance was very small (<0.01). Although there was a statistically significant difference between the pre-tests and post-tests, it is more important to examine the educational significance of the students’ performance. Data regarding the student’s overall performance on the pre-test and post-test are visually depicted in figure one.

One third of the students performed below 50% on the pre-test and performed above 90% on the post-test. Twenty-six of the thirty students performed above 75% on the post-test, many improving their performance by 50% or more. The pre-test and post-test performances were compared by item type and the results are as follows: (a) 76% increase in translating a whole number into a fraction; (b) 68% increase in translating a fraction into a whole number; (c) 63% increase in multiplication of fractions with like denominators; (d) 70% increase in addition/subtraction of fractions with like denominators; (e) 54%
increase in addition/subtraction of mixed numbers with like denominators; and (f) 66.08% increase in multiplication of whole numbers and fractions. Data regarding the student’s performance by item type are visually depicted in figure one.

Anecdotal results

Although formal data were not collected, the researchers observed changes in behaviors during the intervention. Since the students alternated between traditional instruction and Direct Instruction, there was an opportunity to observe the same students and their behavior in each instructional setting. The students appeared to be more engaged in fraction instruction using Direct Instruction. This increase in engagement was observed through the following: the amount of student response and number of correct responses; the amount of on-task behavior such as visually tracking the movements of the instructor, and competing tasks within several seconds of receiving directions; and the amount of disruptive or off-task behavior such as talking to peers, helping instruction, making inappropriate comments, out-of-seat behavior etc... There were more instances of student responding, correct responses and on-task behavior and fewer instances of off-task behavior when students participated in the Direct Instruction group than when participating in the
traditional instructional group.

Discussion

The purpose of the current study was to investigate the effects of a Direct Instruction program on the performance of middle school students without disabilities who were at-risk for math failure within the general education setting. Previous studies have included mostly students with disabilities taught within separate settings such as a resource room (Butler et al., 2003; Scarlato & Burr, 2002; Test & Ellis, 2005). There is a lack of literature regarding interventions studied with students with disabilities used for the benefit of all students with learning needs regardless of disability status. The program used in this study was implemented with minor changes in the structure and existing procedures within the classroom. The students demonstrated significant improvement in skills as a result of their participation in the fraction program. The results were statistically significant as well as educationally significant. The students mastered basic fraction skills over the course of 7 weeks of instruction. An effective and efficient method of instruction was included without taking away from the existing structure and content of the classroom. Student performance increased in a short amount of time (7 weeks of instruction) with few (14) instructional lessons. This study extended the literature in the area of intensive mathematics interventions such as Direct Instruction to include the general education setting, rather than separate settings for students with disabilities. This study demonstrated how such an intervention could be included without taking away from the existing structure while still resulting in improved student performance.

This particular instructional program was chosen based on the needs identified by the teacher. The teacher identified basic fractions as an area of need because this had been a topic previously taught and reviewed in the class. However, the data gathered from district progress assessments showed that the students' performance in this area had not changed as a result of instruction. After seven weeks of instruction (14 instructional lessons), the students' performance changed significantly. These results are consistent with previous research demonstrating Direct Instruction as a powerful instructional model (Hasselbring, et al., 1987; Kelly, Carnine, Gersten, & Grossen, 1986; Kelly, et al., 1990; Kitz & Thorpe, 1995; Tarver & Jung, 1995; Woodward, et al., 1986; Hastings, Raymond, & McLaughlin, 1989; Rivera & Smith, 1988; Wilson & Sindelar, 1999).

The Corrective Mathematics program consists of modules for specific skills such as addition, subtraction, multiplication, basic fractions, advanced fractions, decimals, percents, and ratios and equations. Modules could be chosen based on students' needs. Students could be grouped according to individual needs and different concepts and skills could be mastered in an efficient manner. Middle school is a critical time in student's academic careers, preparing them for more advanced studies critical thinking. There are may be gaps in student's understanding of certain mathematical concepts that could be addressed in an efficient individualized way through the use of these modules. Modules could supplement existing curriculum and allow for intervention without encroaching on the current curriculum or consuming great amounts of instructional time. It is important to view the use of such interventions as supplements to existing curriculum. The use of these interventions should not encompass all mathematics instruction, making deficit areas the sole focus. Addressing deficit areas in this way has the potential for impeding students' progress through the curriculum. This is an issue in the field of special education, in which there are instances of students in middle and high school resource rooms working mostly on basic fact instruction and the gap between their performance and their grade-level peers' performance becomes
wider and wider (Cawley, et al., 1978; Cawley & Miller, 1989; Jones & Thomas, 2003; Warner, et al., 1980). This is problematic and the current study has no intent of promoting such a model. However, if gaps in skills and understanding can be addressed in an efficient manner without taking over the entire curriculum, students will benefit and perhaps progress more successfully into advanced mathematical understanding.

The effect of Direct Instruction on the students' behavior was another interesting finding. This is consistent with previous research that demonstrated decreases in off-task behavior and increases in student engagement (Grossen, 2002). The students participated in each type of instruction on alternate days, providing for observation of the same groups of students in each instructional setting. Even though on-task behaviors and evidence of engaged learning occurred one day, the same group of students behaved in a contrary way the next day when participating in the traditional instructional format.

There may be concerns about the instructional intervention consisting of an existing published program. The availability and accessibility of these resources may be limited for classroom teachers. There are components of Direct Instruction that do not require the use of published materials. Theses include: use of frequent responding; systematic teaching of component skills; immediate feedback; scaffolded instruction through modeling, guiding, and providing independent practice; and including criteria for mastery before proceeding to the next level of instruction. These practices could be used to teach any concept or skill in a way that would increase the likelihood that students would participate actively. Any group of existing curriculum standards could be organized and taught in this way, given time and expertise in the content area.

Another informal observation was student interest in the program. One a number of occasions, the students would ask if they could participate in Direct Instruction on days when they were scheduled to participate in the traditional instruction group. The students appeared to like the program and most reported that they were surprised by their progress. The students performed few errors and completed independent practice activities with at least 90% accuracy. Perhaps their experience with success led to increased desire to participate. The students enrolled in these remedial courses had experienced failure in mathematics and perhaps were not accustomed to success. At the beginning of the study, students reported that they were not skilled in math and that it was their least favorite subject. When the fractions program was introduced, none of the students appeared enthused, reporting that fractions were the hardest parts of math. Despite these feelings and perceptions about math, the students were successful and their perceptions of fractions appeared to change throughout the intervention. During most of the lessons, at least one student would comment that fractions were easy, contrary to previous beliefs.

Although the intervention was successful for all of the students, there are limitations to this study. The classroom teacher did not implement the Direct Instruction program. Very few general education classrooms include more than one instructor to carry out the interventions in this manner. However, other instructional arrangements could be made to deal with this issue. The use of peer tutoring has been shown to be an effective way for students to learn and practice math skills without dependence on the teacher (Calhoon & Fuchs, 2003; Maheady, Sacca, & Harper, 1987). Another way in which Direct Instruction could be implemented is with whole group instruction. The setting within this study is not typical of general education settings that have twice the number of students. Whole group instruction with this type of intervention may be difficult to manage.

Another limitation of this study is that an individual who implements a Direct
Instruction program should also engage in professional development prior to using the program to ensure that instructional procedures are followed with fidelity. The resources needed for that sort of preparation may also be limited. Therefore the ability to generalize these findings is decreased. Future research is needed on how Direct Instruction, such as the use of Corrective Mathematics modules, could be used in a general education setting with one teacher. Future research is also needed to study how some of the components of Direct Instruction could be used to enhance an existing curriculum and the effects of those methods on student achievement. Perhaps existing curriculum modified with Direct Instruction methodology could be compared to traditional instruction as well as existing Direct Instruction programs to study the effects of each on student performance.

References


curriculum or a Direct Instruction curriculum. Effective School Practices, 14, 49–57.


