MARY C. SCARLATO and WENDY A. BURR, Regent University

Teaching Fractions to Middle-School Students

Abstract: This study examined the effectiveness of Direct Instruction for teaching four 7th-graders with learning disabilities fraction and decimal skills derived from Grades 4 through 7 Commonwealth of Virginia Mathematics Standards of Learning (SOLs). Each student was taught in a resource setting via strategies and formats delineated in *Designing effective mathematics instruction: A Direct Instruction approach* (Stein, Silbert, & Carnine, 1997). The teacher incorporated modeling, guided and independent practice, cumulative review, adherence to example selection guidelines, delivery of immediate corrective feedback, and mastery criteria for both guided and independent practice. After 20 weeks, the authors contrasted student progress with that of a non-Direct Instruction comparison group matched by age, sex, disability, and Individual Education Plan (IEP) math content. Results showed the Direct Instruction group outperformed their peers on both standardized and informal assessments. The article discusses implications for teachers, administrators, researchers, teacher training institutions, and students with learning disabilities.

Recent Department of Education statistics (U.S. Department of Education, 2000) reveal that only 33.1% of students with learning disabilities earn standard high school diplomas. Prior statistics from the National Longitudinal Transition Study (U.S. Office of Special Education Programs [OSEP], 1985–1993) indicate that 35% of students with learning disabilities drop out of high school, twice the rate of nondisabled students. Additionally, the study states that only 2% of students with learning disabilities attend four-year college; 14% attend a postsecondary school within 2 years of leaving high school, compared to 53% of the general population.

The Standards Based Reform movement and the Individuals with Disabilities Education Act of 1997 (IDEA 1997) have focused renewed attention on k–12 curriculum for students with learning disabilities. IDEA 1997 stipulates that students with disabilities must have access to, and make progress in, the general education curriculum. It also requires that students with disabilities participate in state and local assessment programs, with appropriate accommodations where necessary (Sec. 612 [a] [17] [A]). These directives along with dismal secondary and postsecondary outcomes for students with learning disabilities should lead educators to more carefully examine both curriculum and strategies used to teach these individuals.

Math instruction is an area of particular importance for all students (Fourqurean, Meisgeier, Swank, & Williams, 1991). The literature identifies a relationship between math skills and success in postsecondary education and employment among students with learning disabilities (Fourqurean, et al., 1991).

Although reading deficiencies are cited as the most significant problem among individuals

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with learning disabilities, math deficiencies are equally serious (Mastropieri, Scruggs, & Shiah, 1991). Numerous factors account for math deficits. Parmar and Cawley (1991) postulate learned helplessness as a major factor. This may stem from children trying to solve problems for which they lack necessary skills and understanding. Without these prerequisites, students come to depend on the teacher for the solution, which fosters the notion that outside help is needed to solve problems correctly. This produces another problem: cognitively passive learners unable to regulate their own learning (Parmar & Cawley, 1991). Self-regulation is fundamental to the acquisition and application of math knowledge and procedures.

Several authorities (Carnine, 1991; Cawley, Miller, & School, 1987; Kelly, Gersten, & Carnine, 1990) emphasize the role of the quality of instruction in math outcomes among children with learning disabilities. A large body of research suggests that quality of instruction is a powerful factor. Studies that used adequate instruction produced improved math performance among students with learning disabilities (Kirby & Becker, 1988; Mastropieri et al., 1991; Mercer & Miller, 1992; Rivera & Smith, 1988; Scheid, 1990; Koscinski & Gast, 1993a; Koscinski & Gast, 1993b; Peterson, Mercer, & O'Shea, 1988; Miller & Mercer, 1993a; Miller & Mercer, 1993b).

Christenson, Ysseldyke, and Thurlow (1989) identified 10 universal factors they claim are necessary for student achievement. These factors include (a) effective and efficient classroom management, (b) a positive school climate, (c) presence of an instructional match between curriculum and students' abilities and needs, (d) clarity of stated goals and expectations along with predetermined mastery criteria, (e) clarity within lessons, (f) quality and level of support provided to each student, (g) adequate and efficient use of academically engaged time, (h) frequent student responses during engaged time, (i) active teacher monitoring of student performance, and (j) appropriate and frequent student evaluation.

An extensive literature review by Mastropieri et al. (1991) identified several effective practices for teaching math to students with learning disabilities. They grouped these interventions into three categories: behavioral, cognitive, and alternative delivery systems. Included among the most effective procedures were (a) modeling and feedback, (b) fluency building opportunities, (c) a concrete to abstract sequence, (d) setting goals, (e) employing verbalization while problem solving, (f) teaching generalizable problem solving and computation strategies, and (g) using computers, videodiscs, and peer tutoring to support instruction.

Direct Instruction

The Direct Instruction approach includes the following elements: (a) specifying long and short term objectives, (b) devising procedural strategies, (c) determining necessary preskills, (d) sequencing skills, (e) delineating a teaching procedure, (f) designing an instructional format (e.g., devising teacher wording, selecting learning tasks, sequencing instruction, devising correction procedures), (g) selecting examples, (h) specifying practice and review, and (i) designing progress-monitoring procedures (Stein, et al., 1997). Numerous studies validate Direct Instruction's effectiveness in teaching math to students with and without disabilities (e.g., Hasselbring, et al., 1987–1988; 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).

Direct Instruction has produced significant math gains among general education students. Hasselbring, et al. (1987–1988) evaluated its effectiveness in teaching two groups of elementary age students the same fraction content in two situations: via videodisc and via the teacher. A control group received instruction via a traditional spiral curriculum. Researchers analyzed the data for both high and average ability students and found that the average ability Direct Instruction groups scored almost as high as the high ability spiral curriculum group. A very large effect size of 1.20 lent support to the Direct Instruction approach. In another study comparing the performance of fourth graders taught via Direct Instruction with peers taught via a traditional textbook approach, Crawford and Snider (2000) found that the Direct Instruction group performed higher on end-of-year criterion-referenced posttests as well as publisher-developed (i.e., SRA and Scott, Foresman) tests. The Direct Instruction group's superior performance is supported by a very large effect size of 1.15. Tarver and Jung (1995) provide further support for Direct Instruction's efficacy in teaching math to general education students. They compared the performance of first and second graders receiving math instruction from *Connecting Mathematics Concepts* with that of non-Direct Instruction controls receiving instruction via *Math Their Way* and NCTM *Cognitively Guided Instruction*. The study included 119 students. After 2 years of instruction, the Direct Instruction group outperformed the controls on the Comprehensive Test of Basic Skills and displayed better math attitudes. The Direct Instruction program emphasized flexible groupings, explicit explanations of mathematical concepts, connections among concepts, strategies for problem solving, and application activities that fostered generalization of skills and concepts. An educationally significant effect size of .78 favored the Direct Instruction group.

Direct Instruction's effectiveness in teaching math to students with learning disabilities is well supported in the literature. Hastings et al. (1989) investigated the approach's efficacy in teaching two secondary students with learning disabilities to count money. In this multiple baseline across-subject design, students were taught to count coins and bills efficiently using a sequential series of steps. Although the students with learning disabilities were significantly slower than the normative comparison group during baseline, after intervention they counted money at least as rapidly as the average rate of the nondisabled group. The Direct Instruction intervention produced fast and accurate money counting skills. Rivera and Smith (1988) taught eight middle school students with learning disabilities to solve long division problems with and without remainders within 2–9 days. Key elements of the approach (i.e., modeling, imitation, set questions, and key guidewords) contributed to student performance in this single participant, multiple baseline, crossover design. Kitz and Thorpe (1995) conducted an 8-week study to compare the effectiveness of two algebra programs with 26 college-age students with learning disabilities and a history of math failure. One group received instruction via a Direct Instruction-based videodisc program while the other received instruction via a traditional textbook-based approach. Results revealed that the Direct Instruction group outperformed the control group on the study's three posttest measures: a videodisc posttest, an algebra text posttest, and the first algebra course grade. Very large and educationally significant effect sizes of 1.88 on the videodisc posttest, 1.07 on the algebra textbook posttest, and .83 on the first algebra course grade, supported Direct Instruction.

Wilson and Sindelar (1991) investigated the use of Direct Instruction to teach addition and subtraction word problems to 62 students with learning disabilities from nine elementary schools in a medium-sized school district. Each received special education in math, scored 80% or better on a test of basic addition and subtraction skills, read at least on a 1.5 grade level and needed instruction in word problem solving. Researchers randomly assigned students to three groups: (a) strategy-plus sequence, (b) strategy-only, and (c) sequence-only. The first two groups received

Direct Instruction (i.e., fast-paced scripted lessons, teacher questioning, hand signals, choral responding, guided and independent practice, and use of the fact-family concept to solve problems). The only difference between these two groups was that the strategy-plus sequence group received lessons that practiced one problem type at a time; the strategy-only group received a balanced combination of practice problems that included within each lesson all four problem types. The four problem types were (a) simple action problems, (b) classification problems, (c) complex action problems, and (d) comparison problems. The third group (sequence-only) received word problem lessons adopted from a basal math series. Results showed that the two Direct Instruction groups performed comparably, and that both of these groups significantly outperformed the sequence-only (basal math series) group. Comparing the strategy-plus sequence group (Direct Instruction) to the sequence-only group (traditional basal), produced an educationally significant effect size of .32 at posttest and a substantially larger effect size of 1.06 at follow-up, 2 weeks later, favoring the Direct Instruction group. Comparing the strategy-only (Direct Instruction) group to the sequence-only group resulted in educationally significant effect sizes of 1.04 on the posttest and at 2-week follow-up, 1.20 favoring again, the Direct Instruction approach.

Kelly et al. (1986) used a Direct Instruction videodisc program to teach fractions to secondary students with learning disabilities. Students were from remedial and general math classes and achieved less than 50% accuracy on a criterion-referenced pretest. After 10 days of intervention, students in the Direct Instruction group showed significantly better performance than the control group on the posttest (95% versus 79%). At follow-up 2 weeks later, the Direct Instruction group demonstrated a high rate of retention by scoring 93.8% compared to the control group that scored 70.2%. A large and educationally significant effect size of 1.32 favored the Direct Instruction group.

An important element of Direct Instruction is its emphasis on effective curriculum design. Kelly et al. (1990) compared the performance of two groups of high school remedial math students learning fraction content. The Direct Instruction group received instruction via a videodisc program that emphasized (a) detailed step-by-step strategies for solving fraction problems, (b) separation of confusing elements and terminology, and (c) using a wide range of examples to illustrate each fraction concept. The control group was taught using a traditional basal textbook. Both groups' pretest scores on a curriculum-referenced test were less than 40%. On posttest, however, the Direct Instruction group's score was 97% while the control group's was 82%.

There is much similarity between Direct Instruction's components and the 10 universal factors that Christensen et al. (1989) claim are necessary for student achievement. For example, teachers who use Direct Instruction effectively maintain classroom management; establish a positive school climate; precisely match curriculum with students' abilities and needs; clarify goals and expectations; set mastery criteria; provide clarity within lessons; provide a high level of student support through modeling, guided practice, immediate feedback, and monitoring; establish high levels of engaged time; and provide continuous evaluation.

Additionally, each of Mastropieri et al.'s (1991) indicators of successful math programming for students with learning disabilities mirror elements of Direct Instruction. Modeling and feedback are foundational to Direct Instruction. Fluency building through cumulative review is a significant element of the approach. Verbalization during problem solving, and the teaching of generalizable strategies are emphasized. In addition to these elements, the use of alternate delivery systems, such as videodiscs, to effectively teach fractions, ratios, and algebra content gives further evidence of how Direct Instruction encompasses all of the strategies cited by Mastropieri et al. as effective practices for teaching math to students with learning disabilities.

Given the Christenson et al. (1989) claims, the Mastropieri et al. (1991) analysis, the extensive support for Direct Instruction in the literature, and the significant skill deficits among the participants in this study, we decided to use the Direct Instruction approach to teach fraction and decimal skills to four of the middle school students with learning disabilities included in this study. We sought to answer the question, "Would using the Direct Instruction method to teach fractions and decimals produce grade level performance in four 7th-graders with learning disabilities receiving daily math instruction in a resource setting?"

Method

Participants

Six 7th-grade boys meeting their district's eligibility criteria for learning disabilities participated in this study. Key information on the participants is given in Table 1. Each student's IEP contained goals and objectives addressing fractions and decimals. All six students received math instruction in a resource classroom within the same school. The students ranged in age from 12 years, 5 months to 13 years, 10 months. Thus, participants were similar in age, grade, sex, school, and IEP goals

Table 1

Participant Profiles

	Direct Instruction participants				Comparison participants	
	Participant 1	Participant 2	Participant 3	Participant 4	Participant 5	Participant 6
Diagnosis	LD	LD	LD	LD and AD/HD	LD	LD
Age (years-months)	12-5	13-2	12-11	13-2	13-10	13-1
Grade	7	7	7	7	7	7
Sex	Male	Male	Male	Male	Male	Male
Teacher	#1	#1	#1	#1	#2	#2
School	J. M. S.	J. M. S.	J. M. S.	J. M. S.	J. M. S.	J. M. S.
Math Setting	Resource	Resource	Resource	Resource	Resource	Resource
IEP Content	Fractions and Decimals	Fractions and Decimals	Fractions and Decimals	Fractions and Decimals	Fractions and Decimals	Fractions and Decimals
KeyMathTotal						
Test SS	94	103	82	88	64	80
SOL Probes Mastered	4%	60%	20%	4%	16%	5%

and objectives. The students in one teacher's classroom became the treatment group and students in another teacher's room became the comparison group. Participants 1–4 were taught via Direct Instruction and Participants 5–6 were taught via a traditional textbook approach and sequence.

Their standard scores on the KeyMath-R (Connolly, 1997) total test ranged from 64 to 103. Participants 3, 5, and 6 had the lowest Total Test scores. Participants 1 and 2 had the highest. The students had mastered between 4% and 60% of probes designed to assess SOLs for Grades 3–7 in the areas of fractions and decimals. Participants 1, 4, and 6 had the lowest percentage of mastered probes. Participant 2 had the highest percentage. These measures and scores are discussed further in the sections on measures and results below.

Although the comparison group is just two students, we believed that because IEP content was similar across participants and since they were matched on significant variables (e.g., age, grade, school, sex, math setting, math IEP content) we can make reasonable comparisons. It is important to note that the two comparison participants (Participants 5 and 6) had the two lowest KeyMath-R Total Test standard scores and Participant 6 had one of the three lowest percentages of probes mastered prior to instruction. Thus, the comparison students appear to have begun the study with weaker overall math skills. However, Participants 1 and 4 (experimental group) demonstrated the weakest skills in SOL fractions and decimals probes of any of the six.

Measures

Prior to instruction students completed the KeyMath-R and informal experimenter-designed probes based on SOLs for Grades 4 through 7 fraction and decimal content. We dissected each SOL into component objectives and for each, developed five-item probes. Fourteen probes were administered individually to each participant. We defined mastery on probes as a minimum of four out of five correct on a probe item. The KeyMath-R is an individually administered standardized test of mathematics. It includes 13 subtests organized into three component scales (Basic Concepts, Operations, and Applications) and a Total Test scale. We used the Normative Update (Connolly, 1997) for deriving all norm-based scores. We report KeyMath-R results for component scales and the total scale in standard scores. These standard scores are norm-referenced with an average of 100 and a standard deviation of 15. They are referenced to the grade placement so if a student's math skills develop at the same rate as those of the norm group, his/her score remains constant. Increases in standard scores indicate that the student is progressing faster than the norm group. Scores on the 13 subtests are given in scaled scores. These are similar to standard scores, except that they have an average of 10 with a standard deviation of 3. The KeyMath-R manual recommends interpreting scaled scores in terms of the following levels of achievement: (a) 15 and above, markedly above average; (b) 13–14, above average; (c) 12, upper average; (d) 9–11, average; (e) 8, lower average, (f) 6–7, below average; and (g) 5 and below, markedly below average.

Procedure

Direct Instruction treatment. Participants 1–4 received 20 weeks of Direct Instruction math 45 min daily in a resource setting. This approach involved using formats and procedures found in the text *Designing Effective Mathematics Instruction: A Direct Instruction Approach* (Stein, et al., 1997). The instructor had completed a graduate course in Direct Instruction math and had 4 years teaching experience, 2 with students with learning disabilities and 2 with students with behavioral disorders.

The four experimental participants were taught math via a three-stage Direct Instruction approach in which the teacher (a) modeled the target skill, (b) provided guided practice on it until the students attained three consecutive sessions of 90% accuracy, and then, (c) introduced independent practice on that skill. Both guided and independent practice consisted of 15 problems. All guided practice problems targeted the skill being taught while independent practice consisted of 10 target-skill problems and 5 prior-learned types of problems. This allowed for cumulative review of previously taught content. Once students attained 90% accuracy on guided practice and 80% accuracy on independent practice, the teacher introduced a new target skill.

Besides modeling, guided and independent practice, and cumulative review, the teacher using the Direct Instruction approach incorporated other key Direct Instruction elements. Prerequisite and component skills were taught systematically prior to introducing a target skill. Students were introduced to one target skill at a time. Mastery on each was required before the student could progress to the next. When students erred, the teacher provided immediate corrective feedback consisting of modeling and guided practice on the particular problem until the student met mastery. To facilitate prompt and accurate acquisition of skills, the teacher applied example selection rules (e.g., when teaching operations with fractions, the teacher included both proper and improper fractions; when teaching addition and subtraction of fractions with unlike denominators, equal numbers of problems requiring different approaches for determining the common denominator were included).

Comparison treatment. The two comparison participants (Participants 5–6) were taught the same fraction and decimal content for the same amount of time (20 weeks) within a resource setting. However, comparison students were taught via traditional textbook for 60 rather than 45 min daily. After 10 weeks, Participant 6 was placed in a general education math class in response to his parents' request. The control participants' special education teacher had 6 years special education teaching experience with students with learning disabilities, but no training in Direct Instruction. The math instruction given to the control participants consisted of teacher presentation of content according to the traditional textbook sequence. In this approach, students were introduced to particular problem types, completed textbook assignments, were tested, and then introduced to new skills, without emphasis on cumulative review or attainment of mastery.

Results

Table 2 shows results on the KeyMath-R. It gives pretests, posttests, changes from pre to post, and change expressed in standard deviations. The change score expressed in standard deviations can be called the standardized change score. It is intended to help understand the size of the changes experienced by the participants. Since the standard deviation of standard scores is 15, the standardized change score is simply the change score divided by 15. As a guide, we could consider a change of less than one quarter of a standard deviation to be "near zero," a change of one quarter to one half standard deviation to be "moderately large," and a change of more than one half standard deviation to be "large."

On the Basic Concepts scale, Direct Instruction students showed changes of between -5 and +8 points and the comparison students showed change of 0 and -1 points. The size of the changes for the Direct Instruction students is quite variable and the change for the comparison students is consistently near zero. On the Operations scale, the Direct Instruction students achieved changes of from 0 to +15 points and the comparison students both showed slight negative (near zero) change. Three of the four Direct Instruction students evidenced large positive changes in Operations. The Application scale was similar; three of the four Direct

Instruction students demonstrated large positive changes and one showed only a very slight change. The comparison students both experienced little if any change. The Total Test scale combines the three previously described scales. On this overall measure, one Direct Instruction student showed a large improvement of 10 points, two showed a moderate improvement of 7 points and one showed a slight improvement of 4 points. In contrast, both the comparison students scored exactly zero change.

For each student, we have three independent scores from the KeyMath-R, one from each of the three component scales. This results in a total of 12 independent scores for the Direct Instruction students and 6 for the comparison students. Of these 12 scores for the Direct Instruction participants, 7 indicated large improvements well in excess of the rate of learning in the test's norm group, 1 showed a gain moderately larger than the norm group, 3 had near zero gains relative to the norm group, and 1 showed a moderate loss compared to the

Table 2

Participants 1–6 Pre and Postinstruction Area and Total Test Standard Scores on KeyMath-Revised

	Direct Instruction				Comparison	
	P1	P2	P3	P4	P5	P6
Basic Concepts						
Pre	102	96	77	94	61	83
Post	97	103	85	92	61	82
Change	-5	+7	+8	-2	0	-1
Std. Change	-.33	+.47	+.53	+.13	.00	.00
Operations						
Pre	91	94	86	87	65	79
Post	105	109	86	96	63	77
Change	+14	+15	0	+9	-2	-2
Std. Change	+.93	+1.00	.00	+.60	-.13	-.13
Applications						
Pre	93	92	80	86	63	81
Post	101	101	91	90	65	81
Change	+8	+9	+11	+4	+2	0
Std. Change	+.53	+.60	+.73	+.27	+.13	.00
Total Test						
Pre	94	93	82	88	64	80
Post	101	103	89	92	64	80
Change	+7	+10	+7	+4	0	0
Std. Change	+.47	+.67	+.47	+.27	.00	.00

Note. Scores of 125 and above are considered markedly above average
Scores of 111–124 are considered above average
Scores of 90–110 are considered average
Scores of 76–89 are considered below average
Scores of 75 and below are considered markedly below average

norm group. In contrast, the comparison students showed near zero change relative to the norm group in all six of their scores.

KeyMath-R Total Test standard scores are also shown in Figure 1. This figure clearly shows the improvement in test performance for all Direct Instruction participants and the lack of change for the comparison participants. It also shows the fact that one of the comparison participants had a KeyMath-R pretest score that was similar to that of one of the Direct Instruction participants, but amount of change for the members of this "matched pair" were quite different. The other comparison participant performed at a substantially different level from the other students on the KeyMath-R pretest and posttest.

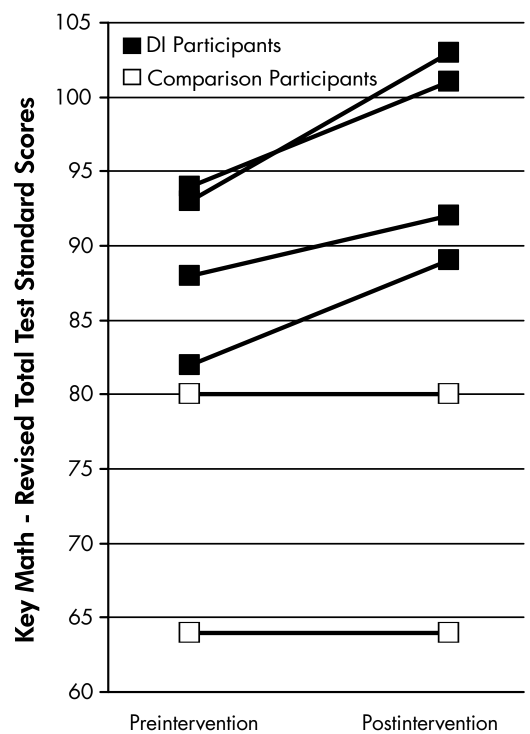
Table 3 displays the pretest, posttest, and change scaled scores for each of the 13 KeyMath-R (1997) subtests. We examined these scores for their numerical value change as well as their associated performance level change. The asterisks beside the "change" values in Table 3 indicate the number of descriptor levels, if any, by which the participant improved pretest to posttest. For example, on the Numeration subtest, Participant 2 scored 8 (lower average) on the pretest and 13 (above average) on the posttest. This represents a jump of three descriptor levels; thus it is marked with three asterisks.

The Direct Instruction participants made substantial progress as measured by pre and postintervention KeyMath-R subtest performance. Participant 1 increased his score on 8 out of 13 subtests; 6 of these constituted an upward level change. Participant 2 increased his score on 9 out of 13 subtests. Of those 9, he had upward level changes on 7 subtests. Participant 3 increased his score on 8 out of 13 subtests achieving an increase in level on 7 subtests. Participant 4 showed improvement on 7 of the 13 subtests, 6 included a positive change in performance level. Overall, the Direct Instruction participants made upward level changes on 50% (26 of 52) subtests while comparison students did so on 12% of the subtests. Most notable are Participant 2's upward level changes of five levels on the addition subtest, moving from below average to markedly above average and his level change of three levels on both the multiplication and numeration subtests. On the multiplication subtest he moved from average to markedly above average and on the numeration subtest he progressed from lower average to above average. Participant 1 showed a three-level increase on the subtraction subtest, going from below average to upper average.

The comparison participants' performance clearly differed from that of the Direct Instruction participants. Participant 5 made no

Figure 1

Subjects 1–6 Key Math-Revised Total Test Standard Scores.



level changes and Participant 6 made level increases on only 3 of the 13 subtests.

Table 4 shows the percent of mastered fraction and decimal probes for each participant pre and postintervention. Upon completion of the study, the Direct Instruction participants demonstrated mastery of 43% to 86% of the fraction and decimal skills taught. In contrast, the comparison participants each showed mastery of 0%. From pretest to posttest, three of the four Direct Instruction participants demonstrated mastery of substantially more probes than prior to interven-

Table 3

Participants 1–6 Pre and Postintervention KeyMath-R (1988,1997) Subtest Scores and Level Changes

	Direct Instruction				Comparison	
	P1	P2	P3	P4	P5	P6
Numeration						
Pre	10	8	5	7	3	5
Post	8	13	8	8	4	5
Change	-2	5***	3**	1*	1	0
Rational Numbers						
Pre	9	9	7	8	4	9
Post	9	9	7	8	3	7
Change	0	0	0	0	-1	-2
Geometry						
Pre	12	12	5	12	1	5
Post	11	11	6	10	1	8
Change	-1	-1	1*	-2	0	3**
Addition						
Pre	8	7	8	7	6	6
Post	12	16	8	11	5	5
Change	4**	9*****	0	4**	-1	-1
Subtraction						
Pre	7	13	7	6	1	4
Post	12	14	8	11	2	3
Change	5***	1	1*	5**	1-	1
Multiplication						
Pre	10	9	11	10	4	9
Post	13	16	9	13	1	10
Change	3**	7***	-2	3**	-3	1
Division						
Pre	9	9	7	9	2	5
Post	13	13	6	10	1	4
Change	4**	4**	-1	1	-1	-1

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tion. Participant 2, however, showed a decrease of 7% in the mastery of the probes from the pretest to the posttest. Examination of the percent of mastered probes for the comparison participants reveals very little difference between pre and postintervention performance. Participant 5 had mastery of 14% of the SOL fraction and decimal probes before instruction; after instruction, he demonstrated mastery of none of the probes. Participant 6 maintained 0% mastery from pre to posttest.

Table 3, continued

Participants 1–6 Pre and Postintervention KeyMath-R (1988,1997) Subtest Scores and Level Changes

	Direct Instruction				Comparison	
	P1	P2	P3	P4	P5	P6
Mental Computation						
Pre	9	9	5	7	3	5
Post	9	9	6	6	3	5
Change	0	0	1*	-1	0	0
Measurement						
Pre	10	9	8	8	3	6
Post	11	12	8	7	4	4
Change	1	3	*0	-1	1	-2
Time & Money						
Pre	8	8	6	8	3	7
Post	8	11	7	7	5	8
Change	0	3*	1-	1	2	1*
Estimation						
Pre	8	6	3	8	3	3
Post	11	9	7	8	3	6
Change	3*	3**	4*	0	0	3*
Interpreting Data						
Pre	9	10	8	8	1	8
Post	10	11	10	10	1	7
Change	1	1	2*	2*	0	-1
Problem Solving						
Pre	9	10	6	6	3	7
Post	12	10	9	8	4	5
Change	3**	0	3**	2*	1-	2

Note. Scores of 15 and above are considered markedly above average
Scores of 13–14 are considered above average
Scores of 12 are considered upper average
Scores of 9–11 are considered average
Scores of 8 are considered lower average
Scores of 6–7 are considered below average
Scores of 5 and below are considered markedly below average

Table 4

Percent of Fraction and Decimal Probes Mastered

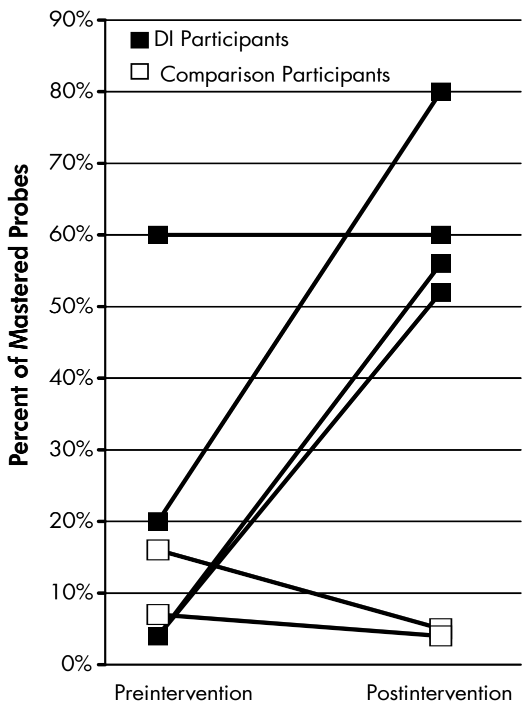
	Direct Instruction				Comparison	
	P1	P2	P3*	P4	P5	P6
Preintervention	0%	50%	25%	0%	14%	0%
Postintervention	86%	43%	75%	43%	0%	0%
Change	+86	-7	+50	+43	-14	+0

* Participant 3 was posttested on only 8 of the 14 probes due to his family's move. His data reflect performance on only those eight probes for which complete data are available.

Figure 2 shows the substantial difference in the patterns of change from pretest to posttest by the two groups on percent of probes mastered. Three of the four students in the Direct Instruction group showed substantial increases and neither of the comparison group students did so. Two of the Direct Instruction participants demonstrated mastery on 0% of the pretest probes, but showed substantial improvement on posttests. This is in contrast to the pattern shown by comparison group participants who began the study with comparable pretest scores.

Figure 2

Subjects 1–6 Percent of Mastered Probes Pre and Postintervention



Discussion

This study includes two bases for judging the progress that the Direct Instruction students made between the pretests and posttests. First, students' progress is compared to that of the normative group for the test. KeyMath-R scores have been given in standard or scaled scores throughout this report. These scores describe the student's ranking within the normative group. Posttest performance was compared to norms of students who were 20 weeks older than those used for the pretest. Thus, the normal, expected growth across 20 weeks is accounted for in the scores. Increases in standard or scaled scores reflect *progress beyond that of the norm group*. The extraordinary gains made by the Direct Instruction students in some of the tests are gains above and beyond that expected of typical students.

In addition to the comparison with the test's norm group, we also compared Direct Instruction students' scores with those of a two-student comparison group. In considering these comparisons, it is important to remember that the comparison participants, though matched to the Direct Instruction participants on the important variables of age, sex, school setting, IEP goals and objectives, and disability classification, they may have been functionally different from the Direct Instruction group on other important variables. KeyMath-R pretests indicated that one of the comparison students had general math skills comparable to the lowest performing of the Direct Instruction students. The other comparison student showed pretest math skills substantially below those of all other participants. However, the two groups appeared to be quite comparable on the specific skills measured by the SOL probes. In addition to differences on the measured math skills, the groups may have differed on unmeasured variables such as organizational skills, motivation, ability to attend, and specific prerequisite math. As a result, the comparison participants may have fared poorly for reasons other than, or in addition to, the instructional method applied. If they had been taught via Direct Instruction, they may not have fared as well as the Direct Instruction participants did, because of these other variables. These problems moderate the validity of the comparison participants' data as a fair test of traditional instruction. However, we believe that the comparison between the groups is informative and useful as long as its limitations are kept in mind.

The tremendous discrepancy between the gains made by students in the Direct Instruction group compared to those of students in the traditional math textbook group appears to support using Direct Instruction to remediate and accelerate the acquisition of math skills in students who are performing several years below grade level. Gains of 1.4 to 4.1 years in half of a school year as measured by the KeyMath-R (1997) give powerful support to the effectiveness of Direct Instruction. Although this study consisted of only six participants who were not well matched at the outset, it shows two very distinct sets of results. The Direct Instruction students exceeded the rate of learning of the norm group to a moderate or large degree on 75% (9 of 12) of the scales (see Table 2). Comparison participants exceeded norm group's learning rate on none of the scales.

Subtest level changes further support the Direct Instruction method. The sharp contrast between the percentage of subtests on which students in the Direct Instruction group improved in level (50%) compared to the minimal percentage of tests on which the comparison participants improved (12%), supports the use of Direct Instruction. Not only did students in the Direct Instruction group exceed their non-Direct Instruction counterparts on the number of KeyMath-R (1997) subtests on which they improved, but also on the magnitude of improvement. Students in the Direct Instruction group improved by more than one level on 29% of the subtests compared to 4% for the control participants. Comparing the Direct Instruction group's subtest performance to the norm group showed that they scored at or above the mean on only 42% of the subtests in the pretest but did so on 63% of them on the posttest. This outcome of students with learning disabilities—performing at essentially the mean of all students on a broad measure of the math skills, concepts, and applications—is certainly extraordinary.

Equally important as the standardized test gains are the gains made by students in the Direct Instruction group on the Grades 4–7 probes assessing Virginia SOLs for fractions and decimals. After 20 weeks of instruction, students in the Direct Instruction group mastered between 43% and 86% of the probes whereas the traditional textbook group mastered 0% of the probes.

Conclusions

The results of this study affirm what is already known about Direct Instruction: when applied well, it has impressive results. Students learn when they receive systematic instruction. The four boys in this study taught via Direct Instruction made substantial progress within a relatively short period of time. What can we conclude from this study's findings?

Assessing preskills and systematically teaching them, as was done in this study, can lay the foundation for impressive instructional gains. The Direct Instruction math students may have been successful because their teacher conducted thorough pretesting via probes and taught each systematically and to a set criterion.

We can also conclude from this study's findings that students with learning disabilities can make dramatic progress when Direct Instruction is carefully and systematically applied. The Direct Instruction students received more than mere exposure to grade level skills; instead, they were required to master them. This occurred by first mastering the prerequisite and component skills and then mastering the grade-level skills. This reflects, in our opinion, the essence of good teaching.

With these students, Direct Instruction provided a framework for diagnosing specific math difficulties and gave a means by which the teacher could address them. When the students were having difficulty, the teacher continued to model and provided guided practice with corrective feedback. Inherent in the Direct Instruction method is the means for diagnosing and remediating.

As evidenced by the success of the Direct Instruction teacher in this study, it appears that this method can provide new teachers with a tremendously powerful tool to help students achieve substantial gains fairly quickly. This was the Direct Instruction teacher's first year teaching students with learning disabilities and her first year teaching math.

Carefully tracking student progress, as was done in this study, may have contributed to these students' systematic improvement. When students were not attaining 90% at guided practice, it was clear to the teacher that she needed to re-model the skill rather than move on to the next skill. In this study the Direct Instruction students did not experience math failure, as they previously did; instead, they remained on a skill until they learned it. This resulted, we believe, in skill retention and mastery. In addition, sharing evidence of progress with the students appeared to produce high levels of motivation. None of the boys had previously succeeded in math. Direct Instruction changed that and their desire to learn soared.

Moreover, students retained what they learned because of the cumulative review they experienced. Perhaps additional cumulative review would have produced even larger amounts of retention as measured by SOL probes.

The kind of teaching and monitoring done in this study should not be considered exceptional; rather, it should be the norm in special and remedial education. This study's findings confirm that systematic, Direct Instruction produces results. Ethically, we must provide our students with opportunities to learn and succeed as these students did. We need not settle for poor performance; our students are capable of more, if we equip them with tools that encourage rather than hinder their academic progress. We owe them at least that much.

Clearly, Direct Instruction can be effective. The literature supports this. This study lends further support to the method because of the substantial math gains it produced in the four Direct Instruction students in a relatively short period of time, with a teacher who was just recently trained in the method. The combination of the results from this study and the previously existing literature on Direct Instruction has significant implications for several stakeholders: (a) teacher training institutions, (b) special and general education teachers, (c) school administrators, and (d) researchers. Teacher training institutions have an ethical responsibility to teach teachers methods that work. Special and general educators must be willing to implement sound instruction and monitor student progress in order to track both student and teacher success and failure. School administrators must be willing to examine the effects of Direct Instruction and commit to training their teachers in the approach. Researchers must be willing to extend Direct Instruction's applicability to new contexts. Each of these stakeholders has a moral and an ethical responsibility to ensure that all children achieve their maximum potentials. Well-designed and delivered instruction can make the difference between learning and failing. It certainly did for the four boys in this study. Ethically, we owe all students this kind of instruction.

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