USING INQUIRY-BASED INSTRUCTION FOR TEACHING SCIENCE TO STUDENTS WITH LEARNING DISABILITIES

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The purpose of this study was to examine the effects of inquiry-based science instruction for five elementary students with learning disabilities (LD). Students participated in a series of inquiry-based activities targeting conceptual and application-based understanding of simple electric circuits, conductors and insulators, parallel circuits, and electricity and magnetism. Students' conceptual understanding of these concepts was measured through a test designed by the investigators. The students' attitudes towards science were measured through scientific attitudes inventory (SAI-II). The results indicated that all students acquired the science content covered during the intervention and maintained their performance six weeks later. In addition, students improved their attitudes towards science. Our discussion focuses on the ways in which we can make science learning accessible to students with learning disabilities by making changes in curriculum, instruction and assessment.

Achieving educational opportunities for all students is one of the most promoted goals of national educational laws, polices and reform documents, such as the No Child Left Behind Act (NCLB) of 2001 (U.S. Department of Education, 2002), Science for All (American Association for the Advancement of Science [AAAS], 1990), and the National Science Education Standards (National Research Council [NRC], 1996). For instance, NCLB requires states to disaggregate test results for all student groups within the educational system and holds them accountable for their achievement. Similarly, reform documents emphasize providing access to quality education for all students and providing adequate resources to support all students' learning in science. (NRC, 2005).

In an effort to provide quality education to all students and ensure the achievement if all students, science education reform documents such as NSES (NRC, 1996) emphasized inquiry skills over rote memorization of facts and expect students to learn science in new ways. Students are expected to understand science facts, understand and apply science concepts in real life situations, and perform scientific processes from measuring and estimation to sustained reasoning through scientific inquiry (NRC, 1996; 2000). Teaching these types of knowledge and skills to students with learning disabilities presents unique challenges to the elementary school teachers who reportedly have insufficient content knowledge, and limited understanding and knowledge of reform-based pedagogies (Appleton, 2005; Dorph, Goldstein, Lee, Lepori, Schneider & Venkatesan, 2007; Fulp, 2002; Roth & Garnier, 2006). In an effort to help elementary school teachers to teach science based on reform objectives, science educators have developed a series of kit-based curriculum materials. These kit-based curriculum materials have been effective in increasing the mainstream students' learning in science (Alonzo, 2008; Aydeniz, 2010; Granger, Bevis, Saka, & Southerland, 2010). Although the use of such kits have reportedly had a positive influence on mainstream students' learning of science, to our knowledge there is not any recent research on investigating their effects on the learning of students with learning disabilities (LD). Therefore, we designed this study to investigate the effects of the Electric Circuits Kitbook (Edamar, Inc., 2008), an inquiry-based curriculum, on elementary students' with LD understanding of simple electric circuits, conductors and insulators, parallel circuits, and electricity and magnetism.

Science Instruction and Students with Learning Disabilities

An extensive review of the literature by Miller (1999) indicated that there have been few studies of students with learning disabilities. The result of previous studies show that students with LD typically perform lower in science compared to their peers and express doubts about their capacity to perform successfully in science courses (Carlisle & Chang, 1996). The existing literature suggests general reasons why students with LD often struggle in science courses. Among these reasons are that: (1) most standard science activities fail to provide accommodations for students with LD (Ormsbee & Finson, 2000), (2) comprehension of content presented in science textbooks is difficult for students with LD due to deficits in reading ability (Horton, Lovitt, & Bergerud, 1990), and (3) the volume of new vocabulary and terminology in science textbooks is problematic for students with LD (Mastropieri & Scruggs, 1993). Additionally, students with LD may not be given enough time or appropriate scaffolding needed for them to process the scientific information presented in the classroom. Finally, students with LD may not be given the opportunity to engage in guided inquiry activities that may help them to acquire the knowledge and skills promoted by curriculum (AAAS, 1993; NRC, 1996; Ormsbee, & Finson, 2000; Steele, 2005).

Limited attention to the learning of students with LD in science at the elementary level is likely to perpetuate failure in science courses at the middle and high school. If students' learning needs in science classrooms are not addressed at the elementary school, they will not have sufficient background knowledge to acquire the cognitive complexity of learning tasks presented in more advanced middle and high school science courses (Donovan & Bransford, 2005). Moreover, if students with LD are not provided opportunities to learn scientific concepts in a meaningful manner, they may develop negative attitudes towards learning science that they are expected to learn later in their academic lives. Given the fact that more than 60% of the students with an Individualized Educational Plan (IEP) take the same standardized test as their general education peers with or without accommodations (Thurlow, Moen, & Altman, 2006), the combined effects of attitude and limited prior knowledge may leave these students behind in life and defy the prominent equity goals of the NCLB and Science for All (AAAS, 1990). Kurz, Elliot, Wehby and Smithson (2009) suggested, *By virtue of being administered the same assessments, students with disabilities have to be afforded the same opportunity to learn the content they are expected to know on these tests* (p. 3). In order for students with LD to be fairly assessed they must receive equitable instruction. Providing equitable instruction will require teachers to develop understanding about the learning needs of students with LD and acquire knowledge and skills to use curriculum materials and instructional strategies that hold promise to be effective for students with LD.

Responsive Science Instruction for Students with Learning Disabilities

A number of specific interventions have been developed and examined to address barriers to science content learning for LD including: (1) reading comprehension strategies (Bakken, Mastropieri, & Scruggs, 1997; Scruggs & Mastropieri, 1993), (2) textbook adaptations and study guides (Horton et al., 1990), (3) mnemonic strategies (Mastropieri, Scruggs, & Levin, 1985), (4) review activities (Maheady, Michielli-Pendl, Mallette, & Harper, 2002), (5) advanced organizers (Lenz, Alley, & Schumaker, 1987) and (6) peer tutoring (Fuchs & Fuchs, 2001). Mastropieri and Scruggs (1992) recommended that study guides and text adaptations demonstrate positive effects on students' learning, behavior, and motivation. Mnemonic strategies have also been helpful in learning the technical language of science and activities-based science curricula were effective for conceptual understanding.

It has been documented that inquiry-based activities increase LD students' understanding and retainment of science concepts more than their peers who learn from text-based or lecture-based approaches (Holahan & DeLuca, 1993; Mastropieri & Scruggs, 1993; 1994). Bredderman (1983) found that the self-discovery component of science curriculum led to higher retention rates. In addition, he found that, *more activity-process-based approaches to teaching science result in gains over traditional methods in a wide range of student outcome areas…* including students with LD. (p. 513). Dalton, Morocco, Tivnan and Mead (1997) stated, *students with LD in activities-oriented learning approach scored higher on immediate and delayed recall tests and reported a strong preference for this kind of learning in terms of enjoyment, interest, and competence* (p. 671). Additionally, engaging students with LD in science learning through hands-on, inquiry-based activities may help address students' misconceptions about the scientific concepts, assist them to acquire skills for the processes of science, and help them develop positive attitudes for learning, and for science itself (Dalton et al., 1997; Mastropieri & Scruggs, 1997; Mastropieri, Scruggs, & Magnusen, 1999; Scruggs & Mastropieri, 2007). However, the impact of kit-based curriculum on LD students' conceptual understanding of simple electric circuits has not been investigated.

The purpose of this study, therefore, was to investigate the effects of the Electric Circuits Kitbook, an inquiry-based curriculum, on elementary students' with LD understanding of simple electric circuits, magnetism and electricity and their attitudes towards science. Specifically, we were interested in answering the following questions: 1) what are the effects of this inquiry-based curriculum on students' conceptual and application-based understanding of simple electric circuits? and 2) what are the students' attitudes towards science and scientific attitudes before and after participating in inquiry-based activities?

Methods

Participants and Setting

This study took place at an elementary school in the southeastern part of the United States. The school serves a predominantly white student population (94.2%). A significant number of students qualify for free and reduced lunch. More precisely, 75.7% of the students are considered to be economically disadvantaged.

Five students, Adam, Beth, Chris, David and Evia were selected to participate based on the following: (a) elementary school enrollment, (b) qualifications for LD services under state and federal regulations, (c) did not receive previous instruction regarding simple electric circuits, (d) parental permission, and (e) student agreement to participate. Specific student characteristics are presented in Table 1. All students received special educational services for a specific learning disability in reading. Chris and Evia also received services for a specific learning disability in mathematics. In addition, the classroom teacher reported that all students were reading at least two grade-levels below their peers without learning disabilities. Adam, Beth and David received 15 hours of special education services weekly. Chris and Evia received 20 hours of special education services weekly. All students received 50 min of educational services in a special education classroom daily for study skills. All phases of this study occurred in the students' resource classroom during study skills.

The students' classroom teacher implemented all phases of this study. The teacher was dually certified to teach both special education and K-6 elementary education. The teacher had five years of teaching experience and a master's degree in special education. The special education teacher had completed a science methods course during her teacher education program and had participated in a learning activity that focused on enhancing pre-service elementary teacher's content and pedagogical content knowledge.

Table 1. Student Characteristics

Students	Age	Grade	FSIQ	Reading Composite[b]	Spelling[b]	Math Composite[b]	SLD
Adam	11.2	5	95	65	68	83	Reading
Beth	12.1	5	105	79	80	91	Reading
Chris	10.9	4	95	57	59	51	Reading, Math
David	9.2	4	92	62	67	85	Reading
Evia	11.5	5	91	60	58	55	Reading, Math

Note. FSIQ = full scale intelligence quotient; SLD = specific learning disability.
[a] = Wechsler Intelligence for Children (3rd ed.). [b] = **Wide Range Achievement Test-Revised.**

Materials

The Electric Circuits KitBook, supporting activities, and quizzes were used in this study. The Electric Circuits KitBook is a self-contained, hands-on curriculum that targets nine different learning activities. However, only four scientific concepts were targeted for this study since students had difficulty understanding and applying these concepts and these concepts correlated directly to the state science curriculum standards which included: (a) simple circuits, (b) conductors and insulators, (c) parallel circuits, and (d) electricity and magnetism. Materials needed to conduct all experiments were included in the booklet including jumper wires with alligator tips, lamp, fixed switch, slide switch, buzzer, lamp, motor color wheel, momentary (push) switch, and batteries. Quizzes covered conceptual-based and application-based problems targeting the four concepts. The simple circuit quiz consisted of five conceptual-based and nine application-based problems for a total of 14 items. The conductor and insulator quiz consisted of seven conceptual-based and six application-based problems for a total of 13 items. The series and parallel circuits quiz consisted of six conceptual-based and six application-based problems for a total of 12 items. The electromagnetism quiz consisted of ten conceptual-based and five application-based problems for a total of 15 items. Appendix A lists sample questions from quizzes. In addition, the Scientific Attitudes Inventory SAI-II (Moore & Foy, 1997) was used to assess students' attitudes towards science.

Data Collection and Design

Students were presented a daily quiz at the beginning of each class. Permanent product recording procedures were used to collect data for each session. A session was defined as one 50-minute class. At the start of each class or session, students had 20 minutes to complete each quiz. The number of problems completed correctly was divided by the total number of problems presented (i.e., 12, 13, 14, 15) to calculate the student's percentage of problems solved correctly for each session. For each skill, quizzes incorporated similar but different conceptual and application problems. Problems were semi-randomly assigned to quizzes and no quiz was presented more than once.

A multiple-probe design across behaviors (Barlow & Hersen, 1984) or science skills with a maintenance phase was used to determine the efficacy of the circuit kitbook for the acquisition and maintenance of science skills. The staggered introduction of the intervention within a multiple-probe design allows demonstration of the experimental effects not only within each data series, but also across data series at the staggered times of intervention. As the student reached criterion to move to the maintenance phase, the use of the circuit kitbook began with the next concept and so forth.

Procedures

Baseline. At the start of each session, students were given a quiz to solve conceptual-based and application-based problems targeting simple electric circuits. Each quiz targeted one of the specific skills. Students were prompted to *try your best* and no additional instructions, prompts, or feedback were provided. The teacher administered quizzes until students achieved a stable baseline for a minimum of five sessions. Science teachers did not introduce or teach these science skills during the course of this study.

Electric Circuit Kitbook. During the intervention, each student was provided an Electric Circuits KitBook and worked in either a group of two or three students. The teacher grouped students in a semi-random order to ensure that groups were composed of different students daily and that each group consisted of at least one student who was progressing proficiently, based on quiz scores, to serve as a potential group tutor. The teacher started each lesson with an overview of vocabulary, questioning student's prior knowledge, and making connections between the content of the lesson and student's everyday life experiences with electricity. For example, the teacher said, *Can you identify devices that have simple circuits in this room?* The teacher also read aloud all content information and directions in the kitbook. Afterwards, the teacher instructed the students to perform the corresponding experiments. Table 2 lists sample experiments for each skill. All students continued to practice solving the simple circuit experiments and problems until they performed 100% on at least two of three quizzes. After reaching criterion, the teacher introduced conductors and insulator experiments and problems to the students. Similarly, the teacher grouped the students, reviewed vocabulary, questioned student's prior knowledge, and made connections between the content of the lesson and the student's experience with electricity. Then, students experimented and practiced solving conceptual and application-based problems targeting conductors and insulator. Likewise, after reaching criterion, the teacher introduced series and parallel circuits, and lastly conceptual and application-based problems and experiments targeting electromagnetism knowledge.

Table 2. Experiment Examples

Skills	Learning Activities/Experiments
Simple circuits	Students constructed two simple circuits to light a bulb and to play a buzzer.
Conductors and insulators	Students were challenged to test five materials and identify electrical conductors and insulators through experimentation.
Parallel circuits	Students were challenged to construct and identify parallel circuits with multiple paths. They were also challenged to trace the current path in complex parallel circuits.
Electromagnetism	Students were challenged to describe how an electromagnet works, construct a working electromagnet and discuss the useful applications of electromagnets.

Maintenance. Follow-up probes were collected six weeks after students reached acquisition criterion for solving electromagnetism problems. Students were given a similar quiz used during baseline and intervention phases requiring students to solve (a) simple circuits, (b) conductors and insulators, (c) parallel circuits, or (d) electromagnetism problems. The purpose of this approach was to determine if the initial intervention instruction affected the student's performance over time.

Science Attitude Assessment. Before the baseline phase and following the conclusion of the study, all students completed the Scientific Attitudes Inventory ([SAI-II] (Moore & Foy, 1997) to assess each student's attitudes towards science. The inventory included 30 items related to student attitudes toward science and their scientific attitudes. Specifically, 13 items inquired about the student's scientific attitudes (e.g., *good scientists are willing to change their ideas; scientists are always interested in better explanation of things; if one scientist says an idea is true, all other scientists will believe it*) and 17 items inquired about the student's attitudes towards science (e.g., *I would enjoy studying science; scientific work is useful only to scientist; scientists have to study too much*) for a total of 30 items. Students responded to each item using a 5-point Likert Scale ranging from 1 *strongly agree* to 5 *strongly disagree*.

Reliability

Interobserver reliability data and procedural reliability were collected independently and simultaneously by the investigator (second author) and classroom teacher. Interobserver and procedural reliability data were collected during at least 25% of baseline and each concurrent phase. Observers independently and simultaneously recorded the number of problems solved correctly on student quizzes. Interobserver agreement was calculated by dividing the number of agreements of student responses by the number of agreements plus disagreements and multiplying by 100. Interobserver reliability was 100% for all students throughout all phases.

Procedural reliability measured the teacher's performance. The teacher was required to provide students with the circuit kitbook and daily quiz. The teacher also was expected to read aloud all content information and directions, group the students, review vocabulary, question student's prior knowledge, and make connections between the content of the lesson and the student's experience with electricity. The procedural agreement level was calculated by dividing the number of observed teacher behaviors by the number of planned teacher behaviors and multiplying by 100. Procedural reliability was 95% for all students throughout all phases.

Results

Group Results: Conceptual Understanding

Overall, the mean percentage of problems solved correctly for simple circuits during baseline was 4.7%. Students improved solving problems targeting simple circuits to 76% when the activity-based circuit kitbook was implemented. The mean percentage of problems solved correctly for conductors and insulators during baseline was 5.5%. Students improved solving conductors and insulators problems to mean of 81.5% during intervention. The mean percentage of problems solved correctly for parallel circuits were 6.8% during baseline. Students improved solving parallel circuit problems to 87.5% when the activity-based circuit kitbook was implemented. Similarly, the mean percentage of problems solved correctly for electromagnetism was 12.6% during baseline. Students improved solving series and parallel circuit problems to 92.8% when the activity-based circuit kitbook was implemented. All students also maintained all skills six weeks later. Data are presented in Table 3.

Individual Performance: Conceptual Understanding

Adam. Figure 1 displays Adam's percentage of problems solved correctly. During baseline, the mean percentage for solving conceptual-based simple circuit problems correctly was 8.0% and 13.2% for application-based problems. When the activity-based Electric Circuit Kitbook was implemented, the mean percentage for solving conceptual-based simple circuit problems correctly increased to 86.7% and 83.0% for application-based problems. For conductors and insulators, the mean percentage for solving conceptual-based problems was 6.0% and 4.9% for application-based problems during baseline. Adam's mean percentage for solving conceptual-based problems increased to 79.6% and 88.1% for application-based problems during intervention. For parallel circuits, the mean percentage for solving conceptual-based problems was 5.6% and 5.7% for application-based problems during baseline. His mean percentage for solving conceptual-based problems increased to 86.0% and 91.5% for application-based problems during intervention. For electromagnetism problems, the mean percentage for solving conceptual-based problems was 6.4% and 10.9% for application-based problems during baseline. His mean percentage for solving conceptual-based problems increased to 91.7% and 90.0% for application-based problems during intervention. Adam also maintained 100% of all skills six week later.

Table 3. Mean Percentage of Correct Science Problems Across Skills.

Students/Phases	Simple Circuits		Conductors & Insulators		Parallel Circuits		Electromagnetism	
	C	A	C	A	C	A	C	A
Adam								
Baseline								
Mean								
Range	8.0	13.2	6.0	4.9	5.6	5.7	6.4	10.9
Intervention	0-20	0-22	0-14	0-17	0-33	0-17	0-10	0-20
Mean								
Range	86.7	83.0	79.6	88.1	86.0	91.5	91.7	90.0
Follow-up	40-100	44-100	43-100	67-100	50-100	83-100	70-100	60-100
Growth	100	100	100	100	100	100	100	100
	78.7	69.8	73.6	83.2	80.4	85.8	85.3	79.1
Beth								
Baseline								
Mean	0	4.4	6.0	4.9	3.8	9.4	10.0	9.1
Range	0-0	0-11	0-14	0-17	0-17	0-17	0-20	0-20
Intervention								
Mean	73.3	77.3	79.6	80.9	85.8	91.5	88.3	83.3
Range	20-100	33-100	28-100	50-100	66-100	83-100	60-100	60-100
Follow-up	100	100	100	100	100	100	100	100
Growth	70.0	74.9	73.6	76.0	82.0	82.1	78.3	74.2
Chris								
Baseline								
Mean	4.0	0	10.0	9.7	9.3	5.7	15.5	18.2
Range	0-20	0-0	0-14	0-17	0-33	0-17	10-20	0-40
Intervention								
Mean	76.7	79.3	81.0	81.0	86.0	80.5	95.0	80.5
Range	40-100	22-100	42-100	50-100	50-100	50-100	80-100	50-100
Follow-up	100	100	100	100	100	100	100	100
Growth	72.7	79.3	71.0	71.3	76.7	74.8	79.5	62.3
David								
Baseline								
Mean	7.6	5.7	2.0	2.4	0	4.4	15.5	21.8
Range	0-17	0-17	0-14	0-17	0	0-22	0-30	0-40
Intervention								
Mean	97.2	97.2	91.9	88.1	70.0	75.5	98.3	96.7
Range	83-100	83-100	57-100	50-100	20-100	33-100	90-100	80-100
Follow-up	100	100	100	100	100	100	100	100
Growth	89.6	91.5	89.9	85.7	70.0	71.1	82.8	74.9
Evia								
Baseline								
Mean	4.0	8.8	4.0	4.9	6.2	7.6	8.2	10.9
Range	0-20	0-22	0-14	0-17	0-14	0-17	0-30	0-40
Intervention								
Mean	66.7	71.8	69.1	76.1	83.3	78.4	95.0	96.7
Range	20-100	44-100	29-100	33-100	50-100	33-100	90-100	80-100
Follow-up	100	100	100	100	100	100	100	100
Growth	62.7	63.0	65.1	71.8	77.1	70.8	86.8	85.8
Overall								
Baseline								
Mean	3.2	6.2	5.8	5.2	6.6	7.0	11.1	14.2
Range	0-20	0-22	0-14	0-17	0-33	0-22	0-30	0-40
Intervention								
Mean	74.7	77.4	80.2	82.9	87.5	87.5	93.7	92.0
Range	20-100	33-100	29-100	33-100	20-100	33-100	60-100	50-100
Follow-up	100	100	100	100	100	100	100	100
Growth	71.5	71.2	74.4	77.7	80.9	80.5	82.6	75.8

Note. C = conceptual-based problems; A = application-based problems.

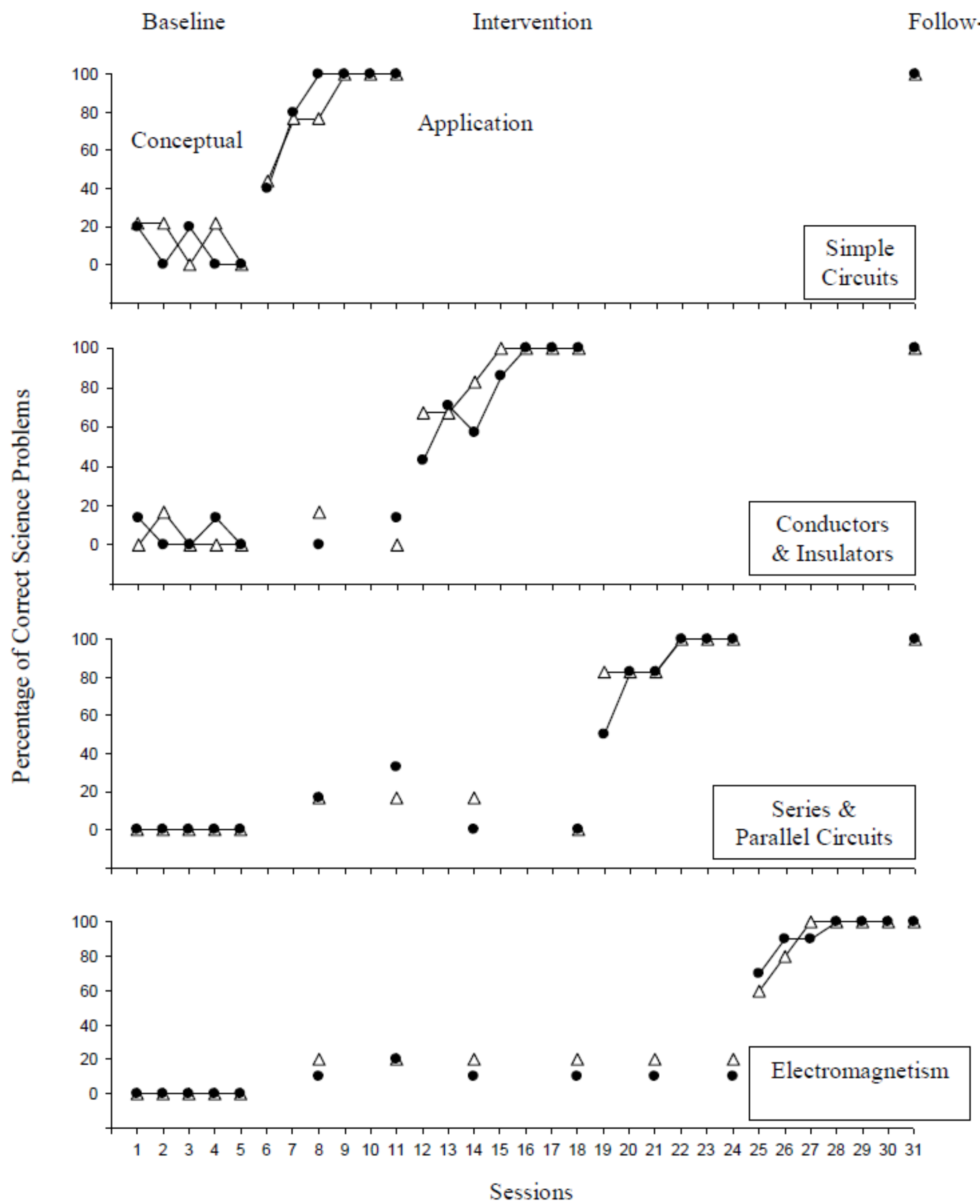

Figure 1. Adam's percentage correct across science skills.

Beth. Figure 2 displays Beth's percentage of problems solved correctly. During baseline, she did not solve and conceptual-based simple circuit problems correctly and a mean of 4.4% application-based problems correct. When the activity-based circuit kitbook was implemented, her mean percentage for solving conceptual-based simple circuit problems correctly increased to 73.3% and 77.3% for application-based problems. For conductors and insulators, the mean percentage for solving conceptual-based problems was 6.0% and 4.9% for application-based problems during baseline. Beth's mean percentage for solving conceptual-based problems increased to 79.6% and 80.9% for application-based problems during intervention. For parallel circuits, the mean percentage for solving conceptual-based problems was 3.8% and 9.4% for application-based problems during baseline. Her mean percentage for solving conceptual-based problems increased to 85.8% and 91.5% for application-based problems during intervention. For electromagnetism problems, the mean percentage for solving conceptual-based problems was 10.0% and 9.1% for application-based problems during baseline. Her mean percentage for solving conceptual-based problems increased to 88.3% and 83.3% for application-based problems during intervention. Beth also maintained 100% of all skills six week later.

Chris. Figure 3 displays Chris' percentage of problems solved correctly. During baseline, the mean percentage for solving conceptual-based simple circuit problems correctly was 4.0% and Chris did not solve any application-based problems correctly. When the activity-based circuit kitbook was implemented, the mean percentage for solving conceptual-based simple circuit problems correctly increased to 76.7% and 79.3% for application-based problems. For conductors and insulators, the mean percentage for solving conceptual-based problems was 10.0% and 9.7% for application-based problems during baseline. Chris' mean percentage for solving conceptual-based problems increased to 81.0% and 81.0% for application-based problems during intervention. For parallel circuits, the mean percentage for solving conceptual-based problems was 9.3% and 5.7% for application-based problems during baseline. His mean percentage for solving conceptual-based problems increased to 86.0% and 80.5% for application-based problems during intervention. For electromagnetism problems, the mean percentage for solving conceptual-based problems was 15.5% and 18.2% for application-based problems during baseline. His mean percentage for solving conceptual-based problems increased to 95.0% and 80.5% for application-based problems during intervention. Chris also maintained 100% of all skills six week later.

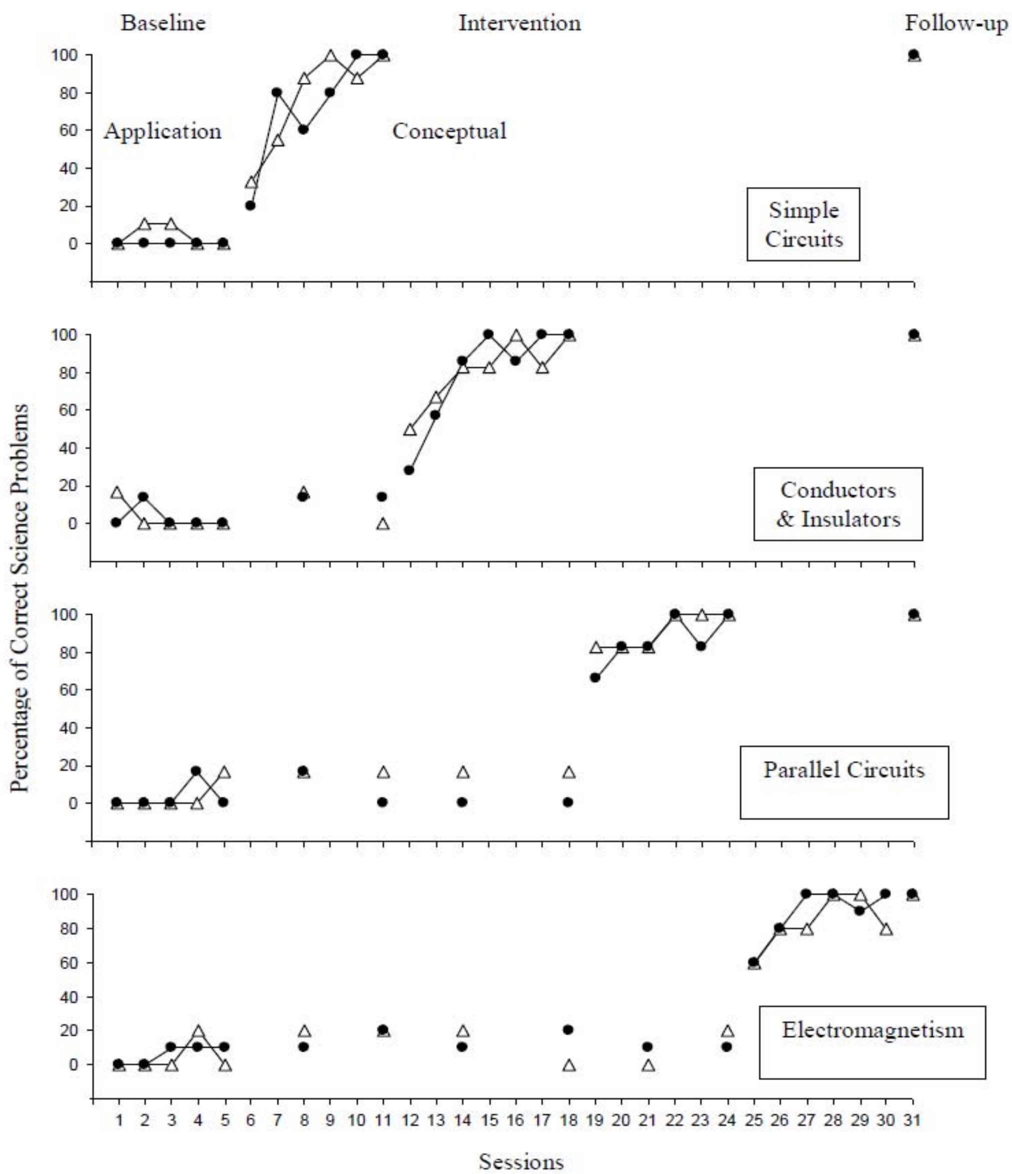

Figure 2. Beth's percentage correct across science skills.

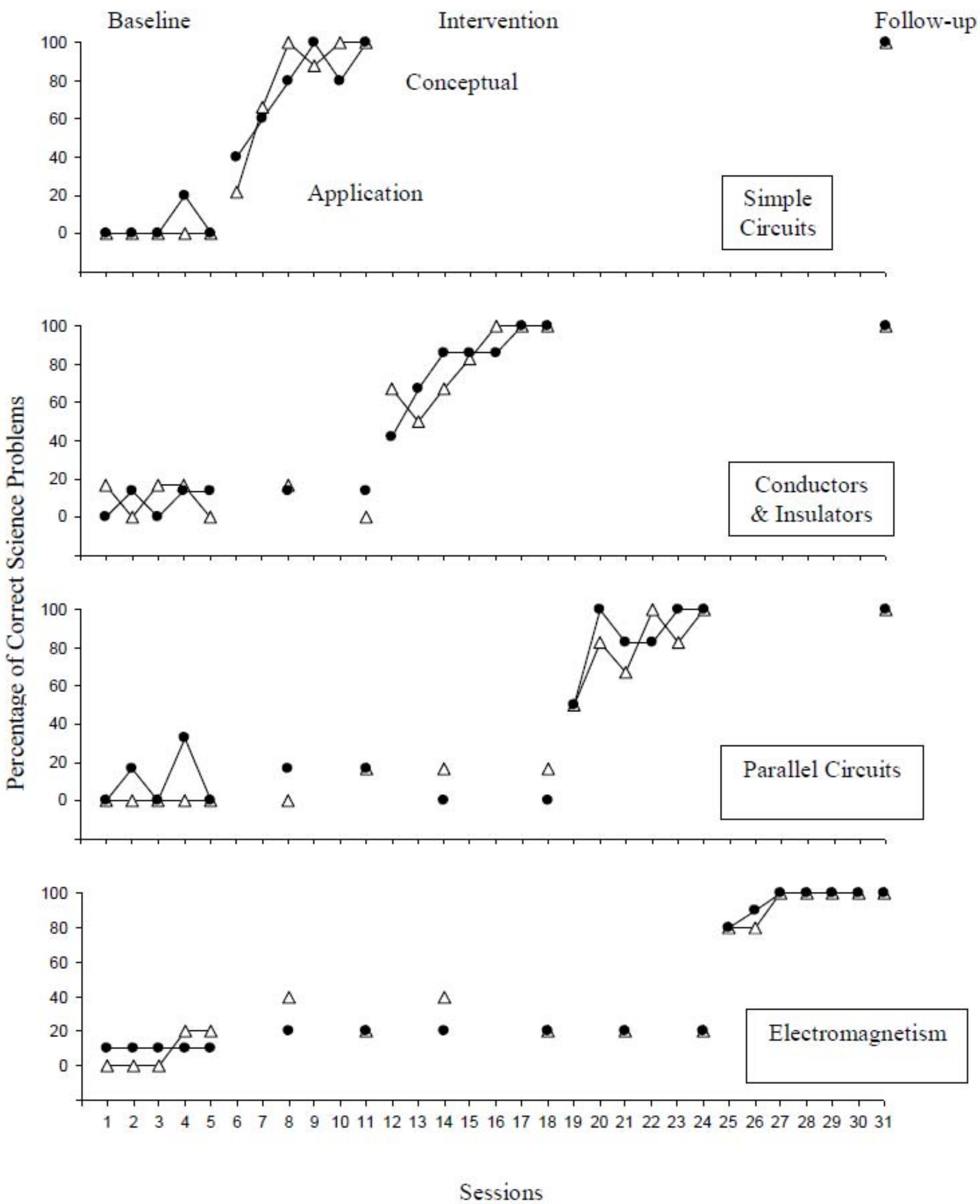

Figure 3. Chris' percentage correct across science skills.

David. Figure 4 displays David's percentage of problems solved correctly. During baseline, the mean percentage for solving conceptual-based simple circuit problems correctly was 7.6% and 5.7% for application-based problems. When the activity-based circuit kitbook was implemented, the mean percentage for solving conceptual-based simple circuit problems correctly increased to 97.2% and 97.2% for application-based problems. For conductors and insulators, the mean percentage for solving conceptual-based problems was 2.0% and 2.4% for application-based problems during baseline. David's mean percentage for solving conceptual-based problems increased to 91.9% and 88.1% for application-based problems during intervention. For parallel circuits correctly solved no conceptual-based problems and 4.4% for application-based problems during baseline. His mean percentage for solving conceptual-based problems increased to 70.0% and 75.5% for application-based problems during intervention. For electromagnetism problems, the mean percentage for solving conceptual-based problems was 15.5% and 21.8% for application-based problems during baseline. His mean percentage for solving conceptual-based problems increased to 98.3% and 96.7% for application-based problems during intervention. David also maintained 100% of all skills six week later.

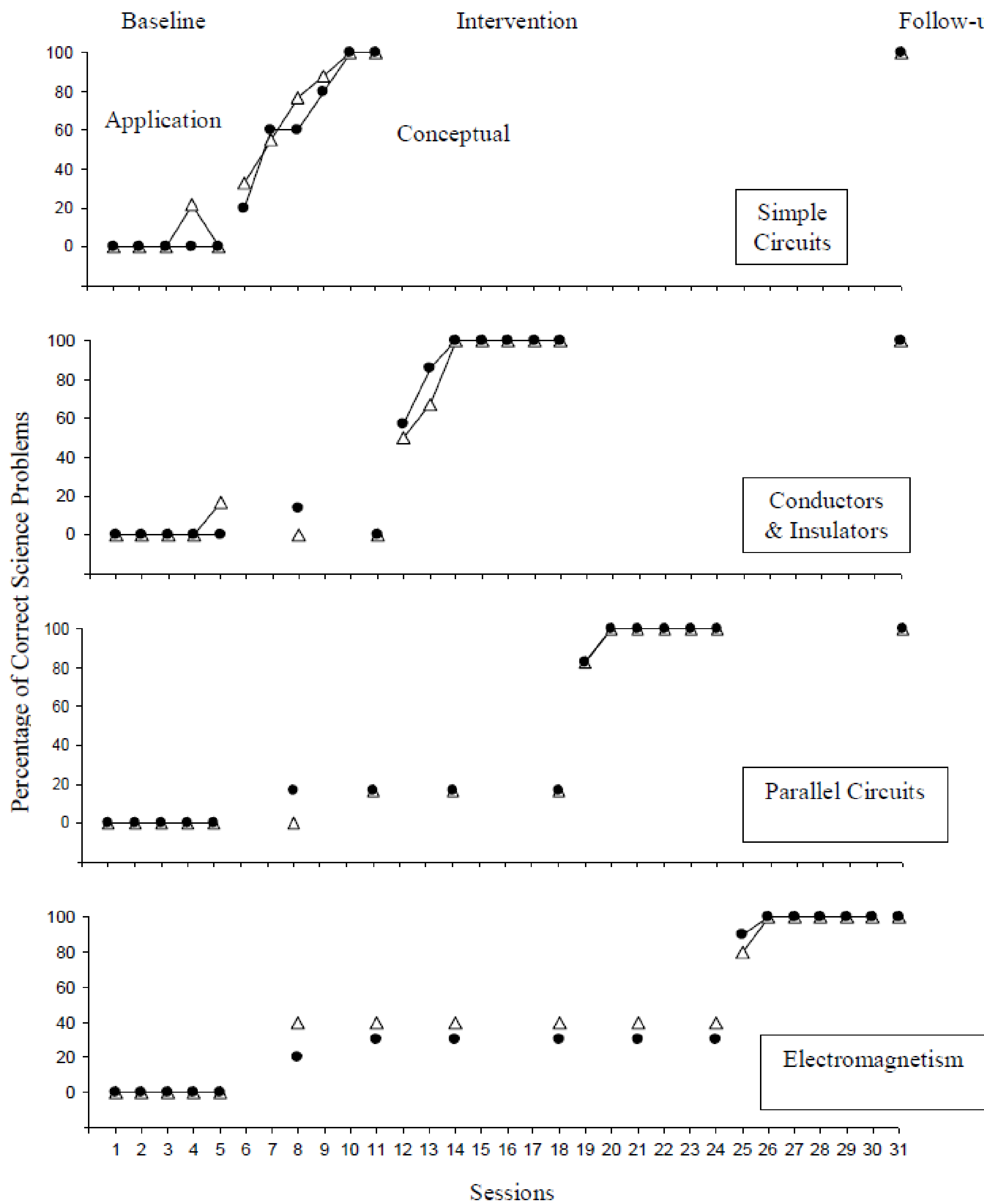

Figure 4. David's percentage correct across science skills.

Evia. Figure 5 displays Evia's percentage of problems solved correctly. During baseline, the mean percentage for solving conceptual-based simple circuit problems correctly was 4.0% and 8.8% for application-based problems. When the activity-based circuit kitbook was implemented, her mean percentage for solving conceptual-based simple circuit problems correctly increased to 66.7% and 71.8% for application-based problems. For conductors and insulators, the mean percentage for solving conceptual-based problems was 4.0% and 4.9% for application-based problems during baseline. Evia's mean percentage for solving conceptual- based problems increased to 69.1% and 76.1% for application-based problems during intervention. For parallel circuits, the mean percentage for solving conceptual-based problems was 6.2% and 7.6% for application-based problems during baseline. His mean percentage for solving conceptual-based problems increased to 83.3% and 78.4% for application-based problems during intervention. For electromagnetism problems, the mean percentage for solving conceptual-based problems was 8.2% and 10.9% for application-based problems during baseline. Her mean percentage for solving conceptual-based problems increased to 95.0% and 96.7% for application-based problems during intervention. Evia also maintained 100% of all skills six week later.

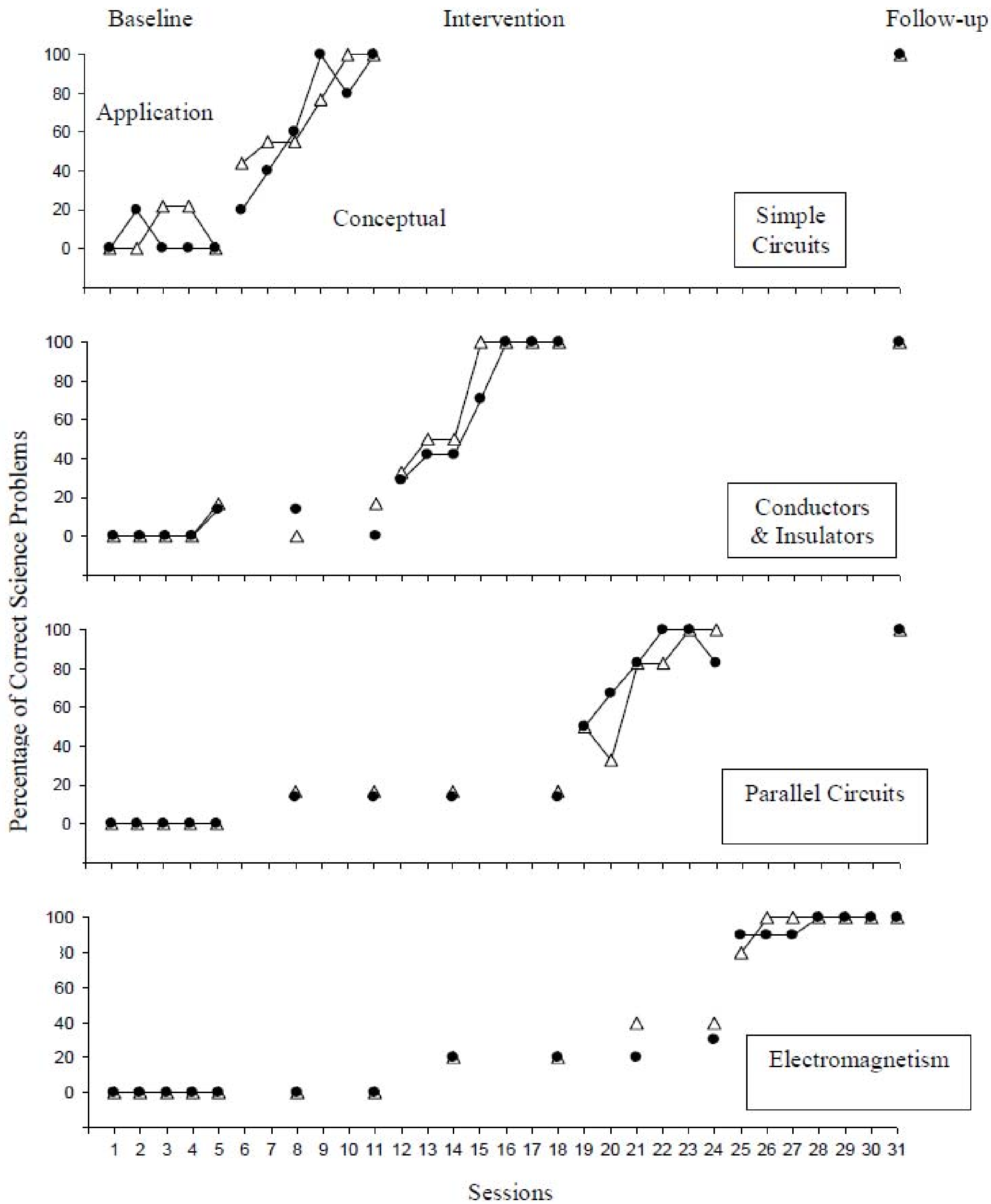

Figure 5. Evia’s percentage correct across science skills.

Science Attitude Assessment

A Wilcoxon matched-pairs signed-ranks test was used to examine student attitudes towards science. Table 5 lists student scores, group means, and statistical analyses on the Scientific Attitude Inventory (SAI-II) (Moore & Foy, 1997) prior to and following the conclusion of the intervention. Students reported significant differences regarding their attitudes towards science. Initially, students reported a mean of 44.0 (SD = 7.65) on scientific attitudes, a mean of 52.8 (SD = 4.76) on their attitudes towards science, and a mean of 96.8 (SD = 7.79) overall. Following intervention, students reported significant improvements about scientific attitudes (*M* = 56.2, *SD* = 2.95, *W* = 2.02), $p < .05$), attitudes towards science (*M* = 73.0, *SD* = 4.69, *W* = 2.06, $p < .05$), and overall (*M* = 129.2, *SD* = 5.35, *W* = 2.03, $p < .05$).

Table 4. Students' Attitudes Towards Science

Students	Pretest			Posttest			*W*	*p*
	Science Attitudes	Attitudes towards Science	Total	Science Attitudes	Attitudes towards Science	Total		
Adam	42	51	93	55	70	125		
Beth	45	55	100	57	75	132		
Chris	35	50	85	52	72	124		
David	56	48	104	60	68	128		
Evia	42	60	102	57	80	137		
Mean	44.0	-	-	56.2	-	-	2.02	.043*
SD	7.65	-	-	2.95	-	-		
Mean	-	52.8	-	-	73.0	-	2.06	.039*
SD	-	4.76	-	-	4.69	-		
Mean	-	-	96.8	-	-	129.2	2.03	.042*
SD	-	-	7.79	-	-	5.35		

Note. *W* = Wilcoxon matched-pairs signed-ranks test. *$p < .05$.

Discussion

The purposes of this study were: 1) to examine the impact of inquiry-based Electric Circuits Kitbook on the acquisition, maintenance and generalization of simple electric knowledge and skills of elementary students with LD and 2) to examine the impact of an inquiry-based curriculum unit, Electric Circuits Kitbook, on student's with LD attitudes toward science and scientific attitudes. The results of the intervention used in this study indicate that inquiry-based Electric Circuit Kitbook had a significantly positive impact on participants' conceptual understanding of the targeted science concepts and their attitudes towards science. We discuss the meaning of these results for enhancing the quality of science learning for students with LD by adopting inquiry-based curriculum materials, using responsive instruction and enhancing pedagogical knowledge of special education teachers in relation to science teaching.

The Impact of KitBook on Students' Conceptual Understanding

The test results show that the use of Electric Circuits Kitbook had a significant influence on the learning of elementary students with LD. With the use of Electric Circuit Kitbook, all students improved their conceptual understanding of simple electric circuits. Students were also able to successfully apply their conceptual understanding to construct and interpret simple, series and parallel electrical circuits. Moreover, students maintained this understanding six weeks later. A functional relation was established since experimental control occurred by demonstration of a covariation between change in behavioral patterns and introduction of the intervention within, at least, three different series at three different points in time (Horner, Carr, Halle, McGee, Odom, & Wolery, 2005).

Previous studies (Asami, King, & Monk, 2000; Wandersee, Mintzes, & Novak, 1994) have shown that mainstream elementary school students struggle to develop conceptual understanding of the concept of electricity and electric circuits. These studies have identified many misconceptions related to mainstream students' conceptual understanding of electricity and simple electric circuits. For instance, Chiu and Lin (2005) found that some students considered that, *electricity moves from one end of the battery to the bottom of the light bulb* and illuminate the bulb (p. 445). Some students also believed that there only needs to be one wire connecting the battery and the light bulb in order for the light bulb to produce light. More precisely, when the students were asked to draw an apparatus that would create a lit light bulb, they would leave out the wire that connects the bulb back to the battery (Chiu & Lin, 2004). These misconceptions are elaborated in Asami et al (2000) and Chiu and Lin (2005). Moreover, literature reveals that many general education students hold these misconceptions about simple electrical circuits even after instruction (Aydeniz, 2010). Misconceptions about electrical circuits may be more common among students with LD, who often struggle with learning academic content (Carlisle & Chang, 1996).

The findings from this study suggest that the use of inquiry-based learning kits can have a significant influence on the learning outcomes of students with LD in science at the elementary school level.

Although this kit-based curriculum proved to be effective in helping students' with LD learning of science, curriculum alone is not sufficient for creating equitable and meaningful learning experiences for students with LD. Teachers' pedagogical content knowledge for teaching inquiry-based science must be taken into consideration in interpreting the effectiveness of learning kits. For instance, we believe that this intervention was successful in part because of teacher's pedagogical knowledge of inquiry-based science and her commitment to providing meaningful learning experiences to her students with LD. The teacher had taken a science methods course while in her teacher education program and had participated in a professional development activity that focused on enhancing elementary teachers' science content and pedagogical content knowledge. These experiences and coaching provided by the principal investigators had equipped her with knowledge skills and motivation to successfully implement the proposed activities through an inquiry framework. Many special education teachers may not have such a background in science content and pedagogy that will enable them to use EC Kitbook with effectively. Therefore, teachers willing to use such Kitbooks must also receive professional development on science content and pedagogy of teaching science with inquiry

Literature reveals that students with LD struggle with staying on task, time management and following directions to complete a learning task when proper accommodations are not provided in traditional lecture-based instructional settings (Bulgren, Deshler, & Schumaker, 1997; Shmulsky, 2003). As indicated in this study, students with LD engage in science learning more effectively when curriculum emphasizes inquiry and performance-based assessments and the teacher is conscious of students' struggles. We attribute this differentiated effect of instruction on students' learning to the fact that lecture-based instruction does not nurture students' curiosity. When students with LD are given a chance to pursue an open-ended question or to figure things out, they are more willing to stay on task and complete the learning assignments. Moreover, when the students with LD learn science through inquiry-based curriculum materials such as Electric Circuits, they are more likely to demonstrate their true potential for learning. As a result, giving the teachers a chance to more accurately gauge their students' knowledge of scientific ideas and processes covered in the class.

Through proper scaffolding, the use of inquiry-based science kits can afford the opportunities for students with LD to construct models simulating the scientific theories (i.e., electric circuits) and discuss their understanding of these theories with their teachers and their peers. The Electric Circuits Kitbook provides such scaffolding through proper sequencing of learning tasks that a teacher can use to teach science. This inquiry-based science kit, which creates a context for and encourages learning activities such as group work and performance-based assessments, has contributed significantly to the learning of students with LD (Schloss, Smith, & Schloss, 2001) and of mainstream students (Granger et al., 2010). Such curriculum materials must be adopted and used by teachers of this group of students to achieve equity in science learning. Adopting such curriculum materials and instructional strategies that accompany them is likely to reduce students' distraction and engage them in the learning of science in a meaningful and an effective way. However, adopting of such inquiry-based curriculum materials alone is not sufficient. In order for teachers of students with LD to create such positive impacts on students' learning, they must also have the pedagogical knowledge to teach inquiry-based science. The issue of special education teachers' science content and pedagogy can partly be addressed through teacher preparation programs, by encouraging the students to take a science methods course. However, this may not be sufficient for addressing the learning needs of students with LD in science. Creating such opportunities in science for all students requires a strong leadership that values both science and students' with LD right to learn science in a meaningful and effective way. The question that remains to be answered is: How do we create such leadership in our schools? The answer to questions like this one is likely to make the learning of science in a meaningful way accessible to all students with LD.

The Impact of Electric Circuits Kitbook on Students' Attitudes towards Science and Scientific Attitudes

The results show that the use of Electric Circuits Kitbook had a positive influence on student's attitudes toward science. Our findings indicate that the participant's attitudes toward science and their scientific attitudes improved significantly as a result of the intervention. These findings are consistent with a growing body of research that links student's meaningful participation in science learning activities and their attitudes towards science learning (Granger et al., 2010; Koballa & Glynn, 2007; Osborne & Collins, 2001). For instance, more students described science as enjoyable and that they would like to become a scientist on the post test than they did on the pre-test. Research shows that attitudes play a key role in a students' effective participation in learning (Koballa & Glynn, 2007; Jenkins & Nelson, 2005). If this is true, we need to use curriculum materials and instructional strategies that are promising in helping the students with LD to develop positive attitudes towards science. The adoption of such curriculum materials and instructional strategies will help achieve the goal of making Science for All a reality in our classrooms.

Limitations

The findings of the current study were limited by a number of factors. First, as with any single subject research design, the small number of students limits the generalizability of the results. Moreover, all students were very cooperative and highly motivated to participate in this study as evident by their attendance. Systematic replication of the use of inquiry-based instruction is needed to build this generality. Second, this study examined the use of inquiry-based instruction outside the student's regular science instruction and in the resource classroom. The combination of inquiry-based instruction within typical classroom instructional practice requires further investigation. Thirdly, generalization was not assessed. Generalization probes during regular classroom instruction are needed. Finally, other confounding factors such as teacher effect and the effect of group-based learning were not controlled. The findings reported here and the implications proposed should be considered in light of these limitations.

Results of this study provide support for the use of inquiry-based scientific instruction as an effective strategy for students with LD. However, future research needs to be conducted to identify additional ways inquiry-based curriculum and science instruction can be used for students with other disabilities to maximize academic learning opportunities. Additionally, future research should target other science skills and include students of various disabilities to assess the versatility of inquiry-based scientific instruction. Finally, the results of this study cannot be generalizable due to limited number of participants involved in the study. Future studies that include a large number of participants and can control for confounding factors more effectively than we were able to in this study will add to the validity of the conclusions drawn from the findings of this study.

Implications

It is noted in the literature that a significant number of elementary teachers do not feel well prepared to teach science concepts effectively. If teachers do not feel confident in teaching science, they are likely to set a great number of students especially students with LD for failure. In addition, limiting students' exposures to the scientific ideas in early grades may lead students to develop negative attitudes towards science later in their academic lives. Elementary teachers hold negative attitudes towards teaching science for various reasons (Appleton, 2008; Koballa, & Crawley, 1985). One of the reasons that elementary teachers do not teach science is because they lack content and pedagogical content knowledge (Appleton, 2008; Fulp, 2002). The adoption of reform-based, teacher friendly curriculum such as the one used in this study may impact elementary school teachers' attitudes towards the teaching of science. The design of the Electric Circuits Kitbook is informed by guided inquiry framework and thus provides scaffolding that students need to engage in learning about simple electrical circuits in an effective manner. Moreover, the adoption of such kits can enhance elementary school teacher's self-efficacy to teach science. Self-efficacy refers to one's belief in one's ability to affect a situation to bring about desirable outcomes (Bandura, 1997). The findings of this study suggest that the use of science kits informed by guided inquiry framework can enhance students' with LD conceptual understanding and their attitudes towards science. Thus, the use of such kits must not only be adopted by school districts but elementary teachers must be held accountable for using such kits in their classrooms. These kits can also be used in professional development programs designed for the teachers of students with LD.

We understand that these kits may not be available in some countries. However, the key point we try to convey to the readers is not the kit itself but the use of instructional strategies that will challenge the students to engage in inquiry-based learning. This can be done without learning kits such as the one described in this paper. Although the kits add a guided structure to the inquiry-based learning tasks pursued, a teacher with adequate pedagogical content knowledge for inquiry-based instruction can provide such scaffolding in the absence of such kits.

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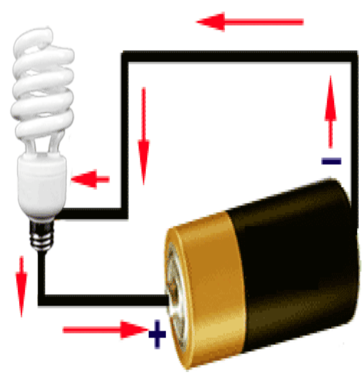
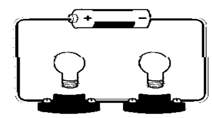
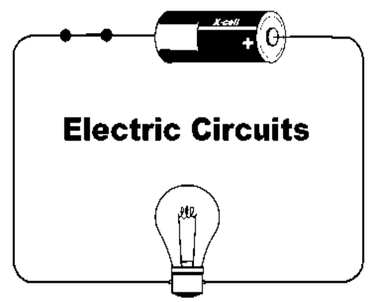
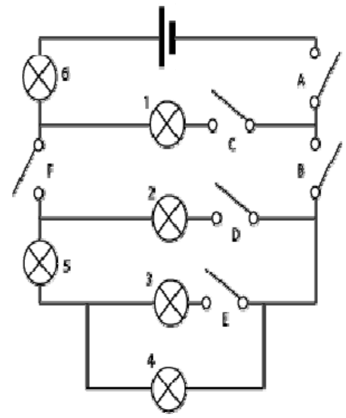
Appendix A. Quiz Item Examples

Skills	Conceptual Problems	Application Problems
Simple circuits	Look carefully at the following diagram representing a series circuit. What happens when you open or close the circuit? 	 The following two circuits use the same battery. The lamp in which circuit will be brighter, A or B? a. A b. B A  B
Conductors and insulators	Measure of the opposition to the flow of free electrons in an electric circuit is known as: a. Current b. Resistance c. Conductance	Which one of the following pairs are insulators a. Copper and iron b. Gold and ceramic c. Plastic and wood d. Steel and mercury

Appendix A (continued)
Quiz Item Examples

Parallel circuits	What is a parallel circuit? a. An electric current having more than one path along which electric current can flow. b. An electric current having more than one path along which electric current can't flow.	In the following circuit, which bulbs will light if only switches A, B, D and F are closed? a. 3, 4, 5 b. 1, 2, 6 c. 6 and 2 only d. 1,2, 3, 5, 6

		
Electromagnetism	When current flows through conductor is produced around it. a. Magnetic field b. Power Energy	You have two electromagnets that are the same except one has 10 coils and one has 20 coils. Which one will pick up more paper clips? Explain your answer. a. 10 coil electromagnet b. 20 coil electromagnet