The Effects of Learning Cycle on College Students' Understandings of Different Aspects in Resistive DC Circuits

by

Salih Ates

Izzet Baysal University,

Golkoy-Bolu, Turkey

Introduction

Over the last two decades, physics education research has revealed that students already have many ideas about how physical systems behave even before they start to study physics (Clement, 1982). In many cases, these ideas called alternative conceptions differ from accepted scientific ideas. Previous research has shown that it is difficult for students to change their initial ideas in physics (Osborne, 1983; McDermott, 1990; Wandersee, Mintzes, and Novak, 1994).

The students' understanding of key concepts on electricity has been extensively studied, ranging from the simple notions treated in primary school science to the more sophisticated notions addressed in introductory physics courses at university level. The research has revealed that students hold many alternative conceptions and have difficulties in understanding the concepts of circuits (Duit et al. 1985; Osborne, 1981; Shipstone, 1985; Borges and Gilbert, 1999; Engelhardt and Beichner, 2004). Most of the studies about investigating students' understanding of key concepts on electricity use similar tasks; i.e., have students perform experiments involving a battery, a bulb and some wires and then asking them to light up the bulb. While they are involved in the task, their actions and behaviors are observed. They are then interviewed and asked to explain what they were thinking while they were doing the task. From the process generated, researchers are able to infer the students' conceptual models used to analyze electric circuits. The literature indicates that students have the followings prominent mental models regarding circuits:

a) Unipolar model: a current flows from positive terminal of the battery to the base of a bulb, where it is all used up (Osborne, 1981).

b) Clashing Current: plus and minus currents travel from the battery terminals to the bulb where they meet and produce energy (Osborne, 1983).

c) Closed circuit model: the circuit elements have two connections. Current circulates around the circuit in a given direction and current flow through a resistive circuit element liberates energy (Kärrqvist, 1985).

d) Attenuation model: a current circulates the circuit and some portion of the current is used up as it goes through each component of the circuits (Osborne, 1983).

e) Constant current source model: battery is seen as a source of constant current. The current supplied by battery is always the same regardless of the circuit features (Kärrqvist, 1985).

f) Scientific view: a current flows around the circuits transmitting energy. Current is conserved and well differentiated from energy. The circuit is seen as a whole interacting system, such that a change introduced at one point of the circuit affects the entire system (Osborne, 1983).

Some of the studies on this issue revealed that the relative popularity of students' mental models changes with students' age and experience from simple intuitive mental models towards some scientific models (Shipstone, 1985 and Osborne, 1983). Osborne (1983) stated that students' mental models about electric circuit improve with age and instruction, but elementary students predominantly hold either a clashing current or non-recursive model. Shipstone (1985) shows the popularity of different models as a function of age.

There is also some evidence to indicate that students change their reasoning pattern to suit the question at hand (Heller & Finley, 1992). Thus, they do not appear to use a single model to analyze circuit phenomena. In analyzing circuits, students use one of three ways of reasoning: sequential, local or superposition. Students using sequential reasoning believe that current is influenced by each circuit element as it is encountered and a change made at a particular point does not affect the current until it reaches that point (Closset. 1984). Local reasoning means that current divides into two equal parts at every junction regardless of what is happening elsewhere (Rhöneck and Grob, 1987). Student using superposition reasoning would conclude that if one battery makes a bulb shine with a certain brightness, then two batteries would make the bulb shine twice as bright regardless of the configuration (Sebastia, 1993).

Results of previous studies revealed that a circuit unit involves several interrelated concepts and a number of different aspects. According to Borges and Gilbert (1999), the following different aspects involve in circuits:

1) Differentiation of basic terms used to speak about electricity, such as current, electricity and energy.
2) Recognition of bipolarity of various circuits elements, like batteries and bulbs.
3) Recognition of the necessity of a closed circuit if a current is to circulate in it.
4) Issue of the conservation of current
5) Effects of electrical resistance on current.
6) Models for current circulation
7) Nature of electric current

Some aspects of circuits are seemed to occupy a more central place in students' mental models so that instruction may affect them to different degrees. For example, a student who does not have a proper understanding about the difference between current and energy is unlikely to adopt a view in which current is conserved. Research findings suggest that students can easily change their views about some of the above-mentioned aspects than about others after instruction (Shipstone, 1985). After students are provided a battery, a bulb and some wires and then are asked to light the bulb, they recognize that circuit elements are bipolar devices and circuits should be closed if current is to circulate in it (Cosgrove, 1995). However, some aspects of students' mental models of electricity are more resistant to change, such as those involving in the concept of current. It is pointed out that this becomes a critical difficulty when students study more complex circuits involving combination of resistors in series and parallel (McDermott and van Zee, 1985) and when they start to learn microscopic process going on in a circuit (Eylon and Ganiel, 1990). Some researchers point out that problem is with the lack of differentiation between current and energy (Arnold and Millar, 1987), while others mentioned that problem is with lack of the robust models of understanding microscopic process leading to the macroscopic phenomena observed (Eylon and Ganiel, 1990).

While researchers have reached a consensus about the nature of student learning difficulties, there is no consensus on appropriate pedagogy to address those difficulties. Shipstone et al. (1988) showed that success of physics instruction on achieving the physics point of view usually is limited to students' conceptions of electricity. It becomes obvious in such learning process studies that the learning pathways students follow are very complicated and a conceptual development towards physics view of electricity is a long lasting process. However, several research based pathways have emerged following a constructivist perspective on teaching and learning of electricity. Some studies suggest analogies and analogical reasoning as a vehicle for inducing conceptual change in the students (Cited in Psillos, 1998). Yet other approaches use conceptual change strategies on teaching and learning of electricity (Licht, 1991; Wang and Andre, 1991; Chambers and Andre, 1997). This study investigates the effects of learning cycle and traditional method of teaching on university students' understanding of several interrelated concepts and a number of different aspects involve in resistive direct current (dc) circuits.

The Learning Cycle

There are different type of learning cycle, i.e., three face learning cycle, 4 E and 5 E. In this study the tree face learning cycle described in Laswson (1995) was used. This learning cycle method is a three-phase inquiry approach consisting of *exploration, term introduction,* and *concept application* (Lawson, 1995). A key element of the learning cycle method is that lab activities that precede lectures. Since its inception in the 1960, the learning cycle has been the focus of many studies conducted to determine its effectiveness. It suffices to say that the learning cycle has been found very effective at teaching science concepts and improving generalizable reasoning skills in students from first grade to college [see Lawson (1995) for detailed review of this subject]. More recently, learning cycle has been found to be effective helping students eliminate scientific misconceptions. Guzzetti, Taylor, Glass, and Gamas (1993) conducted a meta analysis of 47 learning cycle based studies and found effect sizes in favor of the learning cycle students that varied from 0.25 to 1.5 standard deviations. Benford (Cited in Lawson, 2001) found a statistically significant relationship between college students' reasoning improvements and instructors' skill at engaging students in the learning cycle based inquiries.

While instructional methods developed based upon conceptual change approach (i.e., learning cycle and conceptual change texts) have been advocated for helping students to recognize their misconceptions and reject them in favor of a more scientific view. A few research have examined the effectiveness of conceptual change approaches for the topic of circuits (Wang and Andre, 1991; Chambers and Andre, 1997). However, almost none of the previous research has examined the effects of learning cycle method on understanding of several interrelated concepts and of different aspects involve in resistive direct current (dc) circuits. For the topic of electricity, Wang and Andre (1991) investigated the effects of conceptual change approach on conceptual understanding of electric circuits. Their research goal was to determine whether text that challenged misconceptions before presenting a more scientifically correct view would facilitate development of a mature conceptual understanding of electric circuits. They found that conceptual change texts were facilitative for middle school students. Chambers and Andre (1997) investigated relationships between gender, interest and experience in electricity, and conceptual text manipulations on learning fundamental direct current concepts. They found that conceptual change text resulted in better conceptual understanding of electrical concepts than traditional didactic text for college students.

Method

Purpose

This study was conducted to investigate the effectiveness of learning cycle method on teaching the concept of dc resistive circuit for university students. The questions investigated by the study were the following:

1- How does learning cycle method affect the understandings of dc circuits?
2- Does learning cycle method effective to teach all interrelated concepts and a number of different aspects involve in dc circuits?

Participants

Participants were 152 freshmen (69 females and 83 males; age between 17 and 20) enrolled in a one-semester introductory university physics II course from pre-service science teaching department at the Abant Izzet Baysal University in Turkey. Subject had taken all required science and mathematics courses.

An experienced researcher who holds M.A. and Ed.D. degrees in Physics education taught instructional materials to the groups. The researcher has approximately fifteen years teaching experience in high school and introductory university level physics courses and contemporary courses in science education.

Design

In the beginning of spring semester, students in four entire sections (approximately 35 students per class) were taught some electrostatics units with traditional approach of teaching physics (e.g., electric fields, Gauss' Law, electric potential, and capacitance). After teaching the units mentioned above, the intact classes were randomly assigned into one of two treatment groups (2 classes per group). One group completed a simple dc circuits unit with learning cycle approach (n_1=79), while the other completed a simple dc circuits unit with traditional approach (n_2=73). After the groups were formed, all students were administered a test called Determining and Interpreting Resistive Electric Circuits Concepts Test (DIRECT) to measure students' preconceptions of dc circuits' concepts and aspects. Then, students in both groups completed a dc circuits unit specifically designed for the each group. Finally, all students were administered the DIRECT again as posttest. This study, including testing, lasted about two and a half weeks and the researcher taught instructional materials to the groups.

Determining and Interpreting Resistive Electric Circuits Concepts Test (DIRECT)

A diagnostic instrument called Determining and Interpreting Resistive Electric Circuits Concepts Test (DIRECT version 1.1) was developed by Engelhardt and Beichner. The DIRECT was a twenty-nine item multiple-choice test with five answer choices for all questions and has a published reliability (KR-20) of 0.71 (Engelhardt and Beichner, 2004). DIRECT was developed to evaluate high school and university students' understanding of a variety of resistive dc circuits concepts. The instrument took approximately an hour to complete. A correct response is awarded one point and students' total scores for items in this instrument can range from 0 to 29. According to Engelhardt and Beichner, DIRECT is a reliable test for teachers to evaluate effectiveness of their instructional materials and methods and determine their students' conceptual difficulties. The instrument has eleven instructional objectives (hereafter IOs) about dc circuits unit, which involves a number of different aspects. The IOs are shown in Table 1.

Table 1: Instructional Objectives for DIRECT

	Instructional Objectives	**Question Number**
Physical Aspects of DC electric circuits (IOs. 1-5)		
IO-1	Identify and explain a short circuit	10, 19, 27
IO-2 **IO-3**	Understand the functional two-endedness of circuit elements Identify a complete circuit and understand the necessity of a complete circuit for current to flow in the steady state	9, 18
IO-4	Apply the concept of resistance including that resistance is a properties of the object and that in series the resistance increases as more element are added and in parallel the resistance decreases as more elements are added	5, 14, 23
IO-5	Interpret pictures and diagrams of a variety of circuits including series, parallel, and combination of the two	4, 13, 22
Energy (IOs. 6-7)		
IO-6	Apply the concept of power to a variety of circuits	2, 12
IO-7	Apply a conceptual understanding of conservation of energy including Kirchhoff' loop rule and the battery as a source of energy.	3, 21
Current (IOs. 8-9)		
IO-8	Understand and apply conservation of current to a variety of circuits	8, 17
IO-9	Explain the microscopic aspects of current flow in a circuit through the use of electrostatic terms such as electric field, potential differences, and interaction of forces on charged particles.	1, 11, 20
Potential difference (Voltage) (IOs. 10-11)		
IO-10	Apply the knowledge that the amount of current is influenced by the potential difference maintained by the battery and resistance in the circuit.	7, 16, 25
IO-11	Apply the concept of pot. diff. to a variety of circuits including the knowledge that the pot. diff. in a series circuit sums while in a parallel circuit it remain the same.	6, 15, 24, 28, 29
Current and Voltage (IOs. 8 & 11)		26

In this study, Turkish version of the DIRECT was used to measure students' understanding of different aspects of dc resistive electric circuits. The DIRECT was translated and adapted into Turkish by the researcher. First, Turkish version of DIRECT was administered to 125 students from high schools and a university to revise and clarify test questions that were confusing to students. Second, Final Turkish version of the instrument was administered to 357 students (150 from a university and 207 from high schools) to test' reliability. The statistical analysis of the test is presented in Table 2.

Table 2: Statistical results for Turkish version of DIRECT

Statistic:	**Values:**
N	357
Mean	10.48
SD	4,68
SEM	0,25
Range	2 - 23
Reliability (KR-20)	0,74
Average Point-biserial correlation	0,35
Average difficulty index	0,36

Learning Cycle and Traditional instructional Treatments

Both learning cycle and traditional treatments lasted about two and a half weeks of one semester physics II course. The course consisted of three 50-minute lectures and two 3-hour sections per week. The number of chapters assigned in the two instructional approaches was similar. The instructor introduced the following topics: The batteries, electric current, constructing a dc circuit, resistance and Ohm's Law, short circuit, electrical power and energy, batteries in series and parallel, resistors in series and parallel, and Kirchhoff's rules.

For learning cycle group, a total of 12 instructional activities were used. Ten of those were adapted from various sources [i.e., Using the Learning Cycle to Teach Physical Science written by Beisenherz and Dantonio (1996)] and the remaining were developed by the researcher. All of the activities were pilot tested during a two year period. As results of these pilot testing period only minor change were made. Each activity emphasized one major concept or an aspect of dc electric circuits. A sample instructional activity developed for the learning cycle group is presented as Appendix. During the first phase of the learning cycle (exploration), students learned through their own actions and reactions by exploring materials and testing their previous ideas on the subject with minimum guidance. Exploration raised questions, complexities, or contradictions. Explorations also lead to the identification of a pattern of regularity in the phenomena (e.g., the current flow in a circuit increases with number of batteries in series). The second phase, term introduction, was started with the introduction of a new term by the instructor, which is used to refer to the patterns discovered during the first phase such as current, voltage, and resistance. In the last phase (concept application), students applied the new term to additional contexts. For example, after the introduction of resistance, concept application involved determining the variables that affect properties of a resistance (e.g., geometry of object and types of materials with which the object is composed).

In traditional group, the course traditional in format, having lectures, discussions and laboratories. Thus, a concept or an aspect of dc electric circuits is verbally introduced and discussed in the lecture. Then, an appropriate lab activity is performed and used to reinforce previously introduced concept. Students in this group were taught from Turkish version of a traditional text developed by Serway (Serway, 1992).

Data Analysis and Results

Since intact classes participated in the study, there was a possibility that differences in students' pre understanding of a variety of direct current (dc) circuits' concepts could affect the variable under study. To determine group equivalence and possible covariate, pre-DIRECT mean scores of groups were analyzed. ANOVA techniques were used to determine if pre-DIRECT mean scores differed between the groups. The mean score of Experimental group for pre-DIRECT was 14.70, with a standard deviation of 3.66. The mean score of Control group was 13.73, with a standard deviation of 3.82. ANOVA results indicate that there is not a statistically significant difference in pre-DIRECT mean scores for the groups ($F_{1,\,150}=2.58$, $p=0.11$). The groups' pretests mean scores in IOs were also analyzed. The results of analyses show that there are significant differences between groups' pretest mean scores in IO-8 and IO-11. Pretest mean scores of students' for these IOs regarding understanding and applying conservation of current (IO-8) and the concept of potential difference to a variety of circuits (IO-11), were significantly different between the groups. Experimental group students outscored control group students for these two objectives ($F_{1,\,150}=5.95$, $p=0.02$ and $F_{1,\,150}=4.06$, $p=0.05$, respectively). Thus, pretest scores were further analyzed to determine if this variable is a significant predictor of posttest DİRECT score and an appropriate covariate. A pretest score was incorporated into a regression equation for a posttest score. The equation yields an R^2 value of 0.23 and the pretest score is a statistically significant predictor of the posttest score ($t=6.15$, $p=0.00$). The correlation coefficient between two variables was 0.47 and correlation was significant at the 0.01 level. Thus, when posttest DIRECT scores were analyzed, a pretest DIRECT score was used as a covariate.

One of the purposes of this study was to investigate the effects of learning cycle and traditional method of teaching on university students' understanding of resistive dc circuits. The effects of treatments on students' understanding of circuits were examined by using ANCOVA techniques with pretest DIRECT scores used as a covariate. Summary statistics for this analysis are found in Table 3.

Table 3. Summary statistics for post DIRECT mean scores by groups

Groups	**N**	**Mean**	**Adj. Mean**	**SD**
Experimental	79	18.98	19.33	3.20
Control	73	16.23	16.24	2.91

From analysis of covariance data, it was determined that there was a significant difference in posttest adjusted mean scores based upon treatments (Learning cycle versus Traditional method of teaching). Analysis of data revealed that students who experienced the learning cycle activities had higher achievement on the posttest DIRECT when compared with students experiencing the non-learning cycle activities. The results are presented in Table 4.

Table 4. ANCOVA table for post DIRECT mean scores by groups

Source	**SS**	**DF**	**MS**	**F**	***p***
Corrected Model	578.682	2	289.341	38.764	.000
Intercept	1361.789	1	1361.789	182.444	.000
Pre-DIRECT	260.942	1	260.942	34.959	.000
Treatment	231.644	1	231.644	31.034	.000
Error	970.341	149	7.464		
Total	43817.000	152			
Corrected Total	1549.023	151			

R Squared =0.374 (Adjusted R Squared =0.364)

Another purpose of the present study was to investigate the effects of learning cycle to teach several interrelated concepts and a number of different aspects involve in dc circuits. The effects of treatments on students' understanding of concepts and aspects in circuits were also examined by using ANCOVA techniques. Summary statistics, F-ratios, and p-values for these analyses are found in Table 5.

Table 5. Statistics for pre and posttest mean scores in the IOs by the groups

Instructional Objectives	**Groups**	**Pretest**		**Posttest**			
		Mean	**SD**	**Mean**	**SD**	**F**	***p***
IO-1 (3 items)	Experimental	1.81	0.78	**2.58**	**0.62**	**20.90**	**0.000****
	Control	1.90	0.80	**2.09**	**0.78**		
IO-2 & 3 (2 items)	Experimental	1.07	0.78	**1.66**	**0.53**	**12.63**	**0.000****
	Control	1.23	0.78	**1.30**	**0.76**		
IO-4 (3 items)	Experimental	1.64	0.92	**2.08**	**0.78**	**0.14**	**0.71**
	Control	1.38	0.86	**1.95**	**0.54**		
IO-5 (3 items)	Experimental	1.76	0.80	**2.23**	**0.77**	**0.00**	**0.99**
	Control	1.81	0.77	**2.24**	**0.81**		
IO-6 (2 items)	Experimental	0.64	0.61	**0.98**	**0.70**	**8.34**	**0.005***
	Control	0.57	0.57	**0.61**	**0.70**		
IO-7 (2 items)	Experimental	1.16	0.73	**1.57**	**0.60**	**13.42**	**0.000****
	Control	1.11	0.72	**1.13**	**0.72**		
IO-8 (2 items)	Experimental	1.78	0.47	**1.83**	**0.37**	**1.60**	**0.20**
	Control	1.56	0.61	**1.69**	**0.49**		
IO-9 (3 items)	Experimental	0.92	0.74	**1.20**	**0.80**	**0.50**	**0.47**
	Control	0.71	0.74	**1.07**	**0.69**		
IO-10 (3 items)	Experimental	1.60	0.90	**2.02**	**0.79**	**8.28**	**0.005***
	Control	1.48	0.80	**1.60**	**0.86**		
IO-11 (5 items)	Experimental	1.81	0.97	**2.52**	**0.76**	**7.69**	**0.006***
	Control	1.50	0.93	**2.00**	**1.04**		

$*p<0.01$, $**p<0.001$

ANCOVA results revealed that the posttest mean scores of students' responses for the IO-1 regarding identifying and explaining a short circuit were significantly different between treatments. Analysis of covariance results indicated that posttest mean scores of the groups for the IOs-2 & 3 regarding understanding the bipolarity of circuit elements, the necessity of a complete circuit for current to flow, and identifying a complete circuit were statistically significant. In the IOs-6 and 7 regarding applying the concept of power and a conceptual understanding of conservation of energy, there were statistically differences between the groups' posttest mean scores. Results of the analyses also revealed that posttest mean scores of students' responses for the IOs-10 and 11 regarding applying the concept of potential difference and the knowledge that the amount of current is influenced by the potential difference maintained by the circuit elements were different between the groups. The learning cycle method was found to be more effective to teach all of these IOs when compared to Traditional method of teaching. In contrast, ANCOVA results indicated that posttest mean scores of groups IOs 4, 5, 8, and 9 were not statistically different.

Discussion

This study was conducted to explore two ways of teaching and learning dc circuits for university students having different cognitive styles. Results from this study indicate that the implementation of the learning cycle method enhances students' understanding of key aspects and concepts involving in dc circuits.

Possible reasons for this observed difference may include value associated with alternative ways of acquiring knowledge in science and confirmation value of hand-on activities which are key characteristic of learning cycle (Lawson, 2001). During learning cycle, students learned through their own actions and reactions by involving in hands-on activities. They explored new materials and phenomena that raise questions and encourage them to seek answers. Students' exploration involved in gathering and analyzing of data allowed them testing of alternative hypotheses. Students, in the learning cycle group, were also involved in activities that help them to examine the adequacy of their prior conceptions and force them to argue about and test those conceptions. This leads to disequilibrium when predictions based on their prior beliefs are contradicted and provides the opportunity to construct more appropriate concepts. Thus, learning cycle method require a teaching strategies in which students had more opportunity to identify and express their pre conceptions, examine the utility of them, and apply the new concepts and ideas in a context familiar to them. However, in the Traditional group, a concept or a group of related concepts was verbally introduced and explicated in the lecture and then the lab activities followed. Lab activities are used to establish the validity of and reinforce the previously introduced concepts rather than effectively initiate scientific inquiry in this method. Thus, students in traditional group mainly focused on concepts related to the subject that require less conceptual restructuring.

The finding of this study regarding better performance of students in learning cycle group is consistent with the view claiming that correct use of the learning cycle accomplishes effective learning of science concepts (Lawson et al., 2000; Lawson, 2001; Cavallo, 1996). According to Lawson (2001, p.166), "learning new concepts is not a purely abstractive process. Rather, concept acquisition depends upon one's ability to generate and test ideas or hypotheses and reject those that lead to contradictions. Thus, concept learning can be characterized as ‘constructive’, while new conceptual knowledge depends upon skill in generating and testing ideas. As one gains skill in generating and testing hypotheses, concepts construction becomes easier”.

This study also investigated the effects of learning cycle and traditional method of teaching on students’ understanding of a number of different aspects involves in resistive circuits. Results of this study revealed that the main effects of treatments on students’ understanding of some aspects of circuits were significant. The learning cycle group students over scored Traditional group students in understanding of seven IOs involved in circuits. These instructional objectives (IO) dealt with the physical aspect of the electric circuits such as the physical layout. The learning cycle by nature emphasizes hands-on activities whereas in traditional teaching we do not provide these experiences to our students. The results showed no significant difference between the learning cycle and Traditional group students’ understandings on the rest of the instructional objectives. These instructional objectives were related to electric current, energy and potential difference. The data indicated that learning cycle model did not help students in constructing a scientific mental model of electric current, energy and potential difference. Further research need to be conducted in identifying the shortcomings of the learning cycle model.

Results of this study support the findings of previous research which indicated that some concepts and aspects of the circuits play a more central role in students’ mental models. Consequently, instruction may affect some concepts and aspects of electric circuits to different degrees (Shipstone, 1985; Cosgrove, 1995; McDermott and van Zee, 1985). For example, it is indicated that after instruction, students can easily change their views about some of the aspects of circuits than about others (Shipstone, 1985). After students are provided a battery, a bulb and some wires and then are asked to light the bulb, they recognize that circuit elements are bipolar devices and circuits should be close if current is to circulate in it (Cosgrove, 1995). However, some aspects of students’ mental models of electricity are more resistant to change, such as those involving the concept of current. Some researchers point out that the problem is with the lack of clear differentiation between current and energy (Arnold and Millar, 1987), while others mentioned that problem is with lack of the robust models of understanding microscopic process leading to the macroscopic phenomena observed (Eylon and Ganiel, 1990). Thacker et al., (1999) compared the performance of different groups of university students in answering questionnaire designed to probe their understanding of the relationship between macroscopic phenomena of transients in a dc circuit and the microscopic processes that can explain these phenomena. One group studied from a traditional text, the second group used a recently developed text that emphasizes models of microscopic process. They found that most of the students from second group developed a better understanding of the transient phenomena studied. Clearly, this issue merits additional study.

In this study, the effect of learning cycle method was found to be statistically significant on teaching most of the concepts and the aspects involve in circuits but not on teaching conservation of current and explaining the microscopic aspects of current flow in a circuit. Recognizing risk inherent in interpretation of findings from this study, it is suggested that physics educators who teach the circuits unit for pre services science teacher students should consider the effectiveness of including inquiry based activities into their course, even if it is only possible to do so on a limited basis. Inquiry-based activities may be of particular value to the prospective science teacher. Efforts to increase future science teachers' attitudes toward using inquiry approaches are of particular importance in that they may result in effective science instruction, thus affecting large numbers of future science learners.

References

Arnold, M. & Miller, R. (1987). Being constructive: an alternative approach to the teaching of introductory ideas in electricity. International Journal of Science Education, 9 (3), pp. 553-563.

Beisenherz, P. & Dantonio, M. (1996). Using The Learning Cycle To Teach Physical Science: A Hands-On Approach For Middle Grades. Portsmouth, N.H, USA: Heinemann.

Borges, A. T. & Gilbert, J. K. (1999). Mental models of electricity. International Journal of Science Education, 21 (1), pp. 95-117.

Cavallo, A. M. L. (1996). Meaningful learning, reasoning ability, and students' understanding and problem solving in genetics. Journal of Research in Science Teaching, 33, pp. 625-656.

Chambers, S.K & Andre, T. (1997). Gender, prior knowledge, interest, and experience in electricity and conceptual change text manipulations in learning about direct current. Journal of Research in Science Teaching, 34, pp. 107-123.

Clement, J. (1982). Students' preconceptions in introductory mechanics. American Journal of Physics, 50, pp.66-71.

Closset, J. L. (1984). Sequential reasoning in electricity. In Research on Physics Education: proceedings of the first international workshop (La Londe les Maures, France: Editions du Centre National de la Recherche Scientifique), pp. 313-319.

Cosgrove, M. (1995). A study of science-in-the-making as students generate an analogy for electricity. International Journal of Science Education, 17 (3), pp. 295-310.

Duit, R., Jung, W., & Rhöneck, C. von. (1985). Aspects of Understanding Electricity. (Kiel, Germany: IPN)

Duit, R. & Rhöneck, C. von. (1998). Learning and understanding key concepts of electricity. . In Andree T., E. Leonard J., & Jorge B. (eds), Connecting Research in Physics Education with Teacher Education, (http://www.physics.ohiostate.edu/~jossem/ICPE/BOOKS.html).

Engelhardt, P. V. & Beichner, R. J. (2004). Students' understanding of direct current resistive electrical circuits. American Journal of Physics, 27, pp. 98-115.

Eylon, B. S. & Ganiel, (1990). Macro-Micro relationship: The missing link between electrostatics and electrodynamics in students' reasoning. International Journal of Science Education, 12 (), pp. 79-94.

Guzzetti, B., Taylor, T. E., Glass G. V., & Gamas, W. S. (1993). Promoting conceptual change in science: A comparative meta-analysis of instructional interventions from reading education and science education. Reading Research Quarterly, 28, pp. 117-159.

Heller, P. M. & Finley, F. N. (1992). Variable uses of alternative conceptions: A case study in current electricity. Journal of Research in Science Teaching, 29 (3), pp. 259-75.

Kärrqvist, C. (1985). The development of concepts by means of dialogues centered on experiments. In Duit, R., Jung, W., & Rhöneck, C. von. (eds), Aspects of Understanding Electricity. (Kiel, Germany: IPN), pp.215-226.

Lawson, A. E. (1995). Science Teaching and Development of Thinking. Belmont, CA, USA: Wadsworth.

Lawson, A. E., Alkhoury, S., Benford, R., & Falconer, K. A. (2000). What kinds of scientific concepts exist? Concept construction and intellectual development in college biology. Journal of Research in Science Teaching, 37, pp. 996-1018.

Lawson, A. E. (2001). Using the learning cycle to teach biology concepts and reasoning patterns. Journal of Biological Education, 35 (4), pp. 165-168.

Licht, P. (1991). Teaching electrical energy, voltage, and current: an alternative approach. Physics Education, 26 (5), pp. 272-277.

McDermott, L. C. & van Zee, E. H. (1985). Identifying and addressing student difficulties with electric circuits. In Duit, R., Jung, W., & Rhöneck, C. von. (eds), Aspects of Understanding Electricity. (Kiel, Germany: IPN), pp.39-48.

McDermott, L. C. (1991). Millikan lecture 1990: What we teach and what is learned-closing the gap. American Journal of Physics, 59, pp. 301-315.

Osborne, R. (1981). Children’s ideas about electric circuits. New Zealand Science Teacher, 29, pp. 12-19.

Osborne, R. (1983). Towards modifying children’s ideas about electric current. Research in Science and Technological Education, 1(1), pp.73-82.

Psillos, D. (1998). Teaching introductory electricity. In Andree T., E. Leonard J., & Jorge B. (eds), Connecting Research in Physics Education with Teacher Education, (http://www.physics.ohio-state.edu/~jossem/ICPE/BOOKS.html).

Rhöneck, C. von & Grob, K. (1987). Representation and problem-solving in basic electricity, predictors for successful learning. In J. D. Novak (eds), Proceedings of the Second International Seminar on Misconceptions and Educational Strategies in Science and Mathematics, Ithaca, NY: Misconceptions Trust.

Sebastia, J. M. (1993). Cognitive mediators and interpretation of electric circuits. Proceedings of the Third International Seminar on Misconceptions and Educational Strategies in Science and Mathematics, Ithaca, NY: Misconceptions Trust.

Serway, R. A. (1992). Physics for Scientists and Engineers. Philadelphia, PA, USA:Saunders College Publishing.

Shipstone, D. M. (1985). Electricity in simple dc circuits. In R. Driver, E. Guesne, and A. Tiberghein (eds), Children's Ideas in Science. (Milton Keynes, England: Open University Press), pp. 33-51.

Shipstone, D. M., Rhöneck, C. von, Jung, W., Kärrqvist, C., Dupin, J. J., Joshua, S., & Licht, P. (1988). A study of students' understanding of electricity in five European countries. International Journal of Science Education, 10 (3), pp. 303-316.

Thacker, B. A., Ganiel, U., & Boys, D. (1999). Macroscopic phenomena and microscopic process: student understanding of transients in direct current electric circuits. American Journal of Physics, 67 (7), pp. 25-31.

Wandersee, J. H., Mintzes, J. J., and Novak, J. D. (1994). Reserch on alternative conceptions in science. In D. L. Gabel (eds). Handbook of Research on Science Teaching and Learning (p. 542-558). New York, NY, USA: Macmillan.

Wang, T. & Andre, T. (1991). Conceptual change text versus traditional text and application questions versus no question in learning about electricity. Contemporary Educational Psychology, 16, pp. 103-116.

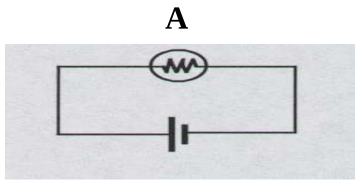
About the author…

Salih Ates is an Assistant Professor in the Department of Elementary Education, College of Education, at Izzet Baysal University, Golkoy-Bolu, Turkey.

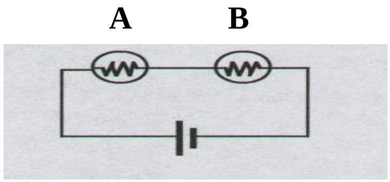
APPENDİX A

Learning Cycle Activity: How can you make Christmas tree lights-the old way?

Materials: Two D size cells, 3 bulbs (1.5 volt), 6 wires.
What to do: Using your materials, construct the Circuit-1.



Circuit 1.



Circuit 2.

What do you expect about the brightness of bulb A comparing to the brightness of bulb B if one more bulb is added to the circuit like the one in Circuit 2? (Predicting)

Using your materials, construct the Circuit-2. (Experimenting)

Compare the prediction and observation you made about the brightness of bulb A and B in Circuit-2.

In Circuit-2, what difference did you observe in the brightness between the two bulbs? (Observing)

Which circuit has the brightest bulb, Circuit-1 or 2? (Classifying). Why did this happen? (Inferring)

What conclusion can you give for this observation? (Inferring)

Using a crayon, draw a line on the Circuit-1 and 2 that shows where the current flows.

When you unscrewed one bulb in Circuit-2, why did the other bulb go out?

What do you predict will happen to the brightness of the bulbs as more bulbs are added to circuit-2? (Predicting)

Try it! (Experimenting). What did you observe?

Suppose you had a string of Christmas tree lights connected like Circuit-2.

What would happen to the bulbs when one of the bulbs burned out? (Predicting)

What is the name of a circuit that contains bulbs arranged like Circuit-2? (Operationally Defining)

What would happen in the appliances in your home were arranged like bulbs in Circuit-2? (Relating)