EXAMINING THE EFFECTIVENESS OF BLENDED LEARNING IN ADDRESSING LEARNER MISCONCEPTIONS ABOUT ELECTRICITY

by

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ABSTRACT

Learner misconceptions about electricity have been researched amongst grade school students, secondary school students, and post-secondary students. These misconceptions have been categorized into common models and have been found to be developed at an early age and to persist into adulthood. It has also been discovered that such misconceptions can persist regardless of the level of education achieved. These misconceptions can be corrected through planned interventions such as conceptual change texts, analogies, and real and simulated experimentation. This study examines the effectiveness of blended learning as an intervention to address learner misconceptions and bring about conceptual change. This involves combining previously researched conceptual change methods with a learning experience that includes both on-line and face-to-face instruction. The effectiveness of this type of intervention was explored using a quasi-experiment involving a cohort of students enrolled in the first year of a three year Engineering Technology program at College of the North Atlantic. The results of an analysis of the pretest and post-test yielded no significant differences between the experimental group and control groups. The results of this study may serve as the foundation for additional research in this area.

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CHAPTER 1: INTRODUCTION

This study investigated the effectiveness of blended learning in addressing learner misconceptions about electricity. To investigate this intervention, several classes of students enrolled in the same course at the Ridge Road campus of College of the North Atlantic were divided into two groups, a control group and an experimental group, and their course results were compared. The comparison is based on the mean scores of a pretest written by both groups of students and the mean scores on the course final exam. The groups consisted of four classes of students enrolled in the first year of a three year engineering technology program with participants being randomly sorted into individual groups at registration.

Motivation for the Study

The motivation for this study originated when it was observed that some students enrolled in the final year of study in electrical and electronics engineering technology programs at the Ridge Road campus of College of the North Atlantic appeared to hold certain misconceptions about electricity. At this point in their respective programs these students would have completed foundation courses in DC and AC electricity, circuit analysis, digital electronics, and analog electronics. In addition, these students would have completed a number of discipline-specific courses which would have required them to apply the concepts developed in their electrical and electronics courses. That student misconceptions about electricity would exist at the end of the program was a source of concern which led to a preliminary investigation of misconceptions about electricity.

It is important that the students enrolled in electrical and electronics engineering technology programs have a correct concept of electricity as this will have an impact on their course performance, employment, and critical and analytical thinking. Holding misconceptions about electricity could cause individuals to make mistakes that could impair system performance or even threaten personal safety.

The nature of the misconceptions about electricity varied from learner to learner. In one instance a student stated in a project report that for a series circuit constructed of light bulbs, similar to Figure 1 below, the bulb labeled A would glow brighter as it receives more current due to its proximity to the power supply.

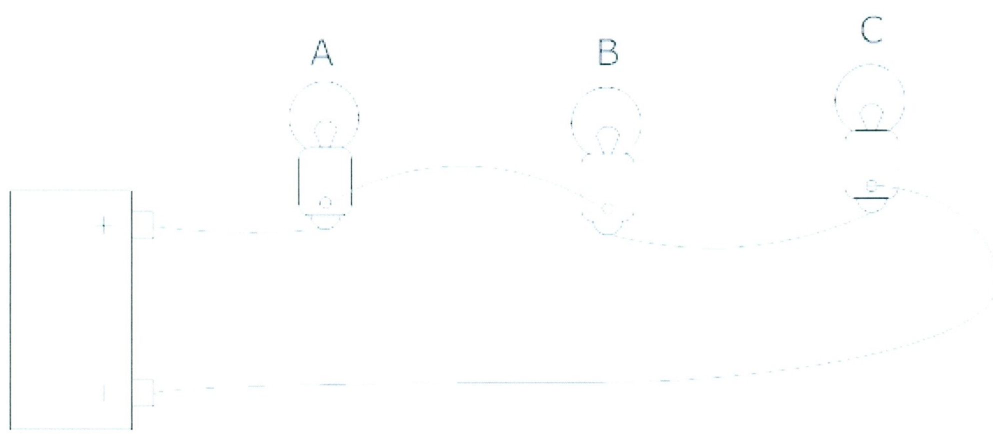

Figure 1. A simple series circuit constructed of three light bulbs, wire, and a battery. Current flows from the negative terminal providing each bulb with the same current and voltage.

That is, it would consume a greater amount of electricity causing it to glow brighter and consequently leave less electricity for the remaining bulbs in the series. This is incorrect on two counts. In the first instance all devices in the circuit would receive the same amount of current as the rate of flow of charge in the circuit is determined by the potential or voltage of the battery and the resistance offered by the three bulbs. As the bulbs are of equal value they would each experience the same voltage drop (i.e., require the same voltage in order to light). There would be no perceptible difference in the amount of light each would emit. Secondly, it was assumed by the student that current would flow from the positive terminal of the battery. This is the conventional current flow model which, while still used in academic settings, is inaccurate in a technology course, particularly one which focuses on electricity and electronics. The actual current flow in this circuit would be from the negative terminal to the positive terminal which, if the student's assumption were correct, would actually cause bulb C to glow brighter. This misconception has been reported by Shipstone (1984) as the "Lessening Current Model".

A separate instance with another student illustrated an inability for the student to convert theory into practice. In this case the student was looking for a flashlight or other light source in order to locate the end of a wire above a drop ceiling. A light source was not immediately available so the student was provided with wire, batteries, and light bulbs in order to construct a rudimentary flashlight. After several minutes the student returned and expressed frustration at not being provided with an adequate light source. Upon questioning regarding why the student had not simply constructed a flashlight from the materials provided he exclaimed that he did not know how to connect the parts together to fashion a light source. The student proceeded to draw the schematic diagram for a simple flashlight on the chalkboard but again stated he did not know how to arrange the parts into a workable circuit. The schematic for the circuit is depicted in Figure 2a.

When pressed to demonstrate how a flashlight could be constructed the student connected a wire to each terminal of the battery and then connected both wires to the base of the bulb as illustrated in Figure 2b. This arrangement was incorrect as the bulb is not a part of the circuit but rather is attached by a single point to the circuit. This misconception is consistent with the "Sink Model" reported by Shipstone (1984) and tested earlier by Fredette and Lochhead (1980).

As in the first case, this student's problem was somewhat disconcerting as foundation courses in electricity are designed to provide each student with two hours per week of laboratory practice during which they construct simple circuits using a schematic diagram. The intention of laboratory practice is to reinforce theoretical concepts as well as develop practical experience with electrical components and test instruments. The inability to convert a schematic diagram into a working circuit was a cause for concern and an indication that laboratory practice required further investigation as to how it might be used to improve learners' knowledge and skill development.

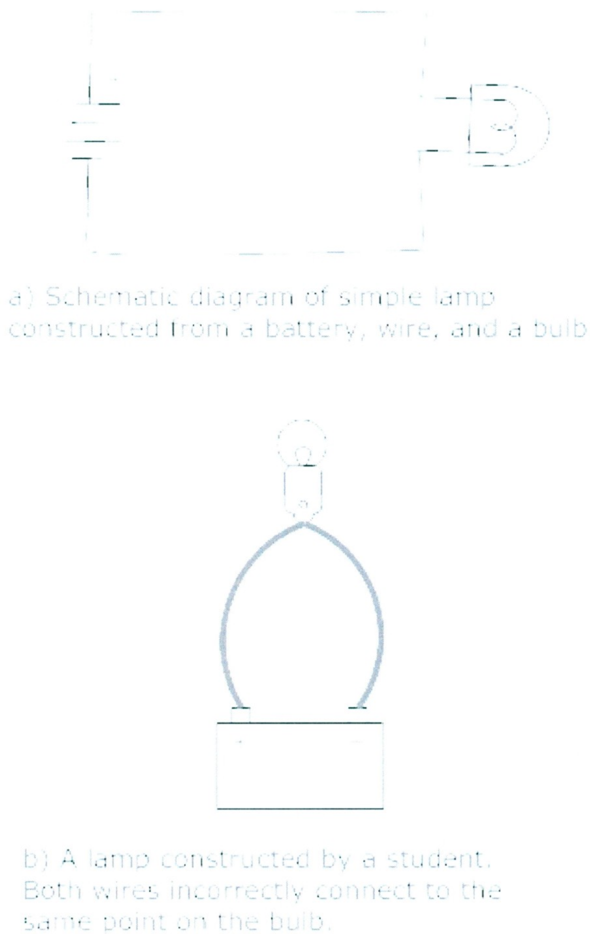

Figure 2. Schematic diagram (electrical drawing) of a simple lamp circuit consisting of a battery, wire, and a bulb; Representation of a lamp circuit incorrectly constructed by a student.

It must be noted that although misconceptions about electricity did not appear to be pervasive amongst the entire cohort of students enrolled in Electrical and Electronics Engineering Technology programs at College of the North Atlantic, that they existed at all was enough to cause concern. As an instructor who has in the past taught courses in

DC and AC electricity, it was alarming to observe that such a lack of student understanding of concepts would be present at such a late stage in their programs. As previously mentioned, the students in these programs complete courses in electrical fundamentals, circuit analysis, analog and digital electronics, as well as having two to three hours of laboratory practice per week, which should provide ample opportunity to develop a thorough understanding of electrical concepts.

Electrical Concepts

The concepts of electricity, which are at the center of the misconceptions held by some students, are fundamental and are often covered in intermediate and secondary school physics and science courses, including the Grade 9 curriculum in Newfoundland and Labrador schools (Department of Education, Government of Newfoundland and Labrador, 2011). These concepts involve three basic quantities: voltage, current, and resistance. Voltage is referred to as either electromotive force (EMF) or potential difference depending on the context in which it is being used. It is the source of energy that allows charge to flow in a closed circuit. As EMF, voltage provides the energy required for electrons to escape from the valence shell of atoms in electrically conductive elements such as copper, silver, and gold. As potential difference it is the energy required to maintain the flow of charge through circuit elements such as resistors.

Current is the flow of charge through a closed circuit. Charge is the opposing forces that exist within the subatomic particles called electrons and protons. Electrons are negatively charged whereas protons are positively charged. Atoms have an equal number of electrons and protons making them electrically neutral. When an electron is freed from an atom, the atom becomes positively charged due to its now surplus proton. This positive charge then attracts an electron that has been freed from a neighbouring atom. This movement of charged particles through the circuit is called current and is defined as the rate of charge flow. The amount of charge that can flow in a circuit is determined by the EMF applied to the circuit and the opposition to charge flow is called as resistance.

Resistance, as defined in the previous paragraph, is the opposition to charge flow or the opposition to current. Resistance in a conductor such as copper wire is a combination of the resistivity of the wire, i.e. how well the specific material conducts a charge, the cross-sectional area of the wire, typically expressed as American Wire Gauge (AWG), and the length of the wire. The resistance of the wire is directly proportional to the cross-sectional area of the wire and inversely proportional to the length of the wire as given by the formula $R = \frac{\rho \times l}{A}$. Thus as the cross-sectional area of the wire increases and its length decreases the resistance of the wire also decreases and vice versa. A decrease in the resistance of the wire allows for an increase in the amount of charge that can be carried through the wire and therefore an increase in the amount of current.

The relationship between voltage, current, and resistance is presented to the students as Ohm's Law and is represented mathematically as $I = \frac{E}{R}$ where I denotes the quantity of current as determined by the applied EMF, E, opposed by the resistance, R. That is to say, the amount of current available in a circuit is determined by the applied voltage and circuit resistance. An increase in voltage will result in a larger current whereas an increase in resistance will result in a smaller current. As both E and R

represent circuit values, that is the amount of voltage applied to the circuit and the amount of resistance in the circuit, then *I* refers to the total amount of current in the circuit. This means that at any point in the circuit if the current were measured it would be exactly the same. These concepts are fundamental to a proper understanding of electricity.

Conceptual Change

While the causes of student misconceptions about electricity are varied, it has been established that such misconceptions can persist and interfere with learning new concepts (Başer & Geban, 2007; Chambers & Andre, 1996). Addressing conceptual inconsistencies requires an external intervention in the form of conceptual change. Conceptual change occurs as a result of four conditions: dissatisfaction, intelligibility, plausibility, and fruitfulness (Posner, Strike, Hewson, & Gertzog, 1982). The first condition, dissatisfaction, occurs when the student becomes dissatisfied with his own conceptual understanding. Intelligibility occurs when a new concept is presented that is both clear and understandable to the student. Applying the new concept to solve an existing problem leads to plausibility. Finally, fruitfulness results from using the new concept to solve future problems. The effectiveness of any conceptual change activity is largely dependent on the motivation of the student. Students who are genuinely interested in understanding the phenomenon in question often respond positively to the conceptual change, whereas it is likely to have a negligible effect for students who lack motivation and see the conceptual change activity as an academic exercise (Chambers & Andre, 1996).

As has been noted by Posner et al. (1982), conceptual change begins to occur when the student becomes dissatisfied with their own concept of a topic. This process can be initiated by the instructor creating a conceptual conflict. To create the conceptual conflict the instructor can make use of techniques such as conceptual change texts, analogies, and questioning. Wang and Andre (1991) conducted conceptual change studies with post-secondary students enrolled in a psychology course. In their study Wang and Andre involved the group, consisting of male and female students, in a series of physics lessons on electricity. The students had no prior experience with college physics and limited experience with high school physics. Wang and Andre compared conceptual change effects of traditional text to conceptual change text, adjunct questions to no questions, and gender.

Chambers and Andre (1997) continued the work of Wang and Andre (1991) in their study of conceptual change. Chambers and Andre reproduced the conditions of the previous study and added the variables of prior knowledge, interest, and experience. Additionally, Chambers and Andre placed greater emphasis on examining the relationship between gender and the effectiveness of conceptual change efforts.

In a study by Başer and Geban (2007), the researchers examined the effectiveness of analogies in creating conceptual conflict in an effort to resolve existing misconceptions about static electricity. As with previous studies by Andre and Wang (1991) and Chambers and Andre (1997), this study made use of a conceptual change to present the study participants with the misconception of the topic under study and the evidence refuting the misconception or proving it as erroneous. In addition to the conceptual change text, the teacher used analogies that were constructed following the recommendations set forth by the Teaching With Analogies (TWA) model developed by Metsela and Glynn (1996). According to TWA, six operations must be taken into account for the conceptual change to be effective. These include "(1) introducing the concept, (2) cuing retrieval of the analogy, (3) identifying relevant features of target and analogy, (4) mapping similarities, (5) indicating where the analogy breaks down, and (6) drawing conclusions" (Başer & Geban, 2007, p. 248).

Blended Learning

The final element of this study to be considered is blended learning. This method of instruction combines traditional face-to-face lectures with learning technologies. Although there is some debate as to what this means, it is commonly accepted that the learning technology is some form of e-learning or online learning technology (Bliuc, Goodyear, & Ellis, 2007, p. 233). One advantage of online blended learning is the additional opportunity it provides for learners to interact with the instructor, the course content, and the other members of the class in different settings, namely in person during class time and online outside of class time (Vaughan, 2007, p. 81). The student interaction model is critical to effective learning and the opportunity for the learner to have this interaction according to his or her schedule without losing the interpersonal aspects of face-to-face learning is beneficial. This method of instruction makes it possible to move away from the traditional presentational style of instruction, where class time is spent downloading facts and information onto the student, and instead engage in discussion and debate (Vaughan, 2007, p. 83). This in itself is both an opportunity and a challenge in the field of technology education. The prevailing belief in engineering technology, for example, is that of the "sage on the stage" whereby the expert (i.e., the instructor) imparts wisdom on the novice (i.e., the student). This is limiting as it does not account for the abilities of self-directed learners who may become easily bored with this form of guided instruction, nor does it consider the student who may lack some of the essential prerequisite knowledge required to learn the particular concepts under study. The traditional lecture format frequently does not provide students with opportunities to consider alternatives or to become engaged with the curriculum in a meaningful way (Garrison & Vaughan, 2008). In these respects blended learning offers several advantages as students can take advantage of class time to delve deeper into alternative concepts or spend additional time on topics that are confusing or troublesome, thus promoting critical and analytical thinking. Blended learning also has the potential to change the students' attitudes towards learning, encourage self-directed learning and promote lifelong learning as they become aware of the alternatives to traditional face-to-face instruction. These are important considerations for learners in the engineering technology field as analytical thinking is a required skill and it is expected that these technologists will continue to educate themselves to remain current within their respective fields (Dearing & Daugherty, 2004; Felder & Brent, 2004).

In this study blended learning refers to the combination of classroom activities such as lecture and discussion and online learning activities. The online learning component utilized Desire2Learn as a means of extending classroom learning. Lecture times were used to introduce the students to new concepts with minimal note writing and more discussion and worksheet activities. The Desire2Learn platform was referenced frequently in class and students were directed to visit the site regularly to obtain notes, complete assignments, and take quizzes. The process of introducing the students to blended learning started with full in-class instruction with worksheets, assignments, and quizzes being completed or submitted during class time. As the students became familiar with the expectations of the course, these course activities moved to Desire2Learn where students completed three quizzes and three assignments. This allowed for more meaningful feedback, analysis of student performance, and repetition of learning activities related to specific topics, both online through D2L and in the classroom.

Purpose of Study

The purpose of this study was to examine the effectiveness of using blended learning in the delivery of an introductory course in electricity to initiate a conceptual change in students who held misconceptions about electricity. The initial concept for the study was derived from observations made by instructors during interaction with students in the final year of a three year engineering technology program. The initial research question that helped to shape this study pertained to the effectiveness of college instruction in preparing students for the study of electricity. A review of the literature revealed that studies of learner misconceptions about electricity have been ongoing for at least three decades and models of these misconceptions have been developed. With the understanding that learner misconceptions frequently existed and were often formed at an early age, the focus of this investigation shifted toward addressing these misconceptions. The results of a further review of the literature provided several reports of studies on conceptual change and the methods that had been employed to initiate conceptual change. In reviewing the literature it was noted that blended learning had not been employed as a conceptual change method. This provided an opportunity to further refine the research question to incorporate the use of a learning management system since these are increasingly combined with classroom instruction and are becoming more commonplace at College of the North Atlantic.

Several courses in the first year of the engineering technology programs offered at the Ridge Road campus of the College have taken advantage of the asynchronous nature of Internet instruction to augment synchronous classroom instruction with on-line assignments and additional course notes, videos, and problems with full solutions and workings provided. The use of web-based learning technologies has not been reported as detrimental to student achievement at the College as there is a growing population of students entering the College who have prior high school experience with "distributed learning" through the Centre for Distance Learning and Innovation (CDLI), an initiative of the Government of Newfoundland and Labrador implemented in 2000 (CDLI, 2009). This is common among students who have attended secondary school in rural areas as many courses such as technology and science may not be available locally and can only be completed by enrolling in courses delivered through CDLI. Although this distance education component, like classroom instruction, may have an impact on the creation of student misconceptions about electricity this study has not controlled for participation in a CDLI course as a variable as the goal of the study was not to identify the causes of misconceptions but rather to seek a means to address misconceptions. The causes of such misconceptions are beyond the scope of this study and would require an extensive review of many variables including prescribed curriculum and classroom instruction methods. The study also excluded prior experience with science courses, particularly physics, prior educational experiences either in a university or college setting, as well as prior experience with first year engineering technology courses. During classroom conversations with the participants in the experimental group, several students self-identified as having prior experience with the course, ET1100 Electrotechnology, post-secondary education at either Memorial University of Newfoundland or College of the North Atlantic, or CDLI. These observations were noted but not factored into the data analysis as they were external to the experimental design of the study and did not contribute to the methods being investigated in this study The result of the literature review has evolved the central question of this thesis – is blended learning effective in addressing learner misconceptions about electricity – into three separate research questions:

1) What are the learner conceptual understandings about electricity prior to entering engineering technology at College of the North Atlantic?;
2) Are the existing conceptions about electricity changed through instruction to be more consistent with accepted scientific conceptions?; and
3) Is blended learning effective in improving student success in an introductory course on electricity?

Although ET1100 (Electrotechnology) is offered at several campus locations of College of the North Atlantic, this study centered on the delivery of ET110 at the Ridge Road campus in St. John's. This group of students was chosen because the cohort of students entering programs at this campus is considerably larger and represents a broad demographic in terms of age, sex, etc. This provided the researcher with an opportunity to create sufficiently large treatment and control groups. The minimum class size for first year engineering technology courses, at the Ridge Road Campus, is 24 and ET1100 classes often contain two student groups, resulting in class sizes of 48 students or more.

It is interesting to note that Bernhard and Carstensen (2002) were similarly motivated to conduct their study of student conceptions of electrical circuit theory following a comment overheard by Bernhard. The comment in question, "What do you *really* do using these complex numbers [in alternating current problems]?" (Bernhard & Carstensen, 2002), was made by Bernhard's co-instructor who had recently earned a doctorate in physics. As posited by Bernhard and Carstensen (2002) this indicates that "a functional understanding is not typically an outcome of traditional instruction" (p. 1) and conceptual understanding problems, with respect to electricity, persist regardless of the education level attained by the individual. This supports the underlying theory being investigated in this study that intervention may be required to ensure correct understanding of electrical concepts.

Relevancy

The literature provides ample evidence that misconceptions about electricity are common amongst students and may often persist regardless of the prior education level attained by students. The literature also provides evidence that well designed interventions can enable conceptual changes amongst students and successfully correct long held misconceptions. The previous research conducted in this area has typically focused on secondary school and university students enrolled in introductory physics courses. There is little prior research of similar studies that have been conducted with college students enrolled in technical programs such as engineering technology. There is also little evidence that blended learning has been used as a contextual change agent against commonly held misconceptions.

This study provides an opportunity to explore conceptual change with students enrolled in a technical program at the college level. It also provides an opportunity to explore blended learning as a teaching and learning tool in this context as well as its effectiveness in addressing learner misconceptions.

Ethical Considerations

Preparation for the commencement of this study involved the approval of the Chair of Institutional Research at College of the North Atlantic and the College Campus Administrator at Ridge Road Campus This research was also approved by the Interdisciplinary Committee on Ethics in Human Research at Memorial University. The ethical considerations considered for the purposes of this study related primarily to the protection of students' privacy (see Appendix A). In light of this, several measures were incorporated to ensure that the protection of privacy was guaranteed. First, all collected materials, including participant consent forms and pretests, were stored in a locked filing cabinet in a secure office. Second, after the data was entered into a spreadsheet, all identifying information, such as names and student numbers, were replaced by a coded number. A separate spreadsheet stored the identifying information and matching codes. Third, all electronic data was stored on a locked computer workstation as an encrypted data file.

Summary

This chapter provided an overview of the research topic including the rationale and motivating factors for selecting a topic in this area of research. Also provided was a brief synopsis of the related literature to provide a framework for this study and to establish the need for this research. As well the purpose of this research was stated, its relevance, and the ethical considerations of the participants in the study. The next chapter will provide a review of the literature related to misconceptions about electricity, methods of conceptual change, and blended learning. Chapter 3 will describe the methodology used in this study and in Chapter 4 will present the results obtained from this study. Chapter 5 is a discussion of the implications of the findings of this study, and finally, Chapter 6 will discuss the limitations of this study and make recommendations for future research.

CHAPTER 2: REVIEW OF THE LITERATURE

The previous chapter identified the motivation for this study and its purpose. That chapter discussed misconceptions about electricity, conceptual change, and blended learning and their impact on this study. This chapter presents a summary of the research literature organized along these three themes. The first section of this chapter will present the literature on misconceptions about electricity. The next section will present the literature on conceptual change as a means of correcting misconceptions about electricity. The final section of this chapter will present the literature on blended learning.

Misconceptions About Electricity

A review of the research literature on misconceptions about electricity reveals that considerable study has been previously conducted on the topic over the past three decades. The majority of these studies have focused on students in primary education and students in physics courses. The few studies conducted at the university level have focused on engineering students enrolled in a first year physics course. These studies have been conducted in a number of countries including the United States, France, Greece, Ireland, and Turkey. It appears that limited research has been conducted in this area in Canada, at the college level, and in technical courses other than physics. The rest of this section will present the significant research which has been conducted in this area and which has informed the research presented in this thesis.

The pioneers in research involving misconceptions about electricity are Tiberghien and Delacôte (1976) whose observations in France formed the basis for the later studies by Fredette and Lochhead (1980), Shipstone (1984, 1988), and Engelhardt and Beichner (2004), amongst others. These studies examined misconceptions about electricity held by learners ranging from primary school through university. Tiberghien and Delacôte (1976) observed children aged 7 to 13 years in an attempt to develop categories of misconceptions to aid other researchers. In their research, Tiberghien and Delacôte (1976) presented children with the basic components of a simple electrical circuit, a battery, wire, and a lamp, and asked the children to construct a circuit to light the bulb. The children worked the components into a variety of arrangements in an attempt to light the lamp. Tiberghien and Delacôte (1976) noted that the children's physical arrangement of the components reflected a conceptual understanding, or rather a misconception, of how electricity must work. In addition to observing the children's attempt to construct the desired circuit, Tiberghien and Delacôte (1976) also interviewed each child, asking questions about how the circuit operated and the operation of electricity in the circuit. Based on this study, Tiberghien and Delacôte (1976) began to develop models of misconception such as the sink model, in which a single connection between the source and device is sufficient to power the device, and the clashing currents model, in which currents from the positive and negative terminals of the source meet at the device and clash, thus powering the device (Chambers & Andre, 1997). These models formed the basis by such as Fredette and Lochhead (1980) and Shipstone (1984, 1988) and have been expanded upon and further refined.

Fredette and Lochhead (1980) reproduced the Tiberghien and Delacôte (1976) primary school study in a university setting with engineering students enrolled in an introductory physics class. In that study Fredette and Lochhead (1980) noted that the approach to constructing the simple circuit consisting of a battery, wires, and a lamp were identical to the primary students of the Tiberghien and Delacôte (1976) study. In that study, the participants were presented with a collection of materials which included wires, a battery and a bulb, and asked the question "can you light the bulb" (Fredette & Lochhead, 1980). From the responses provided by the participants, Fredette and Lochhead (1980) identified two popular, yet incorrect wiring plans. These wiring plans formed the basis of a quiz which was administered to a larger group of freshmen engineering students. The results of this quiz and subsequent interviews with students who participated in the study indicated a conceptual understanding of electricity that was inconsistent with accepted theories. According to Fredette and Lochhead (1980), students entering an introductory physics course lacked an understanding of the "passing-through" requirement of an electric circuit, that is recognition that devices require an "in" and "out" so that current can pass through the device (p. 198). Fredette and Lochhead (1980) concluded that the misconception held by the students would require explicit and prolonged intervention to overcome.

Cohen, Eylon, and Ganiel (1983) conducted a study of student understanding of potential difference and current, two of the key elements in the study of basic electricity. In this study, the researchers posited that although potential difference is the primary concept in the study of electricity, students typically focus on current as the prime concept. In this study the students typically viewed a battery not as a source of potential difference but, rather, as a source of current. According to Cohen et al. (1983), this view limits students' understanding of potential difference including the fact that a potential difference can exist between two disconnected points in a circuit. Although students are able to mathematically solve a circuit analysis problem using algorithmic tools such as Kirchhoff's laws (i.e., total voltage and current is equal to the sum of voltages and currents in series and parallel circuits, respectively), they are limited in their ability to qualify a solution to problems which require a "physical insight" (Cohen et al., 1983, p. 407). This misconception of current as the primary component of a circuit limits the students' ability to understand how changes to the circuit, such as the addition or removal of a component, will affect the circuit overall. This was demonstrated by Cohen et al. (1983) in an experiment with a high school student using a parallel circuit containing a diode in one branch of the circuit. In this experiment a voltage source was connected across the parallel circuit such that the diode was reverse biased, thus preventing the flow of current through the branch containing the diode. In this arrangement the branch containing the diode would appear as an open circuit with all current flowing through the resistor in the parallel branch, forming a simple series circuit. In this arrangement all of the circuit current was drawn by the single series resistor. By reversing the polarity of the battery the diode was forward biased allowing the flow of current through both branches of the circuit, forming a parallel circuit. The resulting resistance of the circuit was smaller than that of the series arrangement which produced a larger current that that of the series circuit. The student participating in this experiment was unable to explain why the total current was larger with the source connected one way but smaller with the source connected in the opposite polarity. The student could state the mathematical facts of the circuit based on an understanding of simple principles but could not explain the discrepancy between the theoretical or calculated values and observed values.

In their study, Cohen et al. (1983) developed a survey instrument comprised largely of qualitative type questions. The questionnaire was administered to 145 high school students and 21 teachers. The majority of the student group consisted of Grade 12 students who had completed the equivalent of college level physics while the remainder of the student group was comprised of Grade 11 students with some prior experience with physics, particularly DC circuits, and Grade 9 students who demonstrated qualitative reasoning skills. All of those in the teacher group possessed a minimum of a B.Sc. in physics, taught high school physics at a senior level, and had participated in an in-service course for teaching electricity. The questionnaire was constructed with 10 multiple choice questions, predominantly qualitative in nature, and 4 open ended questions. The questions were designed to require an analysis circuit operation based on modifications posed in the question rather than seeking a numerical response. The structure of the questionnaire provided the researchers with insight into the respondents understanding of the functional relationship between the variables in the circuit. Overall performance on the questionnaire resulted in an average score of 38.2% for the student participants and 51.5% for the teacher participants. In examining the questionnaire results in detail, Cohen et al. (1983) noted that only 25% of the student respondents answered six or more of the questions correctly whereas 67% of the teachers were successful in answering six or more questions correctly. It was also noted that a third of the teachers were not successful in answering more than four questions correctly. Based on post-questionnaire interviews the researchers conducted with the students, it was determined that the students possessed misconceptions, and in some cases contradictory misconceptions, about electricity. It was apparent to the researchers that the students viewed, incorrectly, current, rather than potential difference as the central element of a circuit. The researchers concluded that this misconception was likely the result of how the students were initially introduced to electricity with current being emphasized as it was a more tangible concept than potential difference, that is the students could more easily visualize the concept of flow than difference of competing charges. Cohen et al. (1983) noted that an alternative approach to introducing students to electricity had been proposed, and they cautioned that this approach had the potential to introduce new misconceptions that could affect students in later studies of electricity. Based on the results from the teacher participants, Cohen et al. (1983) concluded that advanced study in physics did not correct misconceptions but, rather, intervention in the form of a Socratic dialog did challenge the participants to re-examine their own conceptions and change their concept of electricity. This approach to conceptual change is supported by other researchers and will be discussed in greater detail later in this chapter.

Research by Osborne (1981, 1983) and Shipstone (1984, 1988) has also contributed significantly to the understanding of learner misconceptions about electricity. Osborne organized common misconceptions into categories he referred to as the Unipolar Model (1981), Clashing Current (1983), Attenuation Model (1983), and Scientific View (1983). Shipstone further refined the categories of misconceptions into a hierarchy of mental models as depicted in Table 1.

Table 1

Hierarchy of Mental Models of Students Misconceptions about Electricity

Model 0.	(Sink model) A single wire connection between an EMF source and a device allows the device to work.
Model 1.	(Clashing Current model) Current leaves the battery at both terminals and is used up within the circuit elements.
Model 2.	(Lessening Current model) Current flows in one direction around the circuit, becoming gradually weakened as it goes so that later components receive less.
Model 3.	(Shared Current model) Current is shared between the components in a circuit. However, current is not conserved.
Model 4.	(Scientific model) Current flows around the circuit and the amount flowing in the source is the same as the amount flowing out.

Note. Adapted from "Student Misconceptions, Declarative Knowledge, Stimulus Conditions, and Problem Solving in Basic Electricity," by T. Andre and P. Ding, 1991, Contemporary Educational Psychology, 16, p. 304.

Osborne (1983), and later Shipstone (1984), noted that as children learn about electricity they typically develop the Unipolar (Osborne, 1981) or Sink model of misconception at an early age. As these children age and attain further education their conceptions of electricity improve, however, misconceptions can persist into adulthood. Shipstone (1984) noted that the concept of electricity held by the student tended to be a function of age, with students replacing simple concepts with more complex concepts as they age and receive additional education. Several researchers determined that only about 60% of students reached a concept of conservation of energy (Model 4) by age 17 (Closset, 1983; Shipstone, 1983). The report by Cohen et al. (1983) determined that the majority of study participants held the concept of lessening current (Model 2) and only a small number of the teachers involved in the study held the concept of conservation of energy (Model 4).

Recent studies have focused on understanding how students develop alternative concepts about electricity and how to determine when students hold these alternative mental models. Çepni and Keleş (2006) explored instruction in Turkey at various levels from primary school to university to determine the possible causes of student misconceptions about electricity. In this study it was noted that the education system in Turkey was modeled on that of the USA and Europe and that, in theory, science instruction was similar to that provided in those regions. It was further noted that although student-centered learning is recognized as the recommended approach to teaching, there is a disconnect on the practical side of instruction due to several factors including overcrowding in classes, a lack of experimental materials at many institutions, and a perception that laboratory practice wasted valuable instructional time and was unnecessary as questions related to practice were not present on entrance exams for secondary school and university admittance (Çepni & Keleş, 2006).

Çepni and Keleş (2006) conducted a study involving five groups of students at various ages with each group consisting of 50 students. Two of the groups were at the elementary level (Grades 5 and 7, respectively), one group was at the secondary level (Grade 9), and two groups were at the university level (first and fourth year students, respectively). Of the five groups, only the Grade 5 students had not received schooling in electricity. The researchers were interested in examining misconceptions prior to the introduction of formal education. Each participant was presented with the same activity which required them to draw a simple electric circuit consisting of a battery and two light bulbs. The participants were required to indicate the direction of current in the circuit and the polarity of the battery. Each participant was then asked a series of open-ended questions about the circuit. The responses to the questions and the drawing were analyzed and results were recorded as Understanding (Model D), Misunderstanding (Models, A, B, and C), No Understanding, and No Response. From their results Çepni and Keleş (2006) determined that the majority of the Grade 5 participants (58%) held a misunderstanding related to Model A (the Sink Model as described by Osborne (1983) and Shipstone (1984)). The second group, Grade 7, was split between Model C and Model B, 24% and 22% respectively, with 46% indicating no understanding. Models C and B correspond to Osborne's (1983) and Shipstone's (1984) Lessening Current Model and Clashing Current Model, respectively. Similar to the Grade 5 participants, none of the Grade 7 participants indicated any understanding of the concepts of electricity. The final three groups were split between Model C (Lessening Current) and Model D (Scientific View or Conservation of Energy) with the proportions moving toward understanding with advancing levels of education. In the Grade 9 group, 50% of the participants had the Model C misconception while 22% had an understanding (Model D). The results for the university level participants indicated 58% of the first year students and 72% of the fourth year students had an understanding of the concepts of electricity whereas 36% and 20% of the first and fourth year students, respectively, subscribed to the Lessening Current Model of electricity. Similar results were achieved in a study by Osborne and Freyberg (1985), which indicated that students at most age groups held the Lessening Current Model (Model C) as being correct while students aged 17-18 tended towards Conservation of Energy (Model D). This supports Osborne's (1983) and Shipstone's (1984) assertion that students' mental models of electrical concepts evolve from the simple to the complex as they age and their level of education increases and that particular concepts tend to be related to specific ages.

Whereas these early studies sought to define and categorize the various concepts of electricity students possessed, more recent research has focused on refining the nature of students' understanding of concepts and how these have developed. Engelhardt and Beichner (2004) developed an instrument called the *Determining and Interpreting Resistive Electric Circuits Concepts Test* (DIRECT) which was designed to evaluate student understanding of electrical concepts. The instrument, which consists of 29 multiple-choice items, has been tested for validity and reliability and has undergone two minor revisions (with the most recent version being DIRECT v1.2). The first version of DIRECT was administered to 1,135 students, 454 of whom were in high school with the remaining 681 enrolled in university. Version 1.1 was administered to 251 high school students and 441 university students. All of the participants in the version 1.0 study were in the United States, however, the participants in the version 1.1 study were located in three countries. These were: Canada (one high school and one university), Germany (one high school), and the United States (Engelhardt & Beichner, 2004).

The DIRECT v1.2 tests 11 objectives which represent four main themes related to electricity, physical aspects of DC electric circuits, energy, current, and voltage. The objectives and questions which test each theme are presented in Table 2 (Engelhardt & Beichner, 2004, p. 100).

Table 2

Objectives for DIRECTv1.2 and the corresponding questions per objective

Objective	Question Number
Physical Aspects of DC electric circuits (objectives 1 – 5)	
(1) Identify and explain a short circuit (more current follows the path of lesser resistance).	10, 19, 27
(2) Understand the functional two-endedness of circuit elements (elements have two possible points with which to make a connection).	9, 18
(3) Identify a complete circuit and understand how the necessity of a complete circuit for current to flow in the steady state (some charges are in motion but their velocities at any location are not changing and there is no accumulation of excess charge anywhere in the circuit).	
Objectives 1 – 3 combined	27
(4) Apply the concept of resistance (the hindrance to the flow of charges in a circuit) including the resistance is a property of the object (geometry of object and type of material with which the object is composed) and that in series the resistance increases as more elements are added and in parallel the resistance decreases as more elements are added.	5, 14, 23
(5) Interpret pictures and diagrams of a variety of circuits including series, parallel, and combinations of the two.	4, 13, 22
Circuit layout (objectives 1 – 3, 5)	
Energy (objectives 6 – 7)	
(6) Apply the concept of power (work done per unit time) to a variety of circuits.	2, 12
(7) Apply a conceptual understanding of conservation of energy including Kirchhoff's loop rule ($\Sigma V = 0$ around a closed loop) and the battery as a source of energy.	3, 21
Current (objectives 8 – 9)	
(8) Understand and apply conservation of current (conservation of charge in the steady state) to a variety of circuits.	8, 17
(9) Explain the microscopic aspects of current flow in a circuit through the use of electrostatic terms such as electric field, potential differences, and the interaction of forces on charged particles.	1, 11, 20
Potential difference (voltage) (objectives 10 – 11)	
(10) Apply the knowledge that the amount of current is influenced by the battery and resistance in the circuit.	7, 16, 25
(11) Apply the concept of potential difference to a variety of circuits including the knowledge that the potential difference in a series circuit sums while in a parallel circuit it remains the same.	6, 15, 24, 28, 29
Current and voltage (objectives 8 and 11)	26

Note. Adapted from "Students' Understanding of Direct Current Resistive Electrical Circuits," by P. V. Engelhardt and R. J. Beichner, 2004, *American Journal of Physics Teachers, 72*, p. 100.

Engelhardt and Beichner (2004) used the Kuder Richardson 20 (KR 20) test to measure the reliability of DIRECT. DIRECT v1.0 received a KR 20 score of 0.71 and DIRECT v1.2 received a KR 20 score of 0.70. Although both of these are below the desired range of 0.8 – 0.85 (Patock, 2004), the scores are sufficiently high to indicate a strong relationship between test items, thus suggesting these instruments are reliable. Content validity of DIRECT was assessed by submitting the instrument and objectives to a panel of experts who determined whether the questions accurately assessed a specific objective (Engelhardt & Beichner, 2004). In some cases, questions were rewritten when there was not strong agreement between the question and objectives. Engelhardt and Beichner (2004) also employed a factor analysis, using the Little Jiffy method, to evaluate the construct validity of the DIRECT, to determine which groups of items measured the same factor. The result of this analysis revealed that DIRECT v1.0 and v1.1 had eight factors and 11 factors, respectively. DIRECT has been used by several researchers including Afra, Osta, and Zoubeir (2007), Ates (2005), Başer (2006), and O'Dwyer (2009) and it was for this reason, as well as the extensive reliability and validity testing of DIRECT, that it was selected for use as the instrument for this study.

It has been determined that students hold alternative conceptions of scientific principles than is generally accepted and it has been posited that these persistent misconceptions interfere with a student's ability to effectively learn scientific concepts (Arnold & Millar, 1987; Eylon & Ganiel, 1990; McDermott & van Zee, 1985). Peşman and Eryilmaz (2010) sought to determine if there is a cultural aspect to these misconceptions and whether students in a different culture, in this case Turkey, might possess misconceptions that had not been previously identified. In another analysis, Borges and Gilbert (1999) examined the differences in the mental models possessed students and electrical practitioners in Brazil. Like Engelhardt and Beichner (2004), Peşman and Eryilmaz (2010) constructed a test instrument call the *Simple Electric Circuits Diagnostic Test* (SECDT) as a means of identifying whether student misconceptions were present and to what extent were they present. They were also interested in whether or not students in Turkey possessed misconceptions which were not reported in the research literature. Concerned that the standard tests are prone to (a) false positives, (b) students with misconceptions correctly answering questions, and (c) false negatives (i.e., students with correct concepts incorrectly answering questions, a phenomenon reported by Hestenes and Halloun (1995)), Peşman and Eryilmaz (2010) designed the SECDT as a three-tier test in an effort to mitigate this effect. The three-tiers established a student's knowledge of a concept by asking the student to (a) answer a multiple-choice question (First Tier), (b) select the reason for his or her choice of response (Second Tier), and then (c) select his or her level of confidence with their response (Peşman & Eryilmaz, 2010).

Borges and Gilbert (1999) worked with 15 to 17 year old secondary students and professionals in the electrical field (e.g., physics teachers, electrical engineers, electricians, and school-laboratory assistants) to identify the mental models that existed within this community. The participants in the study had various level of instruction in electricity ranging from none or very little to substantial. According to Borges and Gilbert (1999), these models, "electricity as flow, electricity as opposing currents, electricity as moving charges, and electricity as a field phenomenon" (p. 102), differ somewhat from the models previously presented by Osborne (1983) and Shipstone

(1984). Borges and Gilbert (1999) used a semi-structured interview process to pose a set of questions that all participants could answer regardless of prior education or experience. Follow-up interviews were conducted with some of the participants based on their responses to the questions. Borges and Gilbert (1999) determined that individuals possess different mental models of electricity and the model an individual uses to explain a concept is dependent on the specific situation, often failing to correctly illustrate the individual's true concept of electricity. These models change over time as the individual acquires new knowledge and develop a richer vocabulary of the subject (Borges & Gilbert, 1999).

The studies presented in this section explore student misconceptions or alternative concepts about electricity. These concepts have been categorized as a hierarchal model from simple misconceptions to complex understanding of scientific concepts. Using this understanding of student misconceptions, several instruments have been developed by researchers to determine which misconceptions a student might hold. These studies have been conducted at various educational levels including elementary and high school and university. These studies also examine student understanding of electricity within the context of physics instruction. There appears to be a gap in the literature with respect to researching student misconceptions in non-physics instruction, particularly in college courses for technical programs.

Conceptual Change

In addition to the research that has been conducted to identify misconceptions commonly held by students who are beginning science instruction, there has been also been significant effort made to help students correct such misconceptions through conceptual change teaching. The research in this area has explored several approaches to conceptual change teaching including the use of conceptual change texts (Başer & Geban, 2007; Chambers & Andre, 1997; Wang & Andre, 1991), teaching with analogies (Başer & Geban, 2007; Paatz, Ryder, Schwedes, & Scott, 2004), simulation (Zacharia, 2007), video recording (Constantinou & Papadouris, 2004), and confidence levels (Planinic, Boone, Krsnik, & Beilfuss, 2006).

Much of the research surrounding conceptual change teaching is centered on recognition that students have mental models or concepts of electricity that are inconsistent with accepted scientific concepts which may be the result of direct instruction or developed independently. Whatever the cause of these misconceptions amongst students, many researchers have sought to initiate a conceptual change in accordance with Piaget's theory of conceptual change. Piaget (1964, 2001) held that learning was a process of assimilation whereby the learner integrates what is to be learned into an existing mental structure. That is, a connection is made between the new content and an individual's existing understanding. Simply put, knowledge builds on existing knowledge. When the learner lacks this underlying knowledge structure, the new content cannot be easily assimilated and disequilibrium occurs. Piaget (2001) suggested that new structures must be created to assimilate the new content through a process he called accommodation. The general theory behind conceptual change involves the initiation of this disequilibrium state in order to challenge the learner to examine content and develop the new processes required for assimilation. Posner, Strike, Hewson, and Gertzog (1982) and Strike and Posner (1992) expanded on Piaget's theory, suggesting students must first become dissatisfied with their own concepts before a conceptual change can occur. This requires that the students must experience a situation that causes them to question their own understanding. The introduction of a new concept, to replace the existing misconception, must make sense to the student and appear to be plausible in order for it to be successfully assimilated. Finally, the new concept should appear to the student as a means of solving current and future problems related to the situation.

Wang and Andre (1991) explored the use of conceptual change texts to correct student misconceptions about electricity. Their research study involved a group of 139 male and female students enrolled in an introductory psychology course (Wang & Andre, 1991). The students had no prior experience with college physics and many had no experience with high school physics. Wang and Andre organized the participants into two groups with one group using a traditional text and the other using a conceptual change text which was the traditional text with conceptual change sections inserted. The conceptual change text presented students with simple circuit models, asked them whether the circuit would work, and then presented students with the commonly held misconceptions that applied to that circuit along with the evidence refuting the misconception. Wang and Andre (1991) further divided the two groups into two subgroups. One subgroup from each group was presented with additional questions that required the student to either "recognize a new example of a presented concept or apply a presented concept to a new situation" (Wang & Andre, 1991, p. 107). Based on the results achieved by the participants in the study, Wang and Andre (1991) noted several phenomena that partially supported their hypotheses. It was concluded that conceptual change texts and application questions, when applied without a pretest, resulted in a "superior acquisition of electricity concepts" (p. 112). It was also noted that neither the conceptual change text nor the application questions resulted in improved acquisition performance when a pretest was administered. Wang and Andre (1991) concluded that, although traditional texts promote the desired conceptual understanding amongst the majority of students, the students who used conceptual change texts developed more advanced mental models of electricity.

Following the study by Wang and Andre (1991), an interaction between gender and conceptual change was noted and it was posited that this may be the result of interest in the subject with females possibly being less motivated to learn about electricity because of lower levels of interest in the subject. In light of this, Chambers and Andre (1997) subsequently repeated the study conducted by Wang and Andre (1991) to determine whether gender was a factor in the success of a conceptual change activity. This study involved 206 male and female participants enrolled in an introductory psychology course. Chambers and Andre (1997) used the traditional and conceptual change texts and the adjunct questions that were developed for the Wang and Andre (1991) study. In addition to a pretest and a post-test, Chambers and Andre (1997) used a background questionnaire to determine the participants' gender, prior experience with electricity, interest in electricity, as well as their prior academic experience. The results of the study revealed that males had more previous experience (mean = 16.3, mean =

11.6, respectively; $F(1,203) = 76.58$; $p < .0001$; mean square error (MSE) = 14.769) and a greater level of interest (mean = 44.6, mean = 22.7, respectively; $F(1,203) = 127.81$; $p < .0001$; MSE = 185.522) than the females who participated in the study (Chambers & Andre, 1997). Chambers and Andre (1997) further noted significant findings on the post-test when comparing gender, text type, and question type using ANOVA, with males performing better than females (mean = 18.1, mean = 13.8, respectively; $F(1,197) = 16.80$; $p < .0001$), and exposure to conceptual texts resulting in better performance than traditional text (mean = 18.1, mean = 13.8, respectively; $F(1,197) = 16.12$; $p < .0001$). Based on a full analysis of the results attained in the study, Chambers and Andre (1997) concluded that gender had a significant effect on performance when the prior knowledge, experience, and interest were not considered in the analysis. With these covariates included in the analysis, gender had no significant effect on performance. Chambers and Andre (1997) therefore surmised that any differences in performance related to learning about electricity were likely the result of prior knowledge, experience, and interest rather than gender.

Another approach to initiating conceptual change that has received attention in research is the use of analogies. Başer and Geban (2007) explored analogies in a study involving 60 tenth-grade students in Turkey. This study divided participants into two groups for five weeks of instruction in a high school physics course. The control group received traditional instruction whereas the experimental group received instruction based on conceptual change. Both groups used activity sheets to support the learning activities. The control group's sheets were of the traditional quantitative design where the student was required to apply the concepts taught in class to solve the problem. The experimental group received activity sheets which featured conceptual change text and analogies which were developed in accordance with the Teaching with Analogies Model (TWA) (Başer & Gebon, 2007; Glynn, 2008). The control group received the activity sheet at the end of the session in which the concept was taught whereas the experimental group received the activity sheets 3 or 4 days in advance of the session in which the concepts were to be covered. Each analogy presented to the experimental group involved a situation with which the student was familiar, such as water being pumped through a chamber. Students were then asked to answer questions related to an analogy. The analogy was then extended to an electrical concept that demonstrated similar properties. The questions on the activity sheet were first answered by the student and then opened to classroom discussion. The conceptual change text on the activity sheet followed the same format as previous studies by Wang and Andre (1991) and Chambers and Andre (1997).

Başer and Geban (2007) invited all participants in the study to complete three pretests to measure pre-treatment learning about electricity, attitude towards physics, and science process skills. The results of the three pretests, the *Static Electricity Concepts Test* (SECT), the *Physics Attitude Scale* (PAS), and the *Science Process Skill Test* (SPST), revealed that there was no significant difference between the control and experimental groups. Beşer and Geban (2007) used an analysis of covariance (ANCOVA) to compare the effects of the instruction methods on student achievement using science process skills as the covariate. The post-test results of the analysis indicated a significant difference between the control and experimental groups whose test scores has means of 19.83 and 27.67, respectively. Başer and Geban concluded that conceptual change text and analogies are useful tools that can be employed to help students change their misconceptions about electricity, particularly when designed in recognition of the students' preexisting conceptions. However, the researchers also cautioned that additional learning activities and multiple analogies should be incorporated with the instructional strategies presented in their study.

In another study, Zacharia (2007) examined the effect of combining virtual or simulated experiments with real experiments. In this study 90 students enrolled in an introductory physics course were randomly assigned to one of two groups. The control group, consisting of 43 students, completed traditional or real experiments, whereas the experimental group, consisting of 45 students, completed both real experiments and virtual experiments. The real experiments were conducted in a college physics laboratory with participants using batteries and bulbs which served as resistive elements. The virtual experiments were conducted using a software application called "Virtual Labs: Light and Electricity" (Riverdeep Interactive Learning, 2003).

The study involved instruction for the electricity module in a physics course and included a pretest and post-test for the course. The module was delivered as three parts, Part A: Behavior of simple electric circuits, Part B: Measurements of current and resistance, and Part C: Measurement of voltage, with a pretest and post-test for each part. All participants were provided with the same instruction regardless of the group to which they were assigned. The students in the control group completed all laboratory activities using real experimentation whereas the students in the experimental group completed the laboratory activities for Parts A and B using real experimentation and completed Part C using virtual experimentation.

Zacharia (2007) analyzed the results of the course pre- and post-tests and the pre- and post-test of each part using an ANCOVA where the course pretest results were used as the covariate. The findings, from a comparison of virtual experimentation to real experimentation, revealed that students using virtual experimentation developed a greater conceptual understanding of electric circuits than students using real experimentation. This was determined from the pre- and post-test results for Part C where the students in the control group used real experimentation only and the students in the experimental group used virtual experimentation only. Although Zacharia (2007) expressed confidence that virtual experimentation, particularly when used in conjunction with real experimentation, promotes a deeper understanding of electrical concepts than instruction alone or real experimentation alone, he was unable to definitively state the specific aspects of virtual experimentation that could account for the differences in student understanding.

The literature on conceptual change indicates that conceptual change activities can be successful provided when the activities can initiate a sense of dissatisfaction in the student and provide new concepts that are intelligible and plausible. The literature identifies a number of different conceptual change methods that have been successful with students of different ages, genders, and levels of prior knowledge, experience, and interest. The research indicates that although many of the proven methods are beneficial, students achieve greater performance when multiple methods are applied. For example, when conceptual change texts are used in combination with each other and/or analogies, or when real experimentation is combined with virtual experimentation.

Blended Learning

A review of the literature reveals that blended learning is still somewhat of a novel concept, depending on the instructor, program, or institution in question. Much of the research has focused on online or computer based learning as well as computer enhanced learning through the use of simulations. This section will highlight some of the blended and online learning research that is relevant to this study.

Williams (2002) examined the concept of online learning and provided suggestions for improving course delivery at a distance through the use of web technologies. The points raised by Williams are equally valid for hybrid instruction that combines in-person class time with online resources and activities. Many of the suggestions Williams (2002) makes for the design of an online learning web page have become standard in learning management systems such as Desire2Learn. These include a course outline which uses hyperlinks to connect learners with course content, a course schedule for assignments, quizzes, and activities, communication tools such as e-mail and discussion forums, and drop boxes to facilitate electronic submission of assignments. Williams recommended that such a system use terms that students are familiar with such as café, library, and noticeboard to allow them to make connections between virtual space and physical space.

Williams (2002) views online learning as viable means of instruction and learning, provided the experience is designed from a pedagogical viewpoint that promotes an interactive and self-directed learning experience. It was also noted that challenges often exist in terms of student participation and access. Williams (2002) suggests that there is an inherent reluctance among some learners to participate in online discussions because of the permanence of responses and the possibility of appearing uninformed or inarticulate in front of their peers. Nixon and Salmon (1996) and Masterton (1999) state the importance of learner support during the early stages of implementation of online discussion to promote student participation and Graham, Scarborough, and Goodwin (1999) recommend that non-participants should be contacted outside of online course discussion forums to encourage their participation. It is further recommended by Nixon and Salmon (1996) that technical support be available for users experiencing access problems as these technical issues frequently can serve as deterrents to full participation in the online learning experience.

Vaughan (2007) provides a detailed overview of blended learning that identifies the characteristics of a blended learning course, outlines the benefits and challenges to the students, and discusses the perspective of both faculty and administration. Vaughan also reports that one of the criticisms of blended learning is that some courses merely bolt technology to an existing course, relying on technology as a means of teaching "a difficult concept or adding supplemental information" (p. 82). This is consistent with the findings of Bliuc, Goodyear, and Ellis (2007) who noted that much of the research on blended learning efforts were based on existing classroom-based courses with technology extensions. Bliuc et al. also identified the difficulties researchers have faced when trying to find a common definition for blended learning, such as Allen, Seaman, and Garrett (2007), Driscoll (2002), Garrison and Kanuka (2004), Graham (2006), Oliver and Trigwell (2005), and Singh (2003). Allen et al. (2007) define blended learning as a "course that blends online and face-to-face delivery" where a "substantial portion of the content is delivered online, typically uses online discussion, and typically has some face-to-face meetings" (p. 5). In this case Allen et al. (2007) suggest that a typical blended, or hybrid, course involves between 30% and 79% online content. Driscoll (2002) stated that blended learning consists of four concepts which offer different definitions based on who is using blended learning. These concepts include a combination of pedagogical approaches, a combination of instructional technology with face-to-face instructor led-training, a mix of instructional technology with actual job tasks, and a combination of web-based technology to accomplish an educational goal (Driscoll, 2002). Garrison and Kanuka (2004) differentiated between blended learning and other forms of learning by noting both the simplicity and complexity of blended learning models and modalities. According to Garrison and Kanuka (2004), blended learning is the successful integration of technology and face-to-face instruction to create a unique learning experience. As was noted by Vaughan (2007), it is not simply the addition of Internet technology to an existing learning experience. Oliver and Trigwell (2005) were critical of the term blended learning and pointed out that it often does not readily lend itself to a clear definition. They noted that research and writing in the area of blended learning can create confusion because the terms utilized are themselves often without clear definition. Considering these differing viewpoints and opinions, Bliuc et al. (2007) ultimately settled upon the following definition "blended learning describes learning activities that involve a systematic combination of co-present (face-to-face) interactions and technologically-mediated interactions between students, teachers and learning resources" (p. 234).

According to Vaughan (2007) a blended learning experience reduces classroom time and emphasizes active learning to produce "an educational environment that is conducive to student learning" (p. 82). Carr (2000) and Dziuban, Hartman, Juge, Moskal and Sorg (2005) found that students in blended learning courses tend to have lower rates of course withdrawal compared to that of other online courses. Carr (2000) suggested that, although "no national statistics exist yet about how many students complete distance programs or courses" (p. 1) , there is anecdotal evidence that the completion rates for distance education courses tend to be 10% to 20% lower than traditional classroom based courses at some institutions. Howell, Laws, and Lindsay (2004) confirmed Carr's assessment of the lack of data on distance education completion rates and suggested that inconsistencies in how course and program completion is calculated within and between institutions makes it difficult to make a fair comparison between traditional and distance education.

Vaughan (2007) identified time flexibility as one of the chief benefits of blended learning courses from the student perspective. Such flexibility provides students with the opportunity to work from home, which is sometimes viewed as preferable to working from a campus computer laboratory, and provides expanded options with respect to scheduling. This can allow for a better balance between college and other responsibilities such as work and family. It has also been noted that students in blended learning courses tend to perform better than students enrolled in traditional classroom based courses (Vaughan, 2007). This may be due, in part, to the increased writing requirements of blended learning courses which often rely on written exchanges through e-mail and discussion forums rather than verbal exchanges however it is equally likely that people attracted to online or blended learning courses are higher academic achievers.

Vaughan (2007) acknowledged that blended learning is not without challenges and pointed out that expectations, time management, responsibility for learning, and technology adeptness all impact successful learning outside of the traditional face-to-face classroom. He noted that a perception exists among some students that reduced class time equates to reduced coursework. This misconception combined with poor time management skills and a lack of understanding of the students role in active learning, can derail a student's blended learning experience. Technology problems, where they exist, typically pose challenges for students at the start of a course before they become accustomed to the new environment. In some cases, these problems may persist throughout the course, with potentially detrimental effects, in the areas of downloading files and accessing applications.

Faculty and administration have pointed to numerous benefits of blended learning approaches including enhanced interaction between the course instructor and students, increased student engagement, increased flexibility in the learning environment, continuous improvement, enhanced institutional reputation, and cost reduction (Vaughan, 2007). While these do not speak to the overall quality of a blended learning experience, these factors are likely to encourage post-secondary institutions to pursue this method of course delivery in the future.

Evidently, the benefits of blended learning are tempered by the challenges presented to both faculty and administration, in addition to the student body. From a faculty perspective, the time required to plan and implement a blended learning course, along with the professional development required to become familiar and comfortable with the technology involved, represent the biggest challenges to successful blended learning. Administrative challenges include the alignment of blended learning with institutional goals and objectives, faculty and staff resistance to organizational change, and a lack of "collaborative organizational structure and internal partnerships" (Vaughan, 2007, p. 91).

Summary

The research literature on misconceptions about electricity identifies common models of misconceptions that students hold about electricity. It shows that these misconceptions are developed at an early age, are independent of gender, language and culture, and often persist into adulthood. It has also been demonstrated that as students mature, their mental models evolve, however, misconceptions can persist regardless of educational attainment unless some form of intervention occurs.

A review of the literature on conceptual change methods illustrates that conceptual change is a process that starts when students are forced to confront their misconceptions and progresses through to developing a new mental model that is consistent with the accepted view. There are several techniques that been proven effective in initiating a conceptual change, including the use of analogies, simulation, and conceptual change texts.

The growing body of research in the area of blended learning provides an overview of the benefits and pitfalls of forms of learning that combine in-class instruction with online or web-based technologies to offer the student access to course materials, assessments, and synchronous or asynchronous discussions. It would be expected that a well-planned conceptual change activity using blended learning would be successful in changing preexisting learner misconceptions about electricity. This activity would include techniques that have been demonstrated to be successful including in-class activity sheets and group discussions, a conceptual change text and questions, and on-line self-assessment and discussion forums. In order to determine the effectiveness of such an activity a comparison would have to be made to another group of students taking the same course. The use of a pretest instrument would provide a means of both ensuring there was no variance between the two groups as well as identify the misconceptions held by the participants in the study.

The next chapter will present the methods used to conduct this study. This will include a discussion of the pretest and post-test, the intervention using the learning management system Desire2Learn as well as the conceptual change activities used throughout the course.

CHAPTER 3: METHODOLOGY

This chapter will discuss the methodology followed for the research discussed in this thesis. This discussion will start with a brief overview of the purpose of the study. The next section will describe who the participants in the study were and provide an explanation of the data collection process.

Purpose

The first chapter of this thesis introduced the common misconceptions learners often have about electricity. As has been discussed, these misconceptions are common amongst secondary school learners, post-secondary learners, and adults. It has also been demonstrated that these misconceptions can persist unless a conceptual change occurs to correct the misconception. Conceptual changes only occur when it is understood that a misconception exists and measures are taken to identify and correct the misconception. The introductory chapter discussed conceptual change and the four steps or processes required for conceptual change to occur. The steps or processes of conceptual change are dissatisfaction, intelligibility, plausibility, and fruitfulness (Zirbel, 2006).

The research study carried out for this thesis examined the effectiveness of using blended learning to instigate a conceptual change in learners studying an introductory course in electricity as part of an engineering technology program. The learners in this program were males and females with varied academic backgrounds, work experiences, and ranged in age from 18 to 40. Blended learning provided an opportunity for the learners to asynchronously review course material, take assessments, and receive instructor feedback. This blended learning environment differed from the traditional classroom environment in that learners were able to interact with other learners, the course instructor, and course materials asynchronously as with a distance education course. This blended learning model differs from distance education, web-based learning, and e-learning as it provides the learner with direct contact with course instructor and with other learners. Given that traditional classroom based courses have a finite amount of contact time and web-based courses lack the interpersonal contact experienced in the traditional classroom, it could be deduced that blended learning would provide the benefits of both methods while offering advantages over either. For this reason the researcher decided that blended learning may be an effective means of initiating a conceptual change in learners who have misconceptions about electricity. It was also believed that blended learning might be a comfortable learning environment for the learner as many learners entering College of the North Atlantic (CNA) programs have completed at least one online course previously through the Centre for Distance Learning and Innovation (CDLI).

Method

This section will present the study design and discuss the study participants including the composition of experimental and control groups. The following sections will discuss tools used for the intervention including Desire2Learn, the learning management system, the conceptual change text, the simulation software, and meaningful feedback.

Study Design

Given that the intent of this study was to determine the effectiveness of using blended learning to address student misconceptions about electricity, it followed that a comparison between two or more classes of students would be required to determine if a particular learning intervention would have any effect. As the classes of students could not be randomly assigned to either the treatment or control groups a true experimental approach could not be applied. Creswell (2008) and Cohen, Manion, and Morrison (2008) agree that a quasi-experimental approach is appropriate for this type of study which involved intact or non-randomized groups. Instead, the pretest-post-test non-equivalent group design option (Creswell, 2008) applies a pre-test to both the experimental group and the control group at the start of the study and a post-test at the conclusion of the study. With only the experimental group receiving the intervention, the pretest-post-test provides a basis of comparison between the two groups. In the case of this study, a standardized survey instrument served as the pre-test and the final examination for the course served as the post-test, as will be discussed later in this chapter. The data collected was analyzed using both a *t* test and analysis of variance as described in Gravetter and Wallnau (2008).

Study Setting

The Ridge Road campus of College of the North Atlantic typically has between 12 and 14 classes of students enrolled annually in the first year of its Engineering Technology programs. Each class consists of 24 students resulting in a cohort ranging in size from 288 to 336 students. In order to facilitate instruction for classes of this size, classes are often combined for the delivery of lectures. During this study I was the course instructor for a double class of 48 students enrolled in Electrotechnology 1100 (ET1100). In the semester during which this research was conducted there were, including myself, four instructors assigned to deliver instruction for ET1100 to 12 classes of students. Each instructor was assigned a double class of 48 students with two of the instructors also teaching a single class of 24 students and one instructor teaching two double classes. Prior to the start of classes each of these instructors was contacted with the details of the study and an invitation to participate. Only the instructor assigned two double classes and a single class responded and agreed to participate in the study.

The Instructional Coordinator for first year Engineering Technology is responsible for assigning instructors to courses and student groups. The decision of whether groups will be combined is determined by the number of available instructors and the workload assigned to each instructor. I was assigned a double class of students as I had no other instructional duties during the semester in which the study took place. As previously stated the instructor responsible for the control group was teaching ET1100 exclusively and as such was assigned three delivery groups, two consisting of a double grouping and one a single group. Typically the instructor assigned to a course is responsible for both the lecture and laboratory components of the course, unless this results in excessive contact time (in-class hours) for the instructor, in which case the laboratory component of the course may be assigned to an instructor with lower contact time. During the period in which this study occurred I had other non-instructional commitments and as such it was decided by my supervisor that the laboratory component of my course would be assigned to another instructor. This introduced a limitation to this study as having no exposure to the students in a practical setting made it challenging to link theoretical concepts to practical applications. It should also be noted that the maximum capacity of a laboratory group is 24 students and therefore, groups of students that had been combined for lectures were separated for laboratory activities thus separating students who worked on solving problems together during classroom activities. Although it is unlikely that either of these situations had a significant effect on this study, the limited student-student and student-instructor engagement did impede my ability to identify and address student misconceptions in small group settings.

Student assignment to specific classes occurred during the registration process with students being assigned to a class as their registration forms were processed. When the class size reached 24 a new class was started until there were 12 classes, at which point additional students, including general studies students who were not registered in a specific program, were randomly assigned to an existing class resulting in some classes have more than 24 students. Although the assignment of a student to a particular class was random based on when the student registered there were occasions when a student requested to be in a specific class, frequently citing transportation as the need to be in a group with another student. In some instances students requested a class change to either avoid a specific instructor or to have a specific instructor. These requests were only given consideration once all students had registered and only in cases where it was possible to move another student from the class in order to maintain class sizes. Although having self-selection did affect the randomization of students in the control and experimental groups its effect on the study was considered to be negligible.

When all of the class groups were finalized before instruction began, each group of students was met and invited to participate in the study. During this meeting the details of the study were presented, each student was provided with a consent form, and it was explained that each student had the right to decline to participate in the study. The students who volunteered to participate were asked to complete a short quiz called the *Determining and Interpreting Resistive Electric Circuit Concepts Test,* version 1.2 (DIRECT v1.2). This is a standardized survey instrument developed by Engelhardt and Beichner (2004) which had previously been tested for both validity and reliability. The initial design of this study called for the DIRECT v1.2 to be administered again at the conclusion of the study to serve as the post-test, however, this could not be accomplished due to a lack of availability of the students in the control group. Instead, students' final examination grades in ET1100 were used as a proxy.

Study Participants

ET1100 Electrotechnology is a compulsory course in the first year of all Engineering Technology programs offered at College of the North Atlantic. At the Ridge Road campus this course is delivered to between 288 and 336 students organized into 12 to 14 classes. In order to ensure consistency in course delivery, instructors follow a common set of course notes, use the same textbook, and administer the same laboratory activities, as well as a common final exam. Term assessments such as periodic assignments and quizzes are left to the discretion of individual course instructors. The final exam for ET1100 typically consists of 65 to 70 multiple choice questions and is often constructed from questions developed by each of the course instructors. As this course has been offered for the past 16 years, a significant bank of exam questions has been developed.

Experimental Group. For the purposes of this study, the lecture component of ET1100 was delivered to a class of 52 students. This class of students first met on September 8, 2011, at which time they were introduced to the researcher and the details of the proposed study. At this meeting each student was presented with a variety of materials including a consent form that introduced the study, a description of expectations of study participants, a list of possible risks and benefits of the study, a statement of confidentiality, and a list of contacts for both the researcher and the university supervisor. During the presentation, students were provided with a verbal explanation of the purpose of the study and what the researcher hoped to learn from the study. The rights of the participants were outlined in detail, including the right to refuse participation in the study and the right to withdraw from the study without prejudice. The importance of confidentiality was reiterated as was the measures that would be taken to ensure that the personal data of participants was secure at all times. Finally, the students were provided with the opportunity to ask any questions they had about the study.

Students were asked to indicate their willingness to participate in the study by signing a consent form. A copy of this form is available in Appendix A. Students who were not interested in participating in the research were asked to return their unsigned consent forms and were excused from the remainder of the session. Of the 46 students present during this session, 10 elected not to participate in the study. The remaining students signed a consent form and were then provided with a SCANTRON card and a copy of the DIRECT v1.2 survey instrument. As has previously been discussed the DIRECT v1.2 is a 29 item, multiple choice test designed to identify student misconceptions about electricity. A copy of this test (without the answer key) is provided in Appendix B.

Students who participated in the study were instructed to record their names and student numbers on the SCANTRON card provided. This was done to ensure there was a signed consent form for each SCANTRON form submitted. The students were instructed to record their responses on the SCANTRON form either by circling the letter of their response or shading the block containing the letter. The students were also instructed to not write on the test scripts as these would be reused with other groups. Thirty minutes were allocated for the test after which time the SCANTRON forms, consent forms, and test scripts were collected from the students.

Control Group. The control group consisted of three separate classes. Two of the classes had 50 students each and the third had 26 students. The instructor for these classes was contacted prior to the start of the semester to arrange times to meet with the students and write the pretest. It was important to meet with the students before instruction commenced in order to avoid skewing the pretest results.

The first two classes were met on September 9, 2011 and the third class on September 12, 2011. Of the students in these three classes, a total of 64 students agreed to participate in the study (participation of 23, 21, and 20 students in each of the three classes). The meeting with each of the three control groups followed the same process as the meeting with the experimental group. Students were provided with a consent form and an explanation of the purpose of the study. As with the experimental group, students were provided with an opportunity to ask questions about the study. Several students in each of the classes indicated that they did not wish to participate and were excused from the remainder of the class session. The students who agreed to participate in the study were asked to sign the consent form and the SCANTRON card. Each group was given the same instructions as the experimental group and provided 30 minutes in which to complete the test. The test scripts, SCANTRON cards, and signed consent forms were collected after 30 minutes. This was the final direct contact with the students in each of the control groups.

Desire2Learn

Over the course of the study, the Desire2Learn learning management system was used by the instructor to provide the experimental or intervention group with blended learning activities to support their in-class work. Desire2Learn (D2L) was utilized because it has been selected by the provincial Department of Education and all public educational institutions in Newfoundland and Labrador as the preferred learning management system. This provides a common experience to students whether they are taking distance courses through CDLI, Memorial University, or College of the North Atlantic.

D2L enables instructors to develop a media rich learning experience for students by combining text with learning objects, such as audio clips and videos, and hyperlinks. The D2L installation at College of the North Atlantic, depicted in Figure 3, provides instructors with content management tools, discussion tools, a chat tool, a dropbox, quiz facility, competencies, rubrics, and a glossary. The content management tool allows an instructor to import existing files, creating new web documents, or edit existing web documents. The default operation is WYSIWYG (What You See Is What You Get), however, an advanced HTML editor is available for those who wish to create their pages manually or perform edits that are not possible through the default interface. Course content in D2L can be arranged by module or topic, allowing the instructor to organize the course materials according to a lesson plan. Modules serve as higher order organizers whereas topics exist within modules, thus a number of related topics may be organized under a module. Restrictions can be set for each module so as to hide it from student view or to set a start date and/or end date for selected course content and/or activities. This is beneficial in keeping students from advancing too far into the course material or in keeping students on task as they are aware the course material has limited availability. Individual course modules can also have competencies associated with them. Properties set for the module will apply to all objects within the module. That is, if the module is hidden then all topics under that module will also be hidden. Likewise a competency associated with a module will also be associated with all of the topics beneath that module. Topics have similar controls, meaning that individual topics can have their own start and end dates independent of one another and can be hidden individuality. This allows for more refined control as the instructor may not wish for all topics within a module to be available at the same time. This feature is particularly useful as it can be used to focus attention on a particular topic by preventing a class of students from advancing through the course material before the instructor is prepared to move on or can assigned release conditions such as achieving a particular quiz score requiring students to demonstrate understanding of a topic before moving on to the next topic. This latter use can serve as an automated tutor by using randomized quizzes to assess student understanding and only allowing the student to progress when a particular score is achieved.

Figure 3. Instructor view of the Desire2Learn course page used for the study on the effectiveness of blended learning in addressing student misconceptions about electricity.

For the purposes of this study, course modules were created to correspond with the major topics of the course. Within each module several topics were created to address the specific learning objectives corresponding to each major topic. The instructional material contained within each topic was designed according to conceptual change practices established in the literature and were drawn from *Lessons in Electric Circuits Volume I DC*, 5th edition (Kuphaldt, 2011), part of a series of open-source texts on electricity and electronics. The conceptual change practices employed included a conceptual change text, simulation, and use of analogies. The course resources, lecture materials, notes, quizzes, and worksheets will be described in greater detail later in this chapter.

The D2L discussion tool allowed for the creation of discussion topics within the course and provided a forum for students to post questions and comments. The forum provided the global settings for all discussions that take place within the forum. As with the course content, discussions were organized by forum and topic. The instructor could decide whether to allow users to post anonymously, thus hiding their identity from the instructor and other class members, and whether messages needed to be approved prior to posting. This allowed the instructor to moderate the forum and ensure that inappropriate material was not posted. The forum also maintained user statistics which enabled the instructor to see how many, if any, messages were authored by each member of the class, and how many messages, if any, were read by each student. Discussion forums such as the one used in this study are useful for large groups where it is not possible to have a full class discussion during a regular class. Associating a lecture topic with a discussion topic provided students with the opportunity to pose questions about the topic, respond to questions from the instructor or fellow students, or make comments regarding the topic. This study made extensive use of discussion forums, with voluntary participation, and this aspect of student work will be discussed in greater detail later in this chapter.

The D2L quizzes tool is used to construct student assessments. Desire2Learn supports a variety of question types and offers the ability to create random quizzes. It is possible to set a number of restrictions on Desire2Learn quizzes, and commonly used restrictions include setting a start and end date and setting the duration for a quiz. Additionally it is possible to set a password for a quiz, which is useful when administering a quiz in a computer laboratory. The password feature provides an opportunity for the instructor or quiz administrator to give students last minute instructions without delaying the activation of a quiz. It is also possible to restrict access to a quiz by specifying a block of IP addresses, thus enabling the instructor to restrict access to the campus network. Finally the instructor may also limit access to a quiz to specific students. This is a useful feature for providing a make-up quiz or extra credit work. The quizzes tool was used extensively during this study and will be discussed in greater detail later in this chapter.

As has been previously discussed, the competencies feature is not fully implemented in the Desire2Learn installation at College of the North Atlantic. This is unfortunate as there appears to be significant potential in this tool for initiating conceptual change.

Test Results

The results of the study pretest were compiled using Microsoft Excel data worksheets. These data included the names of the study participants, pretest results, and a unique six digit identifier for each student. The starting digit in the student identifier indicated whether the study participant was in the experimental group or the control group. Experimental group participant numbers began with a 1 whereas the control group participant numbers began with a 2. The first student in the experimental group was number 1 (i.e., 100001) with participant numbers increasing sequentially. The control group numbers were similarly assigned with each group continuing from where the previous group ended. The data worksheets were then stored on an encrypted network directory which was only accessible by the researcher. The workbook containing the results of the pretest was the only location where the name of the participant is identified. This workbook served as a legend when entering data into SPSS to ensure the data entered corresponded with the correct individual.

Learning Intervention

The learning intervention for this study centered largely on the use of the learning management system Desire2Learn as a conceptual change tool. The blended learning experience consisted of worksheets, discussions, assignments, and quizzes utilizing in-class and online experiences. Lectures, questions, and conceptual change texts were also employed in an effort to help students correct any misconceptions they held prior to starting their study of electricity. The ET1100 course had three lecture hours and two laboratory hours allocated per week over a 15 week semester. Traditionally the lectures are delivered in three one-hour blocks, however, for the purpose of this study the class schedule was arranged to provide one two-hour lecture block and a single one-hour lecture block. This allowed for time to hold class discussions with students and give them ample to complete course worksheets.

The students in the experimental group were introduced to the blended learning experience during regular classroom lectures. The process followed a simple methodology: (a) introduce a concept in class, (b) engage students in class discussion on the concept, (c) reinforce concept with a worksheet, (d) assess practice with an assignment, and (e) assess students' understanding with a quiz. This process started at the beginning of the semester with 100% of the content delivery, practice, and assessment occurring during the regularly scheduled classes. It concluded with 60% of the classroom time being used to introduce and discuss concepts and 40% being used for assessments. Over the course of the semester the course evolved from being exclusively lecture driven, with quizzes being written during class time, to a more discussion focused seminar with students writing quizzes and completing assignments on-line. The following section documents the approach taken to providing a blended learning experience in the ET1100 course.

Overview of a Sample Lecture

This section will provide a brief overview of a typical lecture used in carrying out this study. This particular lecture occurred early in the course and is representative of how most of the classes were conducted. In this lecture, students in the class were asked to define electricity. This generated some discussion as individuals offered suggestions as to what they understood electricity to be. These definitions were recorded on the board and then addressed in turn identifying those that represented a correct conception of electricity and those that were misconceptions. This was followed by a brief lecture which introduced the basic quantities of current, voltage, and resistance as the primary elements of electricity. Each of these quantities was defined and the relationship between them was explained by way of an analogy. The analogy followed the process outlined in Başer and Geban (2007). The concept under study was first introduced to the students. For this analogy the concept was the relationship between the electrical quantities current, voltage, and resistance. To cue retrieval of the analogy, the students were asked to envision a car on a closed track, in this case the road running adjacent to the campus.

The relevant features of the electrical quantities were presented with voltage representing force, current representing rate, and resistance representing opposition or rate limiting. Similarly the relevant features of the car on the track were also presented with the car's engine representing force, the velocity of the car representing rate, and the road and tires representing opposition or rate limiting. A parallel was drawn between the electrical quantities and the car/track. The car's engine represented the potential of the car, also referred to as the Electromotive Force (EMF) or voltage. The track, specifically the friction between the tires and the track, represented the circuit resistance, and the velocity of the car, or the rate at which it travelled around the track represented the current. At this point the discussion centered on how the analogy could only approximate the electrical quantities. That is to say the analogy is only accurate up to a point after which it begins to break down. In this case the analogy does not account for parallel resistances, alternating current, or various sources of potential. Based on the discussion that followed, however, it was clear that the analogy did prove useful. When asked what effect should be expected if speed bumps were introduced at regularly spaced intervals along the track, several students answered that the velocity of the car would decrease. They then expanded upon this to conclude that a similar increase in circuit resistance would result in a smaller current.

Immediately following the discussion of electricity concepts introduced through the analogy were reinforced using an in-class worksheet. The worksheet was structured to emphasize the concepts that were under discussion during the lecture and cement the knowledge developed through the analogy. The students were encouraged to work together on the worksheet and collaborate on their answers. The questions presented on this worksheet are included in Appendix C. Thirty minutes of class time was allocated to work on the worksheet. During this time the instructor circulated throughout the class listening to the discussions that were occurring about the questions and occasionally either answer a question or posing a new question to help the student draw new conclusions. Time was allocated at the end of the class to review the responses to the questions on the worksheet. The students were then directed to visit the appropriate sections of the course web page to review the notes provided as well as compare their responses to the suggested responses posted on-line. A discussion forum was also created on this topic to allow the students to further engage with one another or pose questions for the instructor.

Conceptual Change Text

Conceptual change texts seek to improve upon traditional texts by directly addressing learner misconceptions and presenting concepts correctly. In this study, a conceptual change text was constructed as a companion to the assigned course text. *Lessons in Electric Circuits* is a six volume set of texts on electrical and electronics topics published under a Design Science License which allows for free copying, modification, and distribution. The first volume in the set is Direct Current (or DC) electricity, the topic of ET1100. A conceptual change text was constructed using this source material and was designed to address some of the related common misconceptions about electricity. Rather than copying the text in its entirety, only passages that specifically addressed the learning outcomes in the course outline were selected for use in the course. These sections were then prefaced with a brief discussion of the topic under study including the misconceptions commonly held about the topic. The selected text was then followed by a summary which reviewed the key points, reiterated the misconception and the correct conception, and posed questions about the topic. Unlike the questions in the course text which tended to be largely quantitative the questions in the conceptual change text were largely qualitative. This was intended to focus the students' energies toward developing an understanding of the concept rather than simply relying on formulas and equations. That is the expectation was that the students would develop an understanding of why or how something happened with respect to current, voltage, and resistance, rather than simply try to determine the quantity or magnitude of the event.

The conceptual change text was made available to the students through Desire2Learn. These course resources were arranged by module and topic and, in this manner directly mirrored the course outline. The conceptual change text was also made available as a Portable Document Format (PDF) file to easily allow students to print the material for review offline.

Simulation

In addition to conceptual change text an effort was made to introduce the study participants to simulation software. The particular software used during this study was a Java based applet called the *Circuit Simulator v1.5* pictured in Figure 4 below (Falstad, 2010). This simulation software allowed the users to experiment with several preconfigured circuits and/or create a new circuit using standard elements such as a voltage source and resistors. The applet provided an opportunity for students to visualize and interact with an electric circuit in a more meaningful way than simply performing calculations. The application, as depicted in Figure 4, allowed students to adjust the speed of the current as it travels around the circuit as well as to control the brightness of devices under power.

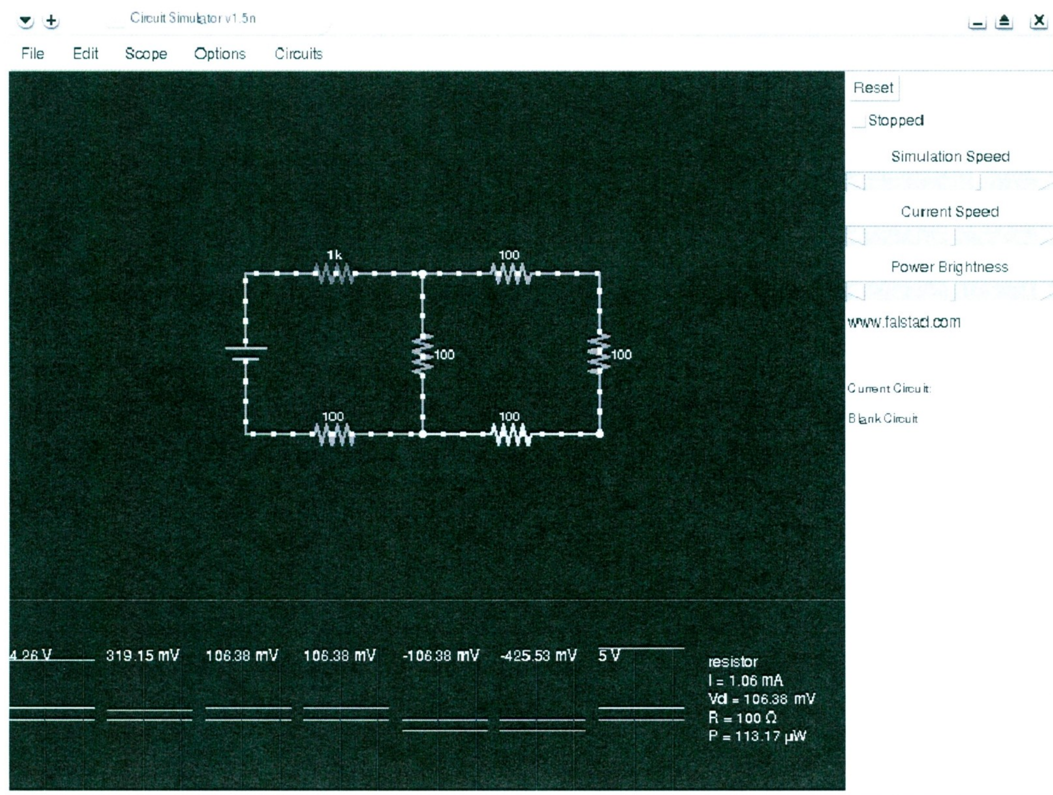

Figure 4. Circuit Simulator v1.5. A Java based applet for simulating electric circuits.

For example, the resistor in the top left branch of the circuit with a value of 1 kΩ is depicted as bright red whereas the other resistors are either grey or light blue. The bright red colour is significant as it indicates this resistor is dissipating more power than the other resistors in the circuit. Power can be calculated as a function of the voltage drop across the resistor and the current through the resistor. In this case the voltage drop across the 1 kΩ resistor is 4.26 V and the current is 4.26 mA resulting in a power of 18.11 mW. Although this may seem to be a rather small value it is considerably larger than the power dissipated by the other resistors. The three resistors making up the outer branch of the circuit each dissipate 113.17 uW whereas the resistor opposite the 1 kΩ and the resistor in the middle dissipate 1.81 mW and 1.02 mW respectively. As noted it is also possible to control the speed of the current as it passes through the circuit. This helps the student better conceptualize the concept of current as the movement of charge, or more specifically, the rate at which charge moves in a circuit.

A useful feature of the simulator is its display of the voltage drop or potential difference across each circuit element along the bottom of the screen along with the display of additional important information such as the magnitudes of current through the device, voltage drop across the device, resistance of the device, and power dissipated by the device in the lower left corner of the display. This information is provided for each element as the student moves the cursor over that element. The use of such simulation software in learning about electric circuits is beneficial as it provides students with an opportunity to visually confirm calculated values and to prepare for real experimentation in a laboratory setting. The ability to simulate or model a circuit prior to constructing one in the laboratory allowed students to focus on the operation of the circuit without having to be concerned with interference from test equipment, faulty components, as so forth. In this manner students were able to compare their calculated values to the actual values that would be expected in the laboratory. This was intended to help students build confidence in their ability to mathematically analyze an electric circuit as well as troubleshoot any problems that may arise in the laboratory as the student can differentiate between the values being obtained in the laboratory and the theoretical values both calculated and measured using the simulation. Situations such as these provide the opportunity to develop a better understanding of electric circuits as well as become familiar with common issues associated with the fabrication of electric circuits such as faulty components, shorts, and opens.

Students participating in the experimental group were introduced to the circuit simulation application during lectures and were encouraged to use this tool in conjunction with the worksheets provided in class. The D2L page for the course provided additional information about the simulation including a tutorial video demonstrating how to construct an electric circuit and take measurements. During class discussions students were asked if they had taken the opportunity to use the application. Several students stated they had experimented with the simulation tool but did not consider themselves computer users and, therefore, were reluctant to invest much of their study time into developing and testing the circuits. They preferred to rely on mathematical calculations instead. By the end of the course, only a small number of the participants (4) had spent time using the simulation tool. This was unfortunate and unintended as use of the simulation software may have helped alleviate frustration experienced by many students in the class during laboratory experimentation.

Meaningful Feedback

The traditional approach used by instructors to provide feedback to students enrolled in ET1100 has been to either simply supply the correct response to questions students answer incorrectly or to provide a complete worked-out solution to the problem in question. In some cases, which are hopefully limited, student responses to questions are simply graded as incorrect with little or no feedback provided. This type of feedback does little to help students develop an understanding of the topic under study and, unfortunately, often reinforces a focus on memorizing formulas and equations. In such cases, rather than developing reasoning or an analytical approach to problem solving, it appears that students may tend to resort to entering numbers into formulas in the hope of achieving the correct answer by chance.

The primary assessments for the offerings of ET1100 under examination in this study were assignments and quizzes. Assignments represented 5% of the total course evaluation whereas quizzes represented a total of 30%. The course material covered by the assignments formed the basis of the quizzes, and each quiz was administered one week after the assignment was graded and returned to students. The students were informed that despite the low value associated with assignments, these course assessments contributed to the grades for quizzes as each assignment constituted practice for the subsequent quiz. For each assignment/quiz pairing during the semester, there was one assignment question which was repeated on the quiz. These questions were altered slightly to make them different from the exact wording of questions on the assignment. This was done to minimize the effect of students who simply memorized the questions and answers from the assignments.

The nature of the feedback provided to students varied from assignment to assignment. The first assignment was paper-based and students were required to submit their solutions at the start of class. This assignment followed the traditional method of feedback for the course in that correct responses were marked with a check and a worked solution was provided for the questions that were answered incorrectly. The graded assignment and feedback was returned to the students within one week of submission. For the second assignment, the instructor feedback provided to students included only the worked solution for each question. This second assignment was administered via Desire2Learn using the quiz tool. Using this tool enabled the instructor to enter generic feedback that would then be provided for each question. The assignment was set up to use the Automatic Grade feature to mark each assignment but not enter the grade into the grade book. This allowed for each assignment to be reviewed individually and specific feedback to be provided for each question the student answered incorrectly. Some of the common student errors for this assignment included using the wrong unit for the quantity in question, the wrong form of the unit for the quantity, or expressing the magnitude of the quantity incorrectly. In many cases the units were entered as lowercase, which incorrectly indicated an alternating current or AC quantity. In other cases, the unit supplied for the quantity was the same as one of the units supplied in the question. For example, when provided with a voltage and current, the student responses were expressed with V or A (i.e., voltage and current respectively) rather than the symbol Ω indicating resistance. Finally, some responses failed to express the magnitude of the quantity and simply provided a number, both the exponential form and engineering prefix simultaneously, or the incorrect engineering prefix. Including both the exponential form and engineering prefix incorrectly identifies the magnitude of a quantity, for example a response of 4×10^{-3} mA would incorrectly indicate a current of 4×10^{-6} A or 4 μA if the correct response was 4 mA. For these responses, the feedback provided to students identified the error made in reporting the quantity and explained the impact of this error such as effect of reporting an incorrect magnitude when implementing an engineering design as a physical system. Responses that reported an incorrect value received feedback that provided the correct response and identified the error made in the calculation. By using Desire2Learn to administer and grade this assignment, it was possible to copy the feedback for each type of error and then paste it on the appropriate questions. This also allowed for grading assignments to start as soon as they were submitted and return the graded assignment as soon as it was ready. The class was notified that late assignments would not be accepted as that would create delays in returning the graded assignments and would therefore restrict the amount of time each student had to review the supplied feedback before writing the quiz.

For the third assignment the feedback given to students was expanded upon from previous assignments to include a description of why the problem was important before the instructor described how the problem could be solved correctly. The following example, taken from assignment three, illustrates the nature of the problems on this assignment and the feedback provided for each response.

Question

> A steel wire has 15 Ω of resistance at 20°C. Calculate its resistance at 75°C. (Enter the numeric value only) (Note: the temperature coefficient of steel is 0.003).

Feedback

> The resistance of a conductor will change with temperature. All values of resistivity provided are referenced to 20°C. It is a common task to determine the new resistance value when the temperature of the conductor increases or decreases.
>
> Solving this problem requires the use of the temperature coefficient, α, of the material, and the temperature difference, ΔT, to determine the new resistance.

The formula for this (derived from the resistivity formula; see page 75 of the text) is $R_2 = R_1(1 + \alpha\Delta T)$. Plugging in the appropriate values will yield a resistance of 17.5 Ω.

Assignments four and five utilized the same forms of feedback used for assignment three. As with assignments two and three, default feedback prepared for each question was provided to students regardless of the whether the question was answered correctly and specific instructor feedback was provided for each question answered incorrectly. This expanded feedback included references to the course text and the corresponding conceptual change text. This feedback directed students to the section that the question was drawn from. The intent of this feedback was to underscore the importance of understanding underlying concepts.

During the ET1100 course, students were required to complete five quizzes. These quizzes were scheduled to be completed after the students received graded assignments with accompanying feedback. The quizzes followed the format of the assignments and addressed the same content. Administration of the quizzes alternated between classroom delivery and online delivery via Desire2Learn. The use of Desire2Learn to administer quizzes allowed for an analysis of student performance on each test item making it easier to identify areas of difficulty and develop worksheets designed to address these specific issues.

The first quiz followed the traditional approach to quizzes in this type of course, that is the questions were computational in nature requiring the students to apply and manipulate equations to find a value or solve a problem. Given the nature of on-line quizzes, this quiz used short answer style questions requiring the student to submit only the response rather than show any workings. Additionally each question required the submission of several responses some of which were used in an equation to find another response. Each problem was constructed to be solvable within a reasonable period of time while also requiring the students to understand the nature of the problem and the process to be followed in order to solve the problem. The default feedback for this quiz was provided using the standard submission view of Desire2Learn which identifies incorrect responses and supplies the correct response. This was supplemented with individualized feedback as each quiz was graded. In order to reduce the amount of time required to manually grade each quiz and provide feedback for each incorrect response, the nature of the incorrect responses were first analyzed and then appropriate feedback statements were recorded for each question. These responses were similar to the feedback provided for the assignments and included comments on the use of symbols and rounding, explained the concept being tested, and referred to relevant sections of the text for additional study and review. In addition to the question feedback for incorrect responses each student received personalized feedback for their overall performance on the quiz and suggestions for review.

The second quiz added a new element to the nature of the questions being asked. In addition to computation-type questions, the students were asked to predict the effect on a circuit if an element were changed. The purpose of this question was to determine if the students correctly considered the circuit as a whole or incorrectly focused on the individual circuit elements. This quiz was administered during class time, however, it was also made available via Desire2Learn after the in-class delivery. This offering had an unlimited number of attempts and did not have an expiration date. Each question had a feedback component that provided, at a minimum, a worked solution for the question and in some cases a detailed discussion of the question and the theory being tested. The students were informed that it would not be possible to provide detailed feedback on each quiz and were encouraged to visit the quiz on Desire2Learn to obtain additional feedback. Ten students in the class elected to write the quiz in this form and two of the students had multiple attempts. Of the 10 students who took advantage of the online quiz 2 students obtained a score similar to the in-class quiz while another 2 of the students did not answer any questions. The feedback for the written quizzes consisted of worked solution to each problem with no elaboration on the theory or the correct approach to solving the problem. The experience with this quiz suggested that the majority of the students were not interested in feedback beyond the correct response to the question or the worked solution as there were 52 students in the class and only 10 of them elected to obtain the additional feedback provided via Desire2Learn. When the quizzes were returned in class and discussed with the students, the only feedback received concerned the question that required them to suggest the effect of the change to a circuit element. The general consensus was that the students preferred questions that required computation and not questions that challenged their understanding of the circuit. This reinforced the theory that students rely on memorizing formulas and procedures rather than understanding how circuit elements function and relate to one another.

Quiz three was delivered in-person during class time and was not accompanied by an online companion. This quiz was graded manually with only the correct response for each question provided as feedback. When graded and returned to the students the discussion centered on particular questions the students found challenging. The students were asked about which type of feedback they preferred. Some were content with simply knowing the correct response whereas others expressed a preference for the worked solution. Only a small number of students stated they preferred the detailed feedback provided via Desire2Learn.

Quiz four was administered via Desire2Learn. The feedback for each question provided a description of how the problem should be solved. Rather than the standard worked solution provided on the written quizzes, this feedback provided both the "how" and the "why" of the solution. The feedback provided to the students described how the problem should be approached, such as identifying all known quantities and defining the unknown quantities, why each step was necessary, and its effect on the overall solution. This feedback was intended to connect the solution to the circuit thus encouraging the students to see beyond equations and formulas and concentrate on the operation of the circuit.

The fifth and final quiz for the course was administered in-class and consisted of computation-type questions. The instructor feedback provided for this quiz consisted of the worked solution. This final quiz generated very little discussion when it was returned to students in the following class.

Throughout the semester during which this study was conducted, a number of students, missed quizzes for several reasons. In some cases students expressed concern that a low grade obtained on a quiz would negatively impact their overall course grade. Rather than defer grades to the final exam or drop the lowest one, the instructor provided students with an opportunity to write make-up quizzes via Desire2Learn. There were five make-up quizzes in total, each mirroring one of the term quizzes. The questions were drawn from a question bank in Desire2Learn that had been compiled over several semesters of delivering ET1100. Feedback was added to each question before activating the quizzes. The quizzes were all 45 minutes in duration and were scheduled to be active during the final two weeks of scheduled classes. Unlike the previous quizzes administered during the course the make-up quizzes graded automatically by Desire2Learn and lacked the personalized feedback provided on previous quizzes. As has been previously stated, the quiz component for the course was 30% averaged over the number of quizzes each student completed resulting in each of the five term quizzes being worth 6%. For students who elected to write all 10 quizzes, the value of each quiz dropped to 3% of the term grade. If a student missed a quiz and wrote the make-up quiz, the grade obtained on the make-up quiz served as the grade for the original term quiz. None of the students elected to write the first make-up quiz and of the remaining four quizzes, a total of 7, 6, 9, and 14 students elected to write quizzes 2, 3, 4, and 5, respectively. Although this was not a factor in the study it did suggest that students were either not concerned with their grade, due to low scores or missing quizzes during the semester, or they had a low level of interest in the specific course subject matter.

Post-Test

The original design of this study included the use of the DIRECT v1.2 as the post-test to simplify the analysis of the treatment effect and the comparison between groups. Following a discussion with the instructor for the control group, it was decided that there was insufficient time for the administration of a post-test due to unforeseen circumstance (e.g., a number of unanticipated campus closures during the semester). As all students enrolled in ET1100 were required to write a common final exam, it was decided that this final exam would be used as the post-test instead.

The common final exam consisted of 65 multiple choice questions testing each of the concepts covered in ET1100. The questions were selected from a test bank that had been developed over a number of years and were based on the common course notes which were available for purchase in the bookstore. The final exam for this course was developed by the instructor for the control group and was made available to all of the other course instructors before the final exam was scheduled to be administered. Students in the experimental group did not receive any specific instruction regarding the final exam. They were informed only that the exam would consist of up to 70 multiple choice questions.

Due to the differences between pretest and post-test it is not possible to make a direct comparison of the two results. The data from the post-test were next analyzed using analysis of variance to determine if a significant difference existed between the experimental group and any of the control groups. Inferences about the effectiveness of blended learning in addressing learner misconceptions about electricity are to be on the final analysis of these results.

The original design of this study included a student satisfaction survey to be administered to all participants. The intent of this survey was to qualitatively assess the effectiveness of instruction in ET1100, particularly the blended learning intervention. As was the case with the post-test, i.e. using the course final exam rather than the DIRECT instrument, there was insufficient opportunity to administer the survey due to external factors. It is recommended that a follow-up study be conducted to include both the DIRECT instrument as a post-test and a student satisfaction survey. This would allow for a more complete comparison of student understanding prior to and following the course instruction as well as measuring student motivation and satisfaction with the instructional model employed.

Summary

This chapter presented the methods followed to compare the experimental and control groups in the study prior to the start of the learning intervention along with the details of the intervention itself, including the use of Desire2Learn, a conceptual change text, simulation, and the provision of meaningful feedback. This was followed by a description of the post-test that was used to compare the experimental and control groups and to determine the effectiveness of the intervention.

The next chapter will present the data collected during this study along with the tools and methods used to analyze this data. The data was collected and organized using Microsoft Excel and all analyses were performed using IBM SPSS Statistics version 19. The data analysis included frequency distributions, *t* tests, and analysis of variance of the pretest and post-test results.

CHAPTER 4: RESULTS

This chapter will present the data that were collected for this study, the methods used to analyze this data, and the implications of these findings. The primary data collected were the pretest and post-test scores. The pretest scores were used to confirm that the experimental and control groups were comparable, whereas the post-test results were used to determine whether the treatment had any effect changing existing misconceptions about electricity.

Pretest Results

The DIRECT v1.2 instrument used for the study was developed around four major themes related to electricity. The first theme is Physical aspects of DC electric Circuits and consists of five objectives. The second theme is Energy and it consists of two objectives. Themes three and four are Current and Potential Difference, each with two objectives. The 29 questions on the DIRECT v1.2 test correspond to one of these 11 individual objectives. Table 3 organizes the themes and objectives for the DIRECT v1.2 and includes the mean score achieved for each objective by group. The following table, Table 4, organizes the post-test by objective and contains the results for the experimental group and the three groups that form the control group. These tables provide a side-by-side comparison of each group by test objective.

Table 3

Pretest questions arranged by objective with mean score by group

Objective	Ques.PreTest	EXP-Pre	CTL1-Pre	CTL2-Pre	CTL3-Pre
1.	10, 19, 27	0.31	0.49	0.43	0.47
2.	9, 18	0.42	0.50	0.48	0.50
3.	27	0.28	0.48	0.52	0.55
4.	5, 14, 23	0.15	0.10	0.20	0.27
5.	4, 13, 22	0.38	0.32	0.41	0.40
6.	2, 12	0.10	0.05	0.13	0.13
7.	3, 21	0.50	0.24	0.33	0.28
8.	8, 17	0.38	0.24	0.30	0.48
9.	1, 11, 20	0.09	0.14	0.13	0.12
10.	7, 16, 25	0.33	0.24	0.41	0.30
11.	6, 15, 24, 28, 29	0.24	0.21	0.23	0.27

Table 4

Post-test questions arranged by objective with mean score by group

Objective	Ques.PostTest	EXP-Post	CTL1-Post	CTL2-Post	CTL4-Post
1.	5, 7	0.32	0.43	0.37	0.45
2.	22, 23	0.50	0.55	0.41	0.45
3.	52, 63	0.51	0.40	0.43	0.65
4.	13, 24, 46	0.51	0.60	0.49	0.53
5.	53, 54, 55	0.27	0.22	0.26	0.35
6.	17, 27, 32	0.66	0.62	0.67	0.70
7.	28, 30	0.54	0.62	0.59	0.58
8.	15, 19	0.56	0.62	0.59	0.48
9.	57, 61	0.54	0.57	0.54	0.50
10.	21, 25	0.47	0.57	0.57	0.55
11.	26, 52, 62	0.40	0.51	0.46	0.67

The pretest was administered to four groups of students over a five day period. The first group to write the pretest was the experimental group on September 8, 2011. On September 9, 2011, two additional groups of students wrote the pretest and the final group wrote the pretest on September 12, 2011. The results of each pretest were entered into an Excel spreadsheet with correct responses being coded as 1 and incorrect responses coded as 0. The spreadsheet was then imported into IBM SPSS Statistics version 19 (SPSS) for analysis. The first analysis of the data was the frequency distribution of the results. The analysis of all 100 participants in the study revealed a mean score of 27.69 (SD = 8.193). This was followed by a comparison of means between groups: experimental group (M = 26.82, SD = 7.469), control group 1 (M= 24.14, SD = 8.376), control group 2 (M = 26.96, SD = 8.301), and control group 3 (M = 30.69, SD = 7.982). These data are presented in Table 5.

Table 5

Mean score by group on the pretest

MinGrp	Mean	N	Std. Deviation
1	26.82	36	7.469
2	24.14	21	8.376
3	29.69	23	8.301
4	30.69	20	7.982
Total	27.69	100	8.193

Two *t*-tests were carried out, first comparing the experimental group to the control group and then comparing the experimental group to each class in the control group. The *t*-test was performed to ensure that the groups were evenly matched prior to the start of the treatment. Levene's Test for Equality of Variances (Muijus, 2011) indicated there was no difference in variance between the two groups so equal variances are assumed. The *t* test indicated no significant difference between the two groups, $t(98) = -.797$, $p = .429$, $d = .169$. The results of this test are provided in Table 6.

Table 6

Individual samples t test between the Experimental group and Control group

	Levene's Test for Equality of Variance		t-test for Equality of Means			
Pretest Scores by Percentage	F	Sig.	t	df	Sig. (2-tailed)	Mean Difference
Equal variances assumed	.965	.328	-.795	98	.429	-1.359
Equal variance not assumed			-.827	81.427	.411	-1.359

The second *t* test compared the experimental group to each class individually. The results of this analysis were $t(55) = 1.250$, $p = .216$, $d = .338$, $t(57) = -1.376$, $p = .174$, $d = .363$, and $t(54) = -1.813$, $p = .075$, $d = .5$ for groups 1-2, 1-3, and 1-4, respectively. Table 7 contains these data in summarized form. As with the comparison between the two major groups, Experimental group and Control group, there was no apparent significant difference between the groups.

Table 7

Results of t test analysis between Experimental group and each class in Control group

Pretest Scores by Percentage		Levene's Test for Equality of Variances F	Sig.	t-test for Equality of Means t	df	Sig. (2-tailed)	Mean Difference
MinGrp 1-2	Equal variances assumed	.529	.470	1.250	55	.216	2.682
	Equal variances not assumed			1.213	38.167	.233	2.682
MinGrp 1-3	Equal variances assumed	.445	.507	-1.376	57	.174	-2.082
	Equal variances not assumed			-1.344	43.357	.186	-2.865
MinGrp 1-4	Equal variances assumed	.222	.639	-1.813	54	.075	-3.870
	Equal variances not assumed			-1.778	37.204	.084	-3.870

Post-Test Results

The second data set collected from the study participants were the results of the post-test. As with the pretest, these were entered into an Excel spreadsheet and coded 1 for correct responses and 0 for incorrect responses. The initial analysis of this data included an independent-measures *t*-test using SPSS and an analysis of variance (ANOVA), also using SPSS. As with the pretest results, these data were examined first with a comparison between the two groups and then the experimental group was compared to each individual class in the control group.

An initial examination of the frequency distribution of the post-test results yielded a mean of 56.31 and indicated that 15 of the original participants did not write the post-test. The initial *t*-test did not indicate any significant difference between the two groups, $t(85) = 1.083$, $p = .282$, $d = .248$. The results of this test are provided Table 8.

Table 8

Results of t test for Experimental and Control groups writing the post-test, equal variances assumed

	Levene's Test for Equality of Variances		t-Test for Equality of Means			
Post-test Score by Percentage	F	Sig.	t	df	Sig. (2-tailed)	Mean Difference
Equal variances assumed	.597	.442	-1.083	83	.282	-3.297
Equal variances not assumed			-1.099	62.242	.276	-3.297

The results of the comparison between minor groups, the experimental group, (M = 54.18, SD = 12.989), and each class group, (M = 53.88, SD = 11.458), (M = 61.44, SD = 14.599), and (M = 57.51, SD = 14.520), for minor groups 2, 3, and 4, respectively, also did not reveal any significant differences between the groups. The difference between groups 1 and 2 was $t(48) = .083$, $p = .934$, $d = .0245$, groups 1 and 3 was $t(46) = 1.791$, $p = .08$, $d = .527$, and groups 1 and 4 was $t(45) = .809$, $p = .423$, $d = .242$. The results of these tests have been aggregated in Table 9. Table 9 presents the mean score achieved by each group on each test objective, first the experimental and control groups and then each individual group.

Table 9

Comparison of mean and standard deviation by objective for major and minor groups

Objective	MajGrp1	MajGrp2	MinGrp1	MinGrp2	MinGrp3	MinGrp4
1	M = .7667, SD = .72793	M = .9636, SD = .74445	M = .7667, SD = .72793	M = .9000, SD = .78807	M = .9444, SD = .80237	M = 1.0588, SD = .65865
2	M = 1.2000, SD = .71438	M = 1.0909, SD = .64615	M = 1.2000, SD = .71438	M = 1.1500, SD = .58714	M = 1.0556, SD = .72536	M = 1.0588, SD = .65865
3	M = 1.2333, SD = .62606	M = 1.1455, SD = .77980	M = 1.2333, SD = .62606	M = .8500, SD = .81273	M = 1.1111, SD = .67640	M = 1.5294, SD = .71743
4	M = 1.8333, SD = .69893	M = 1.8909, SD = .68510	M = 1.8333, SD = .69893	M = 1.9000, SD = .64072	M = 1.8889, SD = .67640	M = 1.8824, SD = .78121
5	M = .9667, SD = .76489	M = .9636, SD = .83807	M = .9667, SD = .76489	M = .7000, SD = .73270	M = 1.0000, SD = .90749	M = 1.2353, SD = .83137
6	M = 2.3667, SD = .80872	M = 2.3091, SD = .87924	M = 2.3667, SD = .80872	M = 1.9500, SD = .88704	M = 2.5556, SD = .85559	M = 2.4706, SD = .79982
7	M = 1.3000, SD = .70221	M = 1.3818, SD = .56078	M = 1.3000, SD = .70221	M = 1.3000, SD = .57124	M = 1.5000, SD = 61835	M = 1.3529, SD = .49259
8	M = 1.3333, SD = .54667	M = 1.3091, SD = .66312	M = 1.3333, SD = .54667	M = 1.3000, SD = .73270	M = 1.5000, SD = .61835	M = 1.1176, SD = .60025
9	M = 1.3000, SD = .59596	M = 1.2545, SD = .69969	M = 1.3000, SD = .59596	M = 1.2000, SD = .76777	M = 1.3889, SD = .69780	M = 1.1765, SD = .63593
10	M = 1.1333, SD = .81931	M = 1.3091, SD = .71680	M = 1.1333, SD = .81931	M = 1.2000, SD = .69585	M = 1.4444, SD = .70479	M = 1.2941, SD = .77174
11	M = 1.4333, SD = .93526	M = 1.8909, SD = .85359	M = 1.4333, SD = .93526	M = 1.6000, SD = .88258	M = 1.7778, SD = .80845	M = 2.3529, SD = .70189

The next analysis examined the post-test questions grouped by objective. This involved combining the questions that tested each of the 11 objectives on the pretest. The analysis compared the major groups and then the experimental group to each of the class groups in the control group. The results of this analysis have been collated in Tables 10 and 11.

Table 10

Results of t test analysis between the two major groups and between the experimental group and each class group in the control group, equal variances assumed

Objective	MajGrp	MinGrp(1,2)	MinGrp(1,3)	MinGrp(1,4)
1	$t(83) = -1.175$, $p = .243$	$t(48) = -.614$, $p = .542$	$t(46) = -.788$, $p = .434$	$t(45) = -1.367$, $p = .178$
2	$t(83) = .717$, $p = .476$	$t(48) = .260$, $p = .796$	$t(46) = .674$, $p = .503$	$t(45) = .669$, $p = .507$
3	$t(83) = .531$, $p = .597$	$t(48) = 1.881$, $p = .066$	$t(46) = .635$, $p = .528$	$t(45) = -1.478$, $p = .146$
4	$t(83) = -.368$, $p = .714$	$t(48) = -.341$, $p = .734$	$t(46) = -.270$, $p = .789$	$t(45) =-.221$, $p = .826$
5	$t(83) = .016$, $p = .987$	$t(48) = 1.228$, $p = .225$	$t(46) = -.136$, $p = .892$	$t(45) = -1.121$, $p = .268$
6	$t(83) = .297$, $p = .768$	$t(48) = 1.717$, $p = .092$	$t(46) = -.767$, $p = .447$	$t(45) = -.425$, $p = .673$
7	$t(83) = -.587$, $p = .559$	$t(48) = .000$, $p = 1.000$	$t(46) = -.998$, $p = .324$	$t(45) = -.274$, $p = .785$
8	$t(83) = .171$, $p = .865$	$t(48) = .184$, $p = .855$	$t(46) = -.974$, $p = .335$	$t(45) = 1.255$, $p = .216$
9	$t(83) = .301$, $p = .764$	$t(48) = .518$, $p = .607$	$t(46) = -.469$, $p = .641$	$t(45) = .667$, $p = .508$
10	$t(83) = -1.027$, $p = .308$	$t(48) = -.299$, $p = .766$	$t(46) = -1.340$, $p = .187$	$t(45) = -.660$, $p = .513$
11	$t(83) = -2.283$, $p = .025$	$t(48) = -.631$, $p = .531$	$t(46) = -1.297$, $p = .201$	$t(45) = -3.524$, $p = .001$

As shown in Table 10 above, there were no significant differences between the major groups except for Objective 11, $t(83) = -2.283$, $p = .025$, $d = .512$. An examination of the minor group comparisons reveals this difference is attributable to the difference between the experimental group and minor group 4, $t(45) = -3.524$, $p = .001$, $d = 1.123$.

In order to determine whether the difference between the experimental group (minor group 1) and minor group 4 for objective 11 was significant, an ANOVA was performed according to the procedures outlined by Cunningham and Aldrich (2012) and Muijs (2011). This ANOVA compared the overall score on the post-test for each of the minor groups and then for the 11 objectives tested by the post-test. The results of the ANOVA are displayed in Table 11. The comparison of the four groups did not indicate any significant differences, $F(3, 81) = 1.413$, $p = .245$, $\eta^2 = .05$. As is the case with the t test, the analysis of variance identifies a significant difference with respect to Objective 11, $F(3, 81) = 4.389$, $p = .007$, $\eta^2 = .14$.

Table 11

Results of ANOVA comparing all four groups against objectives

		Sum of Squares	df	Mean Square	F	Sig.	η^2
PostObj1	Between Groups	.995	3	.332	.596	.619	0.02
	Within Groups	45.052	81	.556			
	Total	46.047	84				
PostObj2	Between Groups	.341	3	.114	.247	.863	0.01
	Within Groups	37.236	81	.460			
	Total	37.576	84				
PostObj3	Between Groups	4.423	3	1.474	2.991	.036	0.10
	Within Groups	39.930	81	.493			
	Total	44.353	84				
PostObj4	Between Groups	.067	3	.022	.046	.987	0.00
	Within Groups	39.509	81	.488			
	Total	39.576	84				

Table 11 (continued)

Results of ANOVA comparing all four groups against objectives

		Sum of Squares	df	Mean Square	F	Sig.	η^2
PostObj5	Between Groups	2.669	3	.890	1.380	.255	0.05
	Within Groups	52.225	81	.645			
	Total	54.894	84				
PostObj6	Between Groups	4.180	3	1.393	1.994	.121	0.07
	Within Groups	56.596	81	.699			
	Total	60.776	84				
PostObj7	Between Groups	.529	3	.176	.463	.709	0.02
	Within Groups	30.882	81	.381			
	Total	31.412	84				
PostObj8	Between Groups	1.292	3	.431	1.121	.346	0.04
	Within Groups	31.131	81	.384			
	Total	32.424	84				
PostObj9	Between Groups	.528	3	.176	.393	.758	0.01
	Within Groups	36.248	81	.448			
	Total	36.776	84				
PostObj10	Between Groups	1.171	3	.390	.678	.568	0.02
	Within Groups	46.641	81	.576			
	Total	47.812	84				
PostObj11	Between Groups	9.616	3	3.205	4.389	.007	0.14
	Within Groups	59.160	81	.730			
	Total	68.776	84				

A post-hoc test was conducted using to determine if the groups were significantly different with regard to Objective 11. The tests used were Tukey's HSD and Scheffé's test. The results of these tests are presented in Table 12. The post hoc comparisons using the Tukey HSD test indicated that the mean score for group 4 (class group 3 of the Control Group) (M = 2.3529, SD = .70189) was significantly different from group 1 (Experimental Group) (M = 1.4333, SD = .93526), and group 2 (class group 1 of the Control Group) (M = 1.6000, SD = .88258). There did not appear to be a significant difference between group 3 (class group 2 of the Control Group) and any of the other groups.

The post hoc comparisons using Scheffé's test indicated that the mean score for group 4 (M = 2.3529, SD = .70189) significantly differed from group 1 (M = 1.4333, SD = .93526). There did not appear to be a significant difference between the other groups.

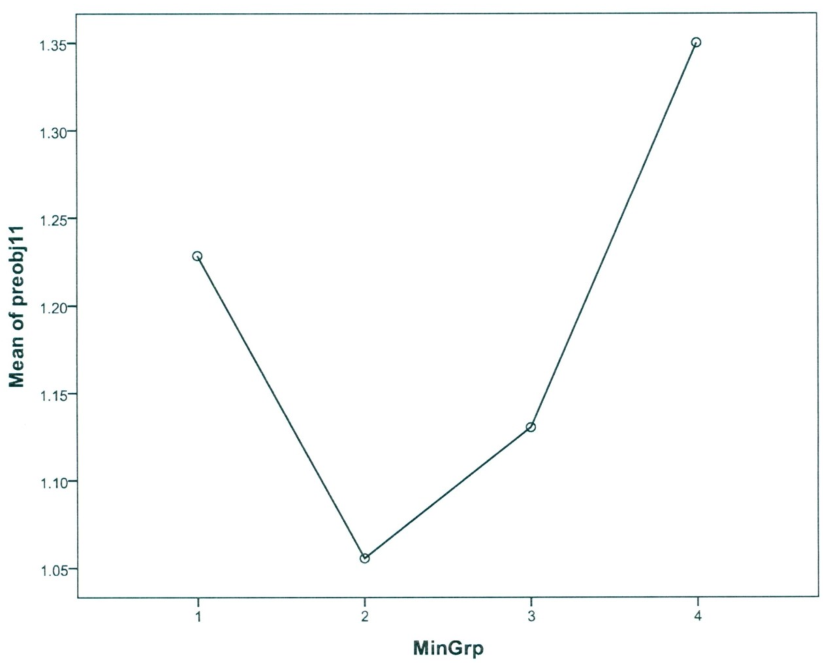

Figure 5. Mean plot of pretest results for Objective 11 for all four groups

Table 12

Post-hoc tests for Objective 11 using Tukey's HSD and Scheffé

	(I) MinGrp	(J) MinGrp	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	Upper Bound
Tukey HSD	1	2	-.16667	.24671	.906	-.8138	.4805
		3	-.34444	.25480	.533	-1.0128	.3239
		4	-.91961*	.25944	.004	-1.6002	-.2391
	2	1	.16667	.24671	.906	-.4805	.8138
		3	-.17778	.27766	.919	-.9061	.5506
		4	-.75294*	.28192	.044	-1.4925	-.0134
	3	1	.34444	.25480	.533	-.3239	1.0128
		2	.17778	.27766	.919	-.5506	.9061
		4	-.57516	.28903	.200	-1.3333	.1830
	4	1	.91961*	.25944	.004	.2391	1.6002
		2	.75294*	.28192	.044	.0134	1.4925
		3	.57516	.28903	.200	-.1830	1.3333
Scheffe	1	2	-.16667	.24671	.928	-.8711	.5377
		3	-.34444	.25480	.611	-1.0719	.3830
		4	-.91961*	.25944	.008	-1.6604	-.1789
	2	1	.16667	.24671	.928	-.5377	.8711
		3	-.17778	.27766	.938	-.9705	.6150
		4	-.75294	.28192	.076	-1.5579	.0520
	3	1	.34444	.25480	.611	-.3830	1.0719
		2	.17778	.27766	.938	-.6150	.9705
		4	-.57516	.28903	.274	-1.4004	.2501
	4	1	.91961*	.25944	.008	.1789	1.6604
		2	.75294	.28192	.076	-.0520	1.5579
		3	.57516	.28903	.274	-.2501	1.4004

Figures 5 and 6 are plots of the means achieved on Objective 11 from the pretest and post-test, respectively. Although the analysis of the results for the pretest score and the individual objective scores did not indicate a significant difference between group 4 and the other groups, the figure clearly indicate that group 4 did achieve higher results on Objective 11 than the other three groups in the study for both the pretest (non-significant) and the post-test (significant).

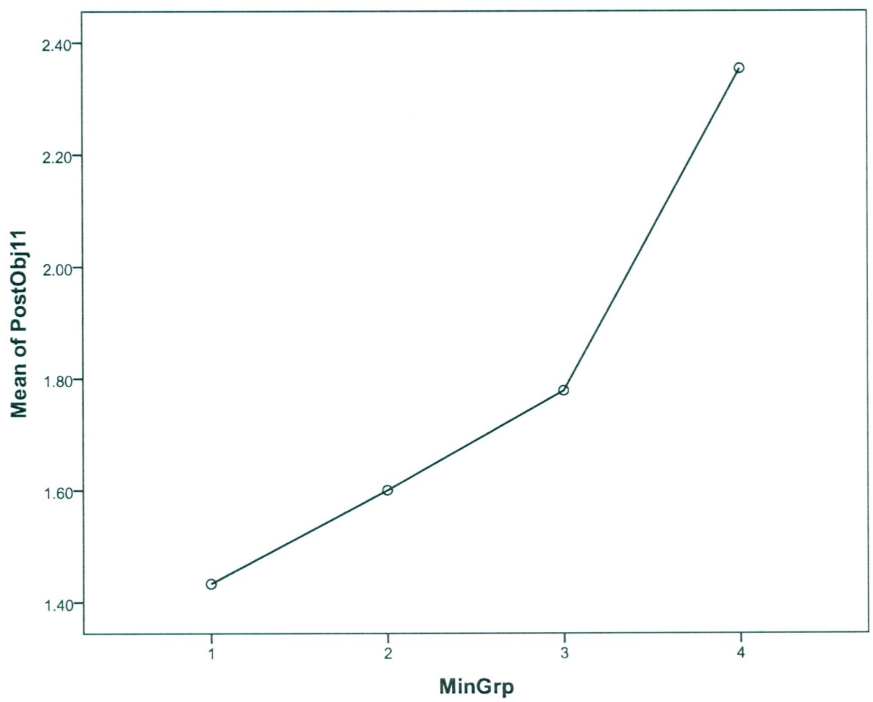

Figure 6. Mean plot of post-test results for Objective 11 for all four groups

Summary

In this chapter the data collected during this study was presented as well as the methods that were employed to analyze this data and identify any significant effects of the intervention employed in this study. The IBM SPSS Statistics version 19 software package was used to perform the analysis of the data. The analysis included descriptive statistics, a frequency distribution of pretest and post-test results, and a comparison of means using an individual samples *t*-test and ANOVA. Both the pretest and post-test analysis included comparisons between the major groups (experimental group and control group) and between the minor groups (individual classes of students). The pretest results revealed that all students participating in the study were evenly matched with no significant differences between any of the classes. Similarly the post-test analysis identified a difference between the experimental group and one of the classes in the control group for one of the objectives on the post-test. Post-hoc comparisons including Tukey's HSD and Sheffé's tests identified the difference existed between the experimental group and class 3 (i.e., minor group 4). The next chapter will discuss of these findings and their implications with respect to the effectiveness of using blended learning to address learner misconceptions about electricity.

CHAPTER 5: SUMMARY AND DISCUSSION

In the previous chapter the results obtained from an analysis of the data collected as part of this study were presented. The analysis of the pretest data using a *t*-test confirmed that the experimental group and the control group were evenly matched with no variation between the two groups at the outset of this study. A further analysis between the experimental group and each of the three classes in the control group also confirmed this finding suggesting that any differences detected in the post-test analysis could result from the intervention employed with the experimental group.

Post-test Analysis

A detailed analysis of the post-test data was performed first using a *t*-test followed by an analysis of variance. The *t*-test comparing the experimental group to the control group did not find any significant variation between the two groups. A second *t*-test, this one comparing the experimental group to each of the classes in the control group, also revealed no significant difference between the groups. The final set of *t*-tests compared objective performance (i.e., how well each group performed on individual test objectives, between the groups). In the first objective *t*-test, the two major groups were compared. This revealed a possible variation between the two groups for Objective 11. Another -test was performed to compare objective performance between the experimental group and each of the classes in the control group. This analysis revealed a significant difference between the experimental group and the control group for Objective 11. This indicates that the possible variation identified in the comparison between the major groups was due to the significant difference between the experimental group and class group 4. The direction of the variation indicates that the class group 4 performed better on Objective 11, dealing with Kirchhoff's voltage laws, than the experimental group. As this result was obtained in the analysis of the experimental group and class 3 of the control group and only indicted in the analysis between the experimental group and the control group, it can be inferred that class 3 also performed better on objective 11 than class 1 and class 2.

The next examination of the study's results involved an analysis of variance between the four groups as minor groups and by objective. The first test compared the experimental group to each of the class groups in the control group based on the post-test score. The result did not indicate a significant difference between the two groups. The next test compared the experimental group to each of the class groups in the control group based on the objective scores on the post-test. The analysis of the objective scores revealed a significant difference for Objective 11. As with the *t* test results this indicates a difference between the experimental group and the control group for Objective 11 which tests Kirchhoff's Voltage Law.

Post hoc comparisons using the Tukey HSD and Scheffé tests indicated a significant difference between the experimental group (group 1) and class 3 of the control group (group 4). The Tukey HSD test also indicated a significant difference between group 2 and group 4. This analysis indicated that group 4 had performed better on Objective 11 than either group 1 or group 2. These findings indicate that a difference exists between group 4 and groups 1 and 2 with respect to their understanding of Kirchhoff's Voltage Law. As both group 2 and group 4 received instruction from the same instructor, it is likely that a difference in class composition can account for the difference in achievement results. This cannot be confirmed as demographic information for these groups such as prior education is not available. Differences in instructional practices are another plausible source of these differences, although it is not possible to confirm this possible with the available data. The analysis of the post-test results indicated that a possible significant difference between the experimental group and one of the classes in the control group. An analysis of variance comparing the objective scores on the post-test revealed that a significant difference existed between group 1 (experimental group) and group 4 (class 3 of control group) for Objective 11 of the post-test. Post hoc analysis confirmed that group 4 performed significantly better on Objective 11 than group 1. No other significant differences between the groups were indicated in the analysis. Based on these findings the results obtained in this study neither support nor disprove blended learning as an effective intervention in addressing learner misconceptions about electricity.

The analysis of the pretest data indicated little variance between the classes of students participating in this study at the outset of the study. While this suggests that all classes in the study were approximately the same with respect to their misconceptions about electricity it is not possible to determine whether these results represent the true nature of student misconceptions, that is whether all students took the test in earnest and answered to the best of their ability. Likewise as the post-test differed considerably from the pretest and was not tested for reliability or validity, it is not possible to make a direct comparison between the pretest and post-test results. This suggests that the effectiveness of this intervention cannot be measured using a pretest-post-test comparison and that additional study may be required to gauge whether blended learning is an effective intervention for addressing learner misconceptions about electricity. While it may be suggested that without a significant difference between the experimental group and the control group the intervention was unsuccessful, this only accounts for the overall intervention not the individual components. This study was not designed to determine whether individual interventions were effective (i.e., conceptual change text, teaching with analogies, simulation, and learning management system) but rather took a holistic approach to blended learning in general using a variety of approaches. Previous studies, as identified in the literature review section of this paper, have demonstrated that interventions such as conceptual change texts, teaching with analogies, and simulation are effective in helping to correct student misconceptions about electricity. As blended learning itself does not constitute a learning intervention, but rather facilitates course delivery and interaction, intervention methods, such as those mentioned above, were required to support conceptual change efforts. The success of these interventions in altering student conceptions of electricity warranted their inclusion in this study as teaching interventions for use with blended learning. The decision to use multiple interventions is supported by Ates (2005) who notes that "while researchers have reached a consensus about the nature of student learning difficulties, there is no consensus on appropriate pedagogy to address those difficulties" (p. 3). The fact that a significant difference did not exist between any of the groups involved in this study suggests that blended learning, in this instance, was no more and no less effective at addressing these learner misconceptions than traditional face-to-face instruction. This does not provide sufficient evidence regarding the effectiveness of the applied interventions but suggest that further study into these interventions may be warranted.

Measuring Student Performance with the DIRECT Instrument

The DIRECT instrument was used in four of the studies presented in the literature review section of this thesis, namely Afra, Osta, and Zoubeir (2007), Ates (2005), Engelhardt and Beichner (2004), and O'Dwyer (2009). Afra et al. (2007) used the DIRECT v1.0 version of the instrument is the study of a physics course offered to grade 9 Lebanese students. In this study the DIRECT instrument was used only as a post-test to determine the effectiveness of an inquiry-based instructional module. Ates (2005) examined the effectiveness of the learning cycle method of teaching with freshmen university students in Turkey. The DIRECT v1.1 version of the instrument was used as a pretest and post-test in this study. Engelhardt and Beichner (2004), in developing the three versions of the DIRECT instrument, v1.0, v1.1, and v1.2, respectively, administered the test to over 1827 students which included 705 high school students and 1122 post-secondary students. Engelhardt and Beichner used the feedback from the students taking different versions of DIRECT to make corrections and improve question quality. O'Dwyer (2009) employed the DIRECT v1.1 version of the instrument to identify misconceptions about electricity amongst a cohort of 83 students enrolled in the first year of a three year, university level technology program. These studies provide an opportunity to compare the students entering College of the North Atlantic to students enrolled at institutions elsewhere. The study by Afra et al. (2007) is not suitable for comparison purposes as it was administered as a post-test only and the participants, being grade 9 students, were well below the mean age of the participants in this and the other studies. Additionally the study by Ates is also not included in this comparison as the instrument was translated into a different language. Although the translated instrument was tested for reliability a comparison of the scores achieved on the two versions of DIRECT cannot be made with confidence. Furthermore the format in which Ates presents the data obtained in this study does not allow for a direct comparison.

When comparing the data collected in this study to existing data from other studies using the DIRECT instrument (Ates, 2005, Engelhardt & Beichner, 2004; O'Dwyer, 2009), it is apparent that students entering College of the North Atlantic perform at a lower level across multiple objectives tested by the instrument. Engelhardt and Beichner noted mean scores of 41 and 52, for high school and university students, respectively, while O'Dwyer notes a mean score of 39 for university students. Comparatively, students at College of the North Atlantic obtained a mean score of 27.69. This implies that alternate conceptions of electricity are more pervasive amongst students entering College of the North Atlantic than those in other parts of Canada, the United States, and Ireland. This would also suggest that students in Newfoundland and Labrador develop misconceptions about electricity at the junior high and secondary levels and that these misconceptions persist beyond high school. As this instrument was not administered to students entering Memorial University it cannot be determined whether these misconceptions are present in the majority of students attending high school in Newfoundland and Labrador or if this is indicative of students choosing to attend College of the North Atlantic. Furthermore as there is no demographic information available to identify where students at College of the North Atlantic attended high school, it is not possible to determine if these misconceptions are common to all provincial junior high and secondary schools or if it isolated to particular schools or a particular school district. That is to say, a determination cannot be made as to whether development of misconceptions about electricity are related to the provincial curriculum or a process related to teaching within specific jurisdictions.

The next section will discuss the implications of this study with respect to students enrolled in Engineering Technology at College of the North Atlantic. The next chapter will present the conclusions reached based on the outcome of this study and make suggestions for future research.

Implications

Although the study did not confirm that blended learning is effective at addressing learner misconceptions about electricity, there are several implications of this research. The first implication deals with preexisting misconceptions held by students entering College of the North Atlantic to study engineering technology. The results achieved on the pretest, DIRECT v1.2, indicated that the majority of the students participating in this study have conceptual concepts of electricity that are not consistent with commonly accepted scientific views. As indicated in Table 13 which compares scores achieved, by objective, for participants in several studies (note the results for Engelhardt and Beichner are composite scores from DIRECT v1.0 and DIRECT v1.2), the students at College of the North Atlantic scored lower in almost every objective on the test. This indicates that students in Newfoundland and Labrador may have more misconceptions about electricity than students in the United States, other parts of Canada, and Ireland. On the surface this indicates that students in Newfoundland and Labrador would likely benefit from conceptual change at an earlier stage in their education, perhaps when these concepts are first introduced in Grade 9, and that greater efforts must be made at the college level to ensure that misconceptions about electricity are identified early and that interventions are available to help the student identify and correct their misconceptions about electricity. As discussed in the previous section a conclusion cannot be made as to whether this is common to all students in Newfoundland and Labrador or particular to students choosing to attend College of the North Atlantic. Given the uncertainty of how pervasive these misconceptions may be it would worth further investigation to determine at what age or grade misconceptions are likely to occur and if there is a geographical component to the misconceptions, that is are misconceptions developed at particular schools or in specific jurisdictions or school districts.

Table 13

Comparison of means scores between studies using DIRECT

Objective	Question No.	O'Dwyer	Engelhardt & Beichner	CNA
Physical aspects of DC electric circuits (objectives 1-5)				
1. Identify and explain a short circuit	10, 19, 27	48	56	42
2. Understand the functional two-endedness of circuit elements	9, 18	56	57	47
3. Identify a complete circuit (objectives 1 to 3 combined)	27	52	71	46
4. Apply the concept of resistance	5, 14, 23	39	50	18
5. Interpret pictures and diagrams of a variety of circuits	4, 13, 22	45	55	38
Energy (objectives 6-7)				
6. Apply the concept of power to a variety of circuits	2, 12	38	33	10
7. Apply a conceptual understanding of conservation of energy	3, 21	33	48	33
Current (objectives 8-9)				
8. Understand and apply conservation of current	8, 17	33	61	35
9. Explain the microscopic aspects of current flow	1, 11, 20	16	25	12

Table 13 (continued)

Comparison of means scores between studies using DIRECT

Objective	Question No.	O'Dwyer	Engelhardt & Beichner	CNA
Potential difference (voltage)(objectives 10-11)				
10. Current is influenced by potential difference and resistance	7, 16, 25	72	49	32
11. Apply the concept of potential difference to a variety of circuits	6, 15, 24, 28, 29	28	36	24

An examination of the post-test results indicates that misconceptions about electricity, in general, are not addressed during the delivery of ET1100 Electrotechnology, as the mean score on the post-test, across all groups, was 56.31. The by-group scores indicate that all groups performed at a low-level on the post-test with group 3 (class group 2 of Control group) (M = 61.44, SD = 14.599) performing slightly better than group 1 (Experimental group) (M = 54.18, SD = 12.989), group 2 (class group 1 of Control group) (M = 53.88, SD = 11.458), and group 4 (class 3 of Control group) (M = 57.51, SD = 14.520). As ET1100 is a compulsory course for all students enrolled in Engineering Technology programs these results include students who have little interest in studying electricity and as such are likely not motivated to develop a thorough understanding of this topic. That is to say, as this course does not represent a significant outcome for the majority of Engineering Technology programs in which students are enrolled, students are likely to focus their attention on traditional science courses such as chemistry and physics, as well as mathematics. It must be noted that the relationship between performance and motivation cannot be qualified as measuring student satisfaction and student motivation were not factors in this study and as such the suggestion that low performance in ET1100 results from low motivation or disinterest is based largely on observation by the researcher. The basic concepts taught in ET1100 are transferrable to other areas of technology as they are effectively concepts of the physical sciences. Additionally many of the technologies, particularly mechanical and architectural programs, draw upon concepts of electricity in building designs and electro-mechanical systems. Students entering these programs would benefit from a better understanding of electricity and holding an acceptable conceptual model of electricity will improve their overall understanding of the physical sciences.

Another implication of this study concerns the use of blended learning in the college environment as College of the North Atlantic's Ridge Road Campus has currently integrated blended learning into all courses in First Year Engineering Technology. The success of blended learning, as noted by several researchers in this area (such as Garrison & Kanuka, 2004; Garrison & Vaughan, 2008; Vaughan, 2007), is dependent on the design of the learning experience and the technology support provided to students. This study lacked sufficient technology support, which will be discussed in the next chapter, which negatively impacted the effectiveness of Desire2Learn as a learning tool in the classroom. For this technology to be effective students require immediate and continuous access to it. This is also the case with the course content as students develop the expectation that course materials will be readily available as the students require the materials. When students experience difficulties accessing the site due to technical issues, or there are delays in posting course materials, assessment results, or responding to questions and discussions, the students will likely become discouraged and ignore the online component of the course. The same is true when course materials simply consist of a "dump" of the instructor's notes on the site.

In addition to the previously stated implications of adding blended learning to on-campus courses there are other considerations that must be taken into account. Although this method of teaching and learning has the potential to enhance learning effectiveness it does have very real costs in terms of increased workloads for students, faculty, and IT staff. As discussed, for blended learning to be effective it cannot simply be considered a web bolt-on to an existing course but rather must be designed to take full advantage of the opportunities presented while also trying to account for the potential pitfalls. From a faculty perspective this requires that courses must be developed to combine both classroom instruction and an online component in a complementary manner. This may require a greater level of planning and technical knowledge than has been required in the past, and as such may be a source of apprehension for faculty involved with blended learning. Additionally the use of a web component with a largely classroom based course could cause students to be reluctant about taking such courses due to the expectation of both in class and online attendance. Finally IT staff may have concerns about supporting the always-on environment of a virtual classroom due to the technical and security complications associated with providing Internet based services. These concerns should not be taken lightly and will require input from all stakeholders to develop a consistent approach to blended learning. One such approach may be dividing lectures between the classroom and the virtual classroom. For example a course with three lectures hours per week may start with full classroom based participation, during which time the students are introduced to the virtual classroom as well as the course itself, before moving to a delivery model that had one or two hours of classroom time with the remaining lectures hours meeting in the virtual classroom, during regularly scheduled times, using conferencing software such as Cisco WebEx or Blackboard Collaborate.

In general, although this study did not produce the desired results, the findings do provide invaluable insights into the conceptual understanding students have when entering engineering technology programs at College of the North Atlantic. By drawing upon this data and developing learning experiences that are designed to address conceptual inconsistencies there is a strong likelihood that student achievement in the area of electricity will improve as students confront their misconceptions and develop conceptual models that are consistent with accepted scientific models.

Summary

This chapter discussed the results of the data analysis in the previous chapter, provides a comparison of performance on the DIRECT instrument between students in this study and two other studies using DIRECT, and discusses the implications of the findings in this study. The first section discussed the results of the post-test analysis, and finding no significant difference between the experimental and control groups, suggests that blended learning, in this context is no more and no less effective than traditional classroom instruction. The comparison between students writing the DIRECT implies that students in Newfoundland and Labrador posses more frequent misconceptions about electricity that students in other regions including other parts of Canada, the United States, and Ireland. It is also suggested that further investigation is required to ensure, as College of the North Atlantic moves to a blended learning model, that instructional resources are pedagogically sound and that technical supports are available to ensure both students and instructors can access the technology without difficulty.

The next chapter will discuss the conclusions reached, the limitations of this study which may have impacted the outcomes achieved, and suggestions for further research. In general, while the study did not produce the desired result, that is confirming blended learning is an effective means of addressing student misconceptions about electricity, it did provide a greater understanding of these misconceptions, how they are created, and the interventions that have been effective in altering student concepts. It is also suggested, based on the findings in this study, that student concepts about electricity be investigated within Newfoundland and Labrador to determine (1) if such alternate conceptions are developed as a result of the provincial curriculum; (2) a related to instructional practices; (3) are related to school or school district; and (4) affect the student's choice of post-secondary participation, that is college versus university. It would also be worth investigating is such misconceptions discourage student participation in post-secondary.

CHAPTER 6: CONCLUSIONS

The previous chapter discussed the findings of this study and their implications. Although the data analysis of post-test results between the experimental and control groups did not yield significant findings, there is merit in this study as it did confirm that misconceptions about electricity do exist amongst students entering engineering technology programs at College of the North Atlantic and that these misconceptions require a planned intervention to correct.

Limitations and Directions for Future Research

In reflecting upon my research, I have concluded that there were several aspects of this study that may have impacted its success. The first, and most significant, was the lack of technical support in the classroom to fully integrate Desire2Learn as a learning tool. Prior to the delivery of ET1100 Electrotechnology in the Fall 2011 semester, I requested the use of a classroom equipped with a SmartBoard and within range of a wireless access point. The classroom I was ultimately assigned lacked both of these features, making it difficult to utilize the D2L site during regular lectures. As such this may have diminished its importance amongst the students resulting in a low attendance rate for the online content. Similarly there was a low participation rate within the D2L discussion forums with the majority of the discussion focused on test dates or questions regarding the relevance of the course content.

To address the lack of continual access to D2L in the classroom I compensated with a laptop and digital projector, however, this did not address the access issue the students experienced. As previously discussed, access to the course site is critical as technical issues and lack of access are more likely to deter students for using the online content (Garrison & Kanuka, 2004). Without access to a wireless network in the classroom, students were unable to use their devices, smartphones, tablets, and laptops to access the content as I was presenting relevant information or demonstrating the use of the site during lectures. This possibly discouraged students from participating in the online portion as their only option was to wait until they were home to access the site. This is not an ideal situation in a blended learning environment as the intent is to integrate the in-class instruction with the online technology rather than maintain them as separate entities.

Another limitation of this study involved time. The original design of this study called for the participants to re-write the DIRECTv1.2 as the post-test and complete a questionnaire based on their experience with the course. My colleague, who delivered the course to the participants in the Control group, was forced to be absent for several classes for reasons not material to this discussion. In order to compensate for this missed class time, it was necessary to use all of the time allotted for the course to do make-up work with students which made it impossible to access the students to complete either a questionnaire or write the post-test. As an alternative, I elected to use the results of the course final exam as this was common to all students including the participants in this study. This exam also was not tested for reliability or validity which brings its usefulness as a post-test into question. The exam was also developed by my colleague teaching the Control group, which also calls the results into question as these students may have had prior knowledge of the exam, particularly if any of the questions had been used on previous assessments in the course.

Other limitations of this study, introduced in Chapter 2, included a lack of access to students in a practical laboratory setting, and interruptions in student-student interaction. The former was a result of operational requirements within the campus. This posed a limitation of the study as I was unable to observe the students in a practical setting as well as reinforce the concepts discussed in the lectures. As such there was no direct linkage between theory and practice which in turn may have impeded the effectiveness of the learning interventions employed in this study, as noted by Zacharia (2007).

The latter condition, interruptions in student-student interaction resulted from students being separated into laboratory time slots and groups different from the lecture groups. That is in the classroom setting students were encouraged to work in small groups to solve problems and discuss the concepts being taught in the course. These students were from two different class groups and as such were scheduled for laboratories at different times. Furthermore the laboratory groups were limited to two students per group. As such it is quite likely that students who had worked together in class may have been in different laboratories or different working groups in the same laboratory. This was compounded with the previously discussed situation where I, as the course instructor, was not the laboratory instructor and as such was limited in my interactions with the students. This limited my interaction to the classroom where there were 50 students, rather than including the laboratories which were restricted to 25 students, allowing for greater opportunities to interact with individuals as well as make connections between the practical activity in the laboratory and the concepts being discussed in class. It is also assumed that student confidence may have been affected as the groups changed between the lectures and the laboratories requiring the students to work with different partners in the lecture and laboratory.

This is an area that is still largely unexplored and worthy of future consideration. At a minimum, I would suggest that researchers conducting a similar study be empowered to exercise independence over the delivery of the course, including scheduling of classes and room assignment. This would ensure that adequate resources exist to make this a true blended learning experience and that the students would have adequate access to online course materials during the in-class lectures. I would also suggest that if time does not permit the administration of a post-test then the pre-test questions should be embedded in the course final exam. This would ensure that, in addition to meeting the course learning objectives and assigned evaluation, more useful data can be collected to provide a clear comparison of results between groups on the pretest and post-test. This would also provide some assurance that an analysis of the post-test data could be carried out to allow for a definitive conclusion regarding the effectiveness of the blended learning activity in addressing learner misconceptions about electricity.

Given that the results of the study did not indicate a significant difference between the blended learning group and the classroom group, and, as previously discussed, there were several limitations to the study, I would suggest a repeat of this study with a new cohort of students. I would further suggest several modifications be made to the study including scheduled dates for the administration of the pre- and post-tests and student survey, access to an appropriate classroom equipped with Internet access and SmartBoard, and assigning the same instructor to both lectures and laboratories. As participation in the discussion forums was voluntary only a few students participated in online discussions. In order to increase participation this would have to be made mandatory and the course evaluation would have to be changed to reflect this component of the course.

In the summary and discussion chapter of this thesis I discussed differences between students in this study and other studies with respect to their performance on the DIRECT instrument. The students in this study were observed to posses more misconceptions about electricity than the other students. As this study did not control for a number of variables related to the students' junior high and secondary school education, including courses taken, school attended, and so forth, this raises several questions about when and how these misconceptions are created. It is unclear whether students developed their alternate concepts of electricity at the junior high or secondary school level; if these misconceptions are related to teaching practices or are inherent in the prescribed curriculum; or whether the development of misconceptions are more prevalent within specific schools or school jurisdictions. It may be worthwhile to conduct a longitudinal study to attempt to answer the above questions as well as determine if alternate conceptions affect a student's decision whether or not they will attend post-secondary and which form of post-secondary will be pursued, i.e. apprenticeship, college, or university. Such a study would involve students from across the province who would write the DIRECT instrument in grade 9 and again in grade 12. This may be administered as post-test only or follow a pretest-post-test model to determine at which point misconceptions begin to present, or if misconceptions might be developed prior to grade 9.

Final Thoughts

This study has provided a rewarding opportunity to gain keener insights into the conceptual models possessed by students entering engineering technology as well as gaining a better understanding of how students develop new knowledge when studying technical content. There is ample opportunity for a variety of studies in this area as new technologies are constantly reshaping teaching and learning. Additionally, technology education has only recently begun to receive attention from researchers and as the need for technologically educated individuals continues to grow this area of education will provide ample opportunities for researchers to explore and investigate topics of learning, instruction, and knowledge construction.

Blended learning, including the use of the Internet as a content management and delivery tool, is a relatively new approach to integrating technology into teaching. In some cases, forms of blended learning may be able to substitute for in-class lectures that can be replaced with Internet-based activities such as online discussions. As institutions compete to recruit new students to meet the growing demands of industry, while also trying to address the issue of shrinking infrastructure budgets, Internet-enable forms of blended learning may represent a viable means of providing quality instruction without increasing physical capacity within institutions.

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Appendix A: Consent Form

Consent form (Experimental Group)

Title: Examining the Effectiveness of Blended Learning in Addressing Learner Misconceptions about Electricity

Researcher: Keith Bussey
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Thesis Supervisor
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Tel: 709.737.7623
Fax: 709.737.2345
E-mail: dkirby@mun.ca

You are invited to participate in a research project entitled "Examining the Effectiveness of Blended Learning in Addressing Learner Misconceptions about Electricity." The purpose of this study is to investigate students' understanding of basic concepts of electricity.

Participation in this research project is entirely at your discretion. If you choose not to take part in the research of if you choose to withdraw from the research once it has started, there will be no negative consequences for you, now or in the future.

What you will do in this study:

As a participant in this study you will be asked to write a pre-test prior to the start of classes and a posttest at the end of the semester. You will also be asked to complete a short survey at the end of the course.

As a participant in this study you will be asked to complete assessments, i.e. assignments, quizzes, etc, electronically using Desire2Learn, a learning management system used by College of the North Atlantic for distance education. You may also be asked to review electronic tutorials such as videos and documents.

As a participant in this study you will be asked to give consent to the researcher to use assessment scores from quizzes, assignments, laboratories, and exams for the purposes of data analysis.

Possible Benefits:

As a participant in this study you will be provided with ongoing assessment of your performance in ET1100 and receive personalized feedback based on these assessments. Additionally you will have access to tutorials designed to help you address and correct any misconceptions you may have about the nature of electricity. The potential benefit of your participation is a greater understanding of electricity.

Possible Risks:

There are no anticipated risks to participation in this study. Students who wish to not participate in the study, or who wish to withdraw from the study may do so at any time.

Confidentiality:

All data collected by the researcher, including assessment scores, pre-test and post-test results, and survey responses will not be available to anyone other than the researcher.

Questions:

You are welcome to ask questions at any time during your participation in this research. If you would like more information about this study, please contact:

Researcher
Keith Bussey
Tel: 709.758.7122
E-mail: keith.bussey@cna.nl.ca

Thesis Supervisor
Dr. Dale Kirby
Tel: 709.737.7623
E-mail: dkirby@mun.ca

The proposal for this research has been reviewed by the Interdisciplinary Committee on Ethics in Human Research and found to be in compliance with Memorial University's ethics policy. If you have ethical concerns about the research (such as the way you have been treated or your rights as a participant), you may contact the Chairperson of the ICEHR at icehr@mun.ca or by telephone at 737-2861.

Consent:

Your signature on this form means that:

- You have read the information about the research
- You have been able to ask questions about this study
- You are satisfied with the answers to all of your questions
- You understand what the study is about and what you will be doing
- You understand that you are free to withdraw from the study at any time, without having to give a reason, and that doing so will not affect you now or in the future.
- If you sign this form, you do not give up your legal rights, and do not release the researchers from their professional responsibilities.

The researcher will give you a copy of this form for your records.

________________________________ ______________________________

Signature of participant Date

Consent form (Control Group)

Title: Examining the Effectiveness of Blended Learning in Addressing Learner Misconceptions about Electricity

Researcher: Keith Bussey
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Dr. Dale Kirby
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Fax: 709.737.2345
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You are invited to participate in a research project entitled "Examining the Effectiveness of Blended Learning in Addressing Learner Misconceptions about Electricity." The purpose of this study is to investigate students' understanding of basic concepts of electricity.

Participation in this research project is entirely at your discretion. If you choose not to take part in the research of if you choose to withdraw from the research once it has started, there will be no negative consequences for you, now or in the future.

What you will do in this study:

As a participant in this study you will be asked to write a pre-test prior to the start of classes and a posttest at the end of the semester. You will also be asked to complete a short survey at the end of the course.

As a participant in this study you will be asked to give consent to the researcher to use assessment scores from quizzes, assignments, laboratories, and exams for the purposes of data analysis. This data will be provided by your course instructor and will not contain identifiers such as your name or student number. Your instructor will only provide assessment information for students who have signed this letter of consent.

Possible Benefits:

As a participant in this study you will be contributing to the researcher's understanding of how students learn about concepts of electricity.

Possible Risks:

There are no anticipated risks to participation in this study. Students who wish to not participate in the study, or who wish to withdraw from the study may do so at any time.

Confidentiality:

All data collected by the researcher, including assessment scores, pre-test and post-test results, and survey responses will not be available to anyone other than the researcher.

Questions:

You are welcome to ask questions at any time during your participation in this research. If you would like more information about this study, please contact:

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The proposal for this research has been reviewed by the Interdisciplinary Committee on Ethics in Human Research and found to be in compliance with Memorial University's ethics policy. If you have ethical concerns about the research (such as the way you have been treated or your rights as a participant), you may contact the Chairperson of the ICEHR at icehr@mun.ca or by telephone at 737-2861.

Consent:

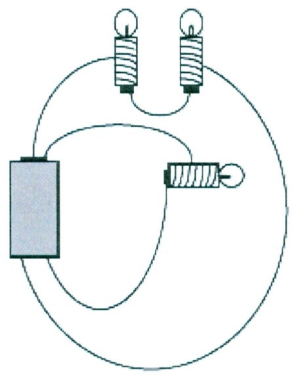
Your signature on this form means that:

- You have read the information about the research
- You have been able to ask questions about this study
- You are satisfied with the answers to all of your questions
- You understand what the study is about and what you will be doing
- You understand that you are free to withdraw from the study at any time, without having to give a reason, and that doing so will not affect you now or in the future.

The researcher will give you a copy of this form for your records.

________________________________	______________________________
Signature of participant	Date

Appendix B: DIRECT v1.2



Determining and
Interpreting
Resistive
Electric Circuits
Concepts
Test Version 1.2

Instructions

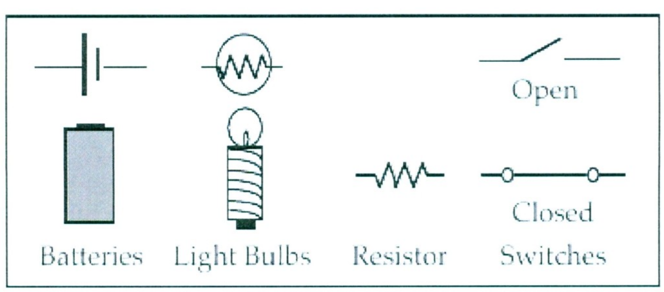
Wait until you are told to begin, then turn to the next page and begin working. Answer each question as accurately as you can. There is only one correct answer for each item. Feel free to use a calculator and scratch paper if you wish.

Use a #2 pencil to **record your answers** on the Opscan sheet, but please **do not write in the test booklet**.

You will have approximately 30 minutes to complete the test. If you finish early, check your work before handing in both the answer sheet and the test booklet.

Additional comments about the test

All light bulbs, resistors, and batteries are identical unless you are told otherwise. The battery is ideal, that is to say, the internal resistance of the battery is negligible. In addition, the wires have negligible resistance. Below is a key to the symbols used on this test. Study them carefully before you begin the test.



by Paula V. Engelhardt and
Robert J. Beichner
North Carolina State University
Department of Physics
Raleigh, NC 27695-8202
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1) Are charges used up in the production of light in a light bulb?

(A) Yes, charge is used up. Charges moving through the filament produce "friction" which heats up the filament and produces light.

(B) Yes, charge is used up. Charges are emitted as photons and are lost.

(C) Yes, charge is used up. Charges are absorbed by the filament and are lost.

(D) No, charge is conserved. Charges are simply converted to another form such as heat and light.

(E) No, charge is conserved. Charges moving through the filament produce "friction" which heats up the filament and produces light.

2) How does the power delivered to resistor A change when resistor B is added to the circuit? The power delivered to resistor A _____.

(A) Quadruples (4 times)

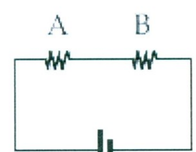
(B) Doubles

(C) Stays the same

(D) Is reduced by half

(E) Is reduced to one quarter (1/4)

Before



After

3) Which circuit or circuits have the GREATEST energy delivered to them per second?

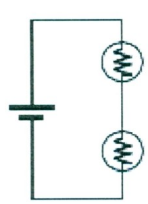
(A) Circuit 1

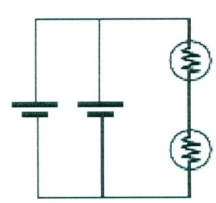
(B) Circuit 2

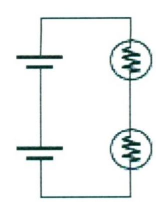
(C) Circuit 3

(D) Circuit 1 = Circuit 2

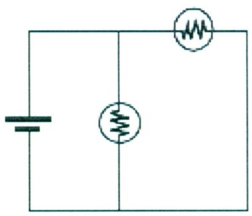
(E) Circuit 2 = Circuit 3


Circuit 1

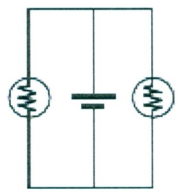

Circuit 2


Circuit 3

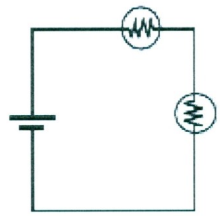
4) Which circuit or circuits below represent a circuit consisting of two light bulbs in parallel with a battery?



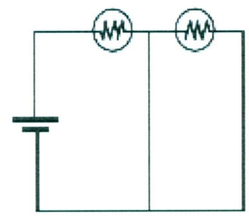
Circuit 1



Circuit 2



Circuit 3



Circuit 4

(A) Circuit 1

(B) Circuit 2

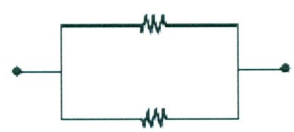
(C) Circuit 3

(D) Circuits 1 and 2

(E) Circuits 1, 2, and 4

5) Compare the resistance of branch 1 with that of branch 2. A branch is a section of a circuit. The resistance of branch 1 is _____ branch 2.

Branch 1



Branch 2

(A) Four times

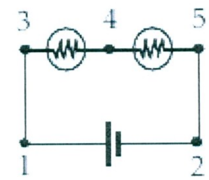
(B) Double

(C) The same as

(D) Half

(E) One quarter (1/4)

6) Rank the potential difference between points 1 and 2, points 3 and 4, and points 4 and 5 in the circuit shown below from HIGHEST to LOWEST.



(A) 1 and 2; 3 and 4; 4 and 5

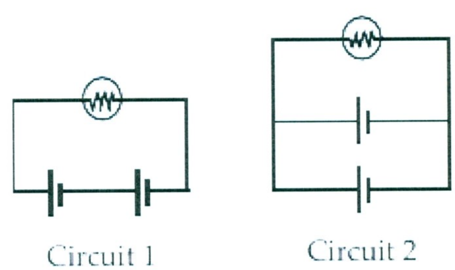
(B) 1 and 2; 4 and 5; 3 and 4

(C) 3 and 4; 4 and 5; 1 and 2

(D) 3 and 4 = 4 and 5; 1 and 2

(E) 1 and 2; 3 and 4 = 4 and 5

7) Compare the brightness of the bulb in circuit 1 with that in circuit 2. Which bulb is BRIGHTER?



(A) Bulb in circuit 1 because two batteries in series provide less voltage

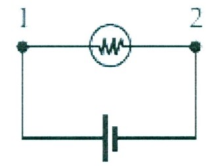
(B) Bulb in circuit 1 because two batteries in series provide more voltage

(C) Bulb in circuit 2 because two batteries in parallel provide less voltage

(D) Bulb in circuit 2 because two batteries in parallel provide more voltage

(E) Neither, they are the same

8) Compare the current at point 1 with the current at point 2. At which point is the current LARGEST?



(A) Point 1

(B) Point 2

(C) Neither, they are the same. Current travels in one direction around the circuit.

(D) Neither, they are the same. Currents travel in two directions around the circuit.

9) Which circuit(s) will light the bulb? (The other object represents a battery.)

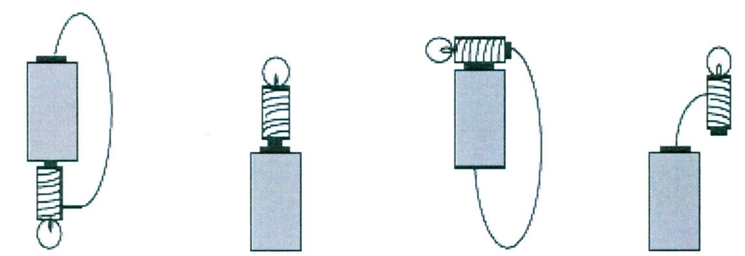
(A) Circuit 1

(B) Circuit 2

(C) Circuit 3

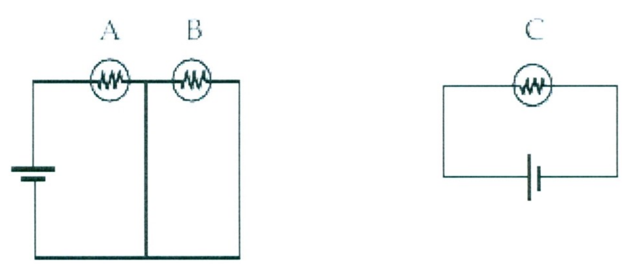
(D) Circuits 1 and 3

(E) Circuits 1, 3, and 4



Circuit 1 Circuit 2 Circuit 3 Circuit 4

10) Compare the brightness of bulbs A, B, and C in these circuits. Which bulb or bulbs are the BRIGHTEST?



(A) A

(B) B

(C) C

(D) A = B

(E) A = C

11) Why do the lights in your home come on almost instantaneously when you turn on the switch?

(A) When the circuit is completed, there is a rapid rearrangement of surface charges in the circuit.

(B) Charges store energy. When the circuit is completed, the energy is released.

(C) Charges in the wire travel very fast.

(D) The circuits in a home are wired in parallel. Thus, a current is already flowing.

(E) Charges in the wire are like marbles in a tube. When the circuit is completed, the charges push each other through the wire.

12) Consider the power delivered to each of the resistors shown in the circuits below. Which circuit or circuits have the LEAST power delivered to them?

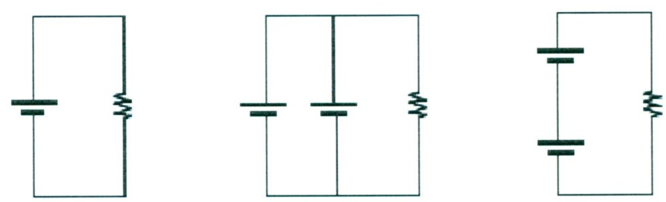
(A) Circuit 1

(B) Circuit 2

(C) Circuit 3

(D) Circuit 1 = Circuit 2

(E) Circuit 1 = Circuit 3



Circuit 1 Circuit 2 Circuit 3

13) Which schematic diagram best represents the realistic circuit shown below?

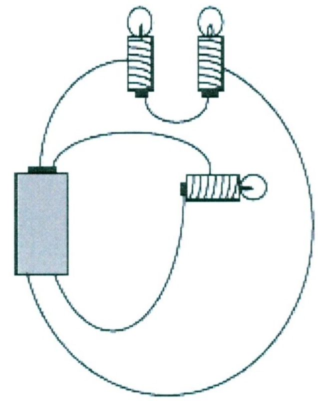
(A) Circuit 1

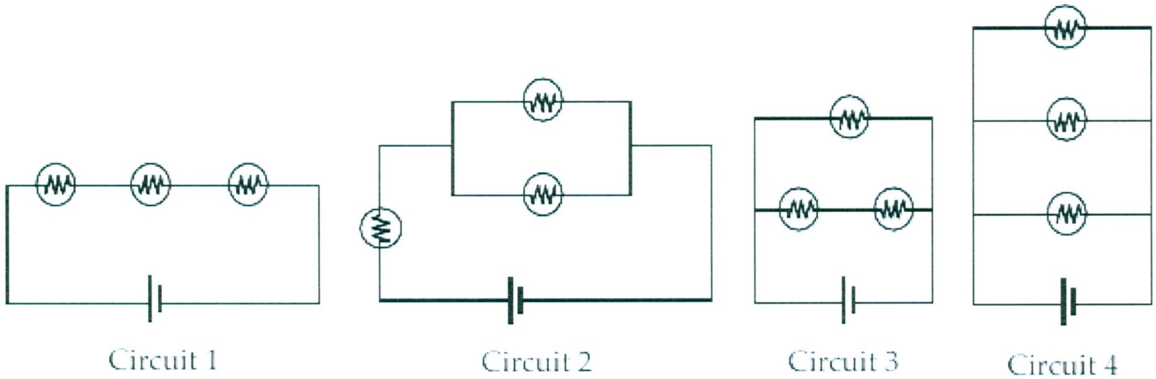
(B) Circuit 2

(C) Circuit 3

(D) Circuit 4

(E) None of the above





14) How does the resistance between the endpoints change when the switch is closed?

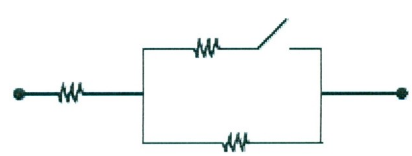
(A) Increases by R

(B) Increases by R/2

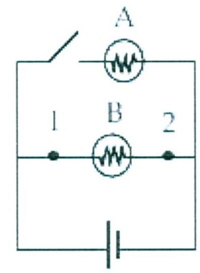
(C) Stays the same

(D) Decreases by R/2

(E) Decreases by R



15) What happens to the potential difference between points 1 and 2 when the switch is closed?



(A) Quadruples (4 times)

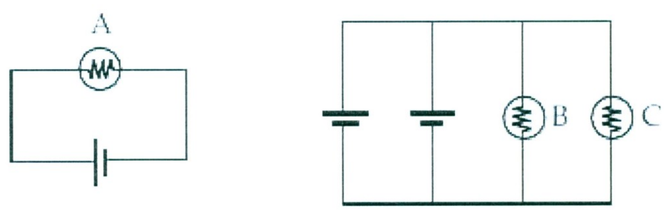
(B) Doubles

(C) Stays the same

(D) Reduces by half

(E) Reduces by one quarter (1/4)

16) Compare the brightness of bulb A with bulb B. Bulb A is _____ bright as Bulb B.



(A) Four times as

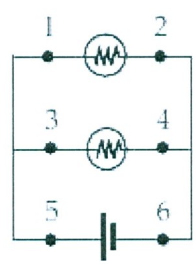
(B) Twice as

(C) Equally

(D) Half as

(E) One fourth (1/4) as

17) Rank the currents at points 1, 2, 3, 4, 5, and 6 from HIGHEST to LOWEST.



(A) 5, 3, 1, 2, 4, 6

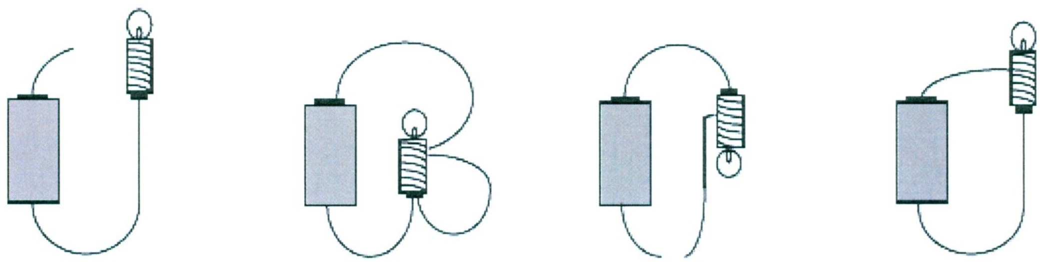
(B) 5, 3, 1, 4, 2, 6

(C) 5 = 6, 3 = 4, 1 = 2

(D) 5 = 6, 1 = 2 = 3 = 4

(E) 1 = 2 = 3 = 4 = 5 = 6

18) Which circuit(s) will light the bulb?



Circuit 1 Circuit 2 Circuit 3 Circuit 4

(A) Circuit 1

(B) Circuit 2

(C) Circuit 4

(D) Circuits 2 and 4

(E) Circuits 1 and 3

19) What happens to the brightness of bulbs A and B when a wire is connected between points 1 and 2?

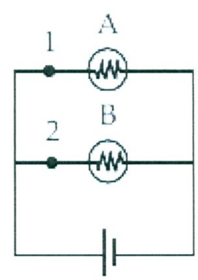
(A) Both increase

(B) Both decrease

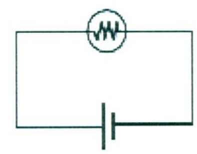
(C) They stay the same

(D) A becomes brighter than B

(E) Neither bulb will light



20) Is the electric field zero or non-zero inside the bulb filament?



(A) Zero because the filament is a conductor.

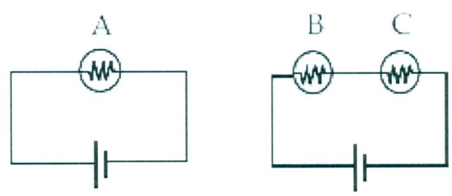
(B) Zero because a current is flowing.

(C) Zero because there are charges on the surface of the filament.

(D) Non-zero because a current is flowing which produces the field.

(E) Non-zero because there are charges on the surface of the filament which produce the field.

21) Compare the energy delivered per second to each light bulb shown below. Which bulb or bulbs have the LEAST energy delivered to them per second?



(A) A

(B) B

(C) C

(D) B = C

(E) A = B = C

22) Which realistic circuit or circuits represent the schematic diagram shown below?

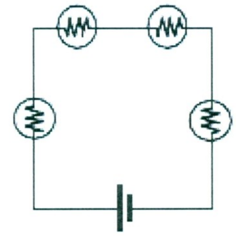
(A) Circuit 2

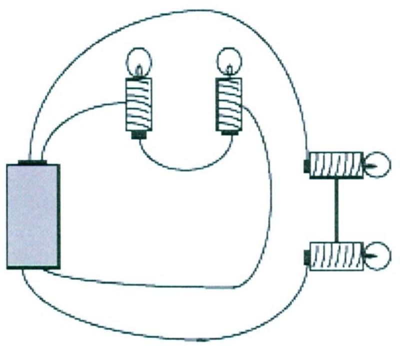
(B) Circuit 3

(C) Circuit 4

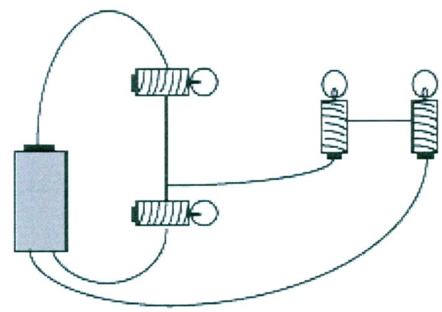
(D) Circuits 1 and 2

(E) Circuits 3 and 4

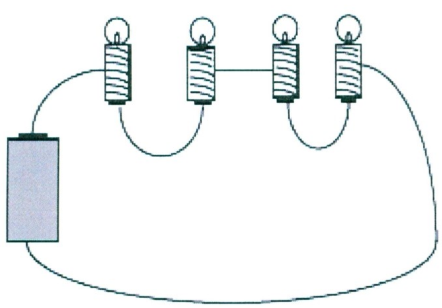




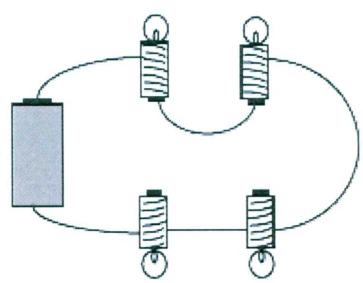
Circuit 1



Circuit 2

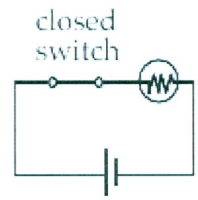


Circuit 3



Circuit 4

23) Immediately after the switch is opened, what happens to the resistance of the bulb?



(A) The resistance goes to infinity.

(B) The resistance increases.

(C) The resistance decreases.

(D) The resistance stays the same.

(E) The resistance goes to zero.

24) If you double the current through a battery, is the potential difference across a battery doubled?

(A) Yes, because Ohm's law says $V = IR$.

(B) Yes, because as you increase the resistance, you increase the potential difference.

(C) No, because as you double the current, you reduce the potential difference by half.

(D) No, because the potential difference is a property of the battery.

(E) No, because the potential difference is a property of everything in the circuit.

25) Compare the brightness of bulb A with bulb B. Bulb A is _____ bright as bulb B.

(A) Four times as

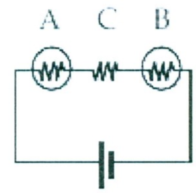
(B) Twice as

(C) Equally

(D) Half as

(E) One fourth (1/4) as

26) If you increase the resistance C, what happens to the brightness of bulbs A and B?



(A) A stays the same, B dims

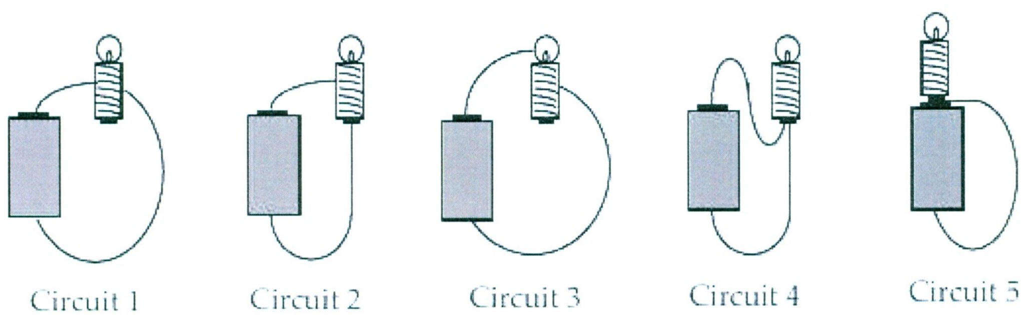
(B) A dims, B stays the same

(C) A and B increase

(D) A and B decrease

(E) A and B remain the same

27) Will all the bulbs be the same brightness?



(A) Yes, because they all have the same type of circuit wiring.

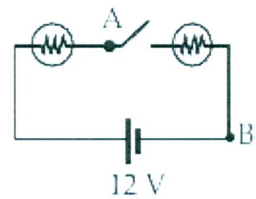
(B) No, because only Circuit 2 will light.

(C) No, because only Circuits 4 and 5 will light.

(D) No, because only Circuits 1 and 4 will light.

(E) No, Circuit 3 will not light but Circuits 1, 2, 4, and 5 will.

28) What is the potential difference between points A and B?



(A) 0 V

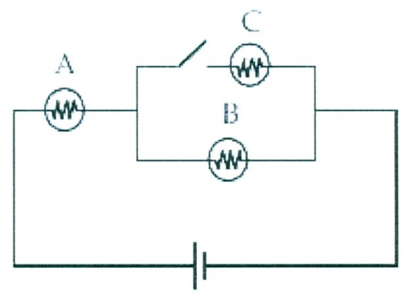
(B) 3 V

(C) 6 V

(D) 12 V

(E) None of the above

29) What happens to the brightness of bulbs A and B when the switch is closed?



(A) A stays the same, B dims

(B) A brighter, B dims

(C) A and B increase

(D) A and B decrease

(E) A and B remain the same

Answers:

Appendix C: Worksheet Questions

1. Describe what "electricity" is, in your own words.

2. Explain what the electrical terms voltage, current, and resistance mean, using your own words.

3. What units of measurement are used to express quantities of voltage, current, and resistance?

4. Voltage is also known by another name: electromotive force, or EMF. Explain what this other name for voltage means.

5. How many physical points must be referenced when speaking of the following electrical quantities?
   a. Voltage
   b. Current
   c. Resistance

   In other words, does it make sense to speak of voltage at a single point, or between two points, or between three points, etc.? Does it make sense to speak of current at a single point, between two points, between three points, etc.?

6. Lightning is a natural, electrical phenomenon. It is caused by the accumulation of a large electrical charge over time resulting from air, dust, and water droplets transporting small electrical charges.

   Explain how the terms voltage, current, and resistance relate to the process of lightning. In other words, use these three terms to explain the cycle of charge accumulation and lightning discharge.

7. What is the difference between DC and AC electricity?

8. Voltage is commonly defined as "electrical pressure." The unit of the volt, however, may be defined in terms of more fundamental physical units. What are these units, and how do they relate to the unit of the volt?

9. Electric current is measured in the unit of the ampere, or amp. What is the physical definition for this unit? What fundamental quantities constitute 1 ampere of electric current?

10. Suppose a battery outputs a voltage of 9 volts. Using algebra, calculate how many joules of energy are imparted to every individual electron moving through this battery.

11. Is it possible to have a condition where an electrical voltage exists, but no electric current exists?

    Conversely, is it possible to have a condition where an electric current exists without an accompanying voltage? Explain your answers, and give practical examples where the stated conditions are indeed possible.