AN INQUIRY-BASED SIMULATION-SUPPORTED APPROACH TO ASSIST STUDENTS' LEARNING OF BASIC ELECTRIC CIRCUITS

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ABSTRACT

Important aspects of teaching and learning are to understand what difficulties students have, why they face these difficulties, and how to help them overcome these difficulties. This research investigated the alternative conceptions that students hold pertaining to the concepts of open circuits and short circuits in a Basic Electric Circuits course. Data gathered from different sources including interviews, tests and documents were analyzed to characterized students' conceptual learning difficulties. The researcher adapted a diagnostic instrument that consists of 12 multiple choice items for the pretest and posttest. The participants were 80 first-year students enrolled in a Diploma in Electrical Engineering programme at one local public university; where 47 students constituted the treatment group and 33 students constituted the control group. The pretest was administered to both groups during the first week of the semester. An inquiry-based simulation-supported approach session was conducted with the treatment group after the pretest. The inquiry-based simulation-supported approach incorporated predict-observe-explain (POE) tasks. The extent to which this approach can assist students' in developing conceptual understanding was investigated. Students' verbal responses during the circuit simulation using Multisim software were recorded and analyzed. The posttest was administered during the final week of the semester to both groups. Research findings are presented in two parts. The first part is a quantitative analysis of students' performance on the pretest and posttest. The second part is a qualitative analysis of students' documents and interviews to identify their alternative conceptions. Findings reveal that the inquiry-based simulation-supported approach positively impacted students' conceptual understanding. The advantages and disadvantages of applying the inquiry-based simulation-supported approach in Basic Electric Circuits are discussed.

ABSTRAK

Aspek penting dalam pengajaran dan pembelajaran ialah memahami apa kesukaran yang dialami oleh pelajar, mengapa mereka mengalami kesukaran ini dan bagaimana membantu mereka menyelesaikan kesukaran ini. Kajian ini menyelidik konsep sampingan yang pelajar miliki berkaitan konsep litar buka dan litar pintas dalam kursus “Basic Electric Circuits”. Data yang dikumpul daripada pelbagai punca termasuk temubual, ujian dan dokumen telah di analisis untuk menyatakan kesukaran pembelajaran konsep pelajar. Penyelidik telah mengadaptasi instrumen diagnosis yang mengandungi 12 soalan pelbagai pilihan untuk untuk kegunaan ujian awalan dan ujian akhiran. Sampel terdiri daripada 80 orang pelajar tahun satu jurusan Diploma Kejuruteraan Elektrik di sebuah universiti awam tempatan; di mana 47 pelajar membentuk kumpulan rawatan dan 33 pelajar membentuk kumpulan kawalan. Ujian awalan kepada kedua-dua kumpulan telah dikendalikan pada minggu pertama semester. Sesi pendekatan simulasi-berbantu berasaskan-inkuiri telah dijalankan dengan kumpulan rawatan selepas ujian awalan. Pendekatan simulasi-berbantu berasaskan-inkuiri ini menggabungkan tugasan predict-observe-explain (POE). Sejauh mana pendekatan ini dapat membantu pemahaman konsep pelajar telah dikaji. Pernyataan daripada sesi perbualan pelajar semasa menggunakan perisian Multisim dirakam dan dianalisis. Ujian akhiran telah dikendalikan pada minggu terakhir semester kepada kedua-dua kumpulan. Dapatan kajian telah dipersembahkan dalam dua bahagian. Bahagian pertama mengambilkira dapatan kuantitatif mengenai prestasi pelajar dalam ujian awalan dan ujian akhiran. Bahagian kedua mengambilkira dapatan kualitatif melalui analisis dokumen dan temubual untuk mengenalpasti konsep sampingan pelajar. Dapatan kajian mendedahkan bahawa pendekatan simulasi-berbantu berasaskan-inkuiri telah memberi impak positif kepada pemahaman konsep pelajar. Kebaikan dan keburukan mengaplikasikan pendekatan simulasi-berbantu berasaskan-inkuiri dalam “Basic Electric Circuits” turut dibincangkan.

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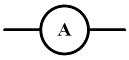
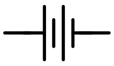
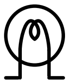
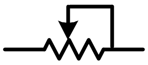
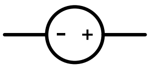
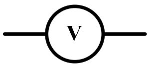
LIST OF ABBREVIATIONS

AC	-	Alternating Current
BEC	-	Basic Electric Circuits
CDR	-	Current Divider Rule
DC	-	Direct Current
KCL	-	Kirchoff’s Current Law
KVL	-	Kirchhoff’s Voltage Law
VDR	-	Voltage Divider Rule

LIST OF SYMBOLS

	- Ammeter
A	- Ampere
	- Battery
	- Bulb
Ω	- Ohm
	- Resistor
R	- Resistor
	- Switch
	- Variable Resistor
	- Voltage Source
	- Voltmeter
V	- Volts

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CHAPTER 1

INTRODUCTION

1.1 Introduction

Education in Malaysia is a growing industry where Malaysia is gaining recognition as a reputable study destination in the region where this sector offers a variety of higher educational programmers as well as professional and specialized skill courses that are competitively priced and of excellent quality (Ministry of Higher Education, 2011). Due to the increasing number of higher education institutions in Malaysia, students are provided with more options and can be selective based on their career aspirations. Engineering education encompasses teaching, learning and assessment activities of engineering and technology at school, college and university levels to develop the knowledge, skills, and attitudes of students. Integrating engineering curriculum across fields is vitally important in improving the quantity and quality of engineering graduates.

Engineering education is the activity of teaching knowledge and principles related to the professional practice of engineering and should provide a method that students can link the basic knowledge and skills from the teaching and experimental to the professional practical experience (Guo and Lu, 2011). Students' achievements in knowledge and skills and their change in attitudes would depend on many factors such as the teaching and learning instructions, assessment methods employed by the lecturers, learning environments and students' own efforts and initiatives (Salim, Daud and Puteh, 2009). Learning is a process of knowledge construction, individually and socially (Zhou, 2010). The success is with the involvement of lecturers and students.

The traditional method of teaching circuits focuses on procedural, quantitative and analytical methods to describe individual circuits because traditional lectures only concentrate on learning 'recipes', or 'problem-solving strategies' without attending to developing conceptual understanding (Richardson, 2002). These methods encourage a surface approach to learning, where students try to follow routine solution procedures and match patterns, rather than a deep approach to learning, where students will develop a conceptual understanding of how the circuits operates (Hudson and Goldman, 2007).

Meaningful learning, which connotes the ability to interpret and use knowledge in situations different from those in which it was initially acquired, requires that students be intellectually active, and have multiple opportunities to use skills in different contexts (Brooks and Koretsky, 2010; McDermott, 1996). Therefore, learning for understanding involves developing recognition of the deep structure of an idea or situation including why and how particular aspects are relevant (Bransford *et al.*, 2006). Brooks and Koretsky (2010) states that learning for understanding makes new learning easier and leads to the development of expertise. Understanding implies that the student do not merely accepted a particular scientific explanation as valid but can explain their ground for doing so, having reasoning in relation to evidence and explanation (Donald, Bohm and Moore, 2009).

Students bring prior knowledge to their learning which will affect how students encode and later retrieve new information (Svinicki, 2008). An incorrect bit of prior knowledge which is not corrected could keep students from understanding an entire lecture (Svinicki, 2008). Naive conceptions of natural laws must be unlearned before the correct version can be understood (DiCerbo, 2007). Information about students' prior knowledge can be used to create more effective lessons and material. It is always a good idea to check for faulty prior knowledge regularly so that it is not allowed to continue to detract from learning (Svinicki, 2008). Students' preconceived ideas can be determined using conceptual tests. Conceptual surveys have become increasingly popular to probe various aspects of science learning such as measuring students' understanding of basic concepts and assessing the effectiveness of instructional material (Wuttiprom *et al.*, 2009).

Successful teaching involves a variety of strategies and techniques for engaging, motivating and energizing students. There are a number of pedagogical techniques, such as collaborative learning, cooperative learning, problem-based learning, that focus on providing activities for learners to perform either in groups or as individuals that help to create deeper, swifter and more effective learning which one of those is in the form of simulations (Britain, 2004). Students' understanding of engineering concepts can be enhanced through the use of hands-on experiments and demonstrations (Williams and Howard, 2007) and in-class simulations (Holton and Verma, 2009) with the ability to help learning process.

Many research findings indicate that the development of teaching and learning sequences and instructional strategies (McDermott, 1996; Prince, Vigeant and Nottis, 2009b; Smaill *et al.*, 2011) should concern important issues in matching students' learning difficulties with instructional strategies (Bransford *et al.*, 2006; Jaakkola, Nurmi and Veermans, 2011; Kearney, 2004; Prince *et al.*, 2009b; Streveler *et al.*, 2006). While the findings of Banky (2005), Banky and Wong (2007) and Holton and Verma (2009) seem to suggest that circuits simulators are well-recognized as effective learning aids in circuits and electronics courses.

1.2 Background of Problem

Engineering faculty need to continue to learn new approaches to teaching and learning (Fink, Ambrose and Wheeler, 2005). One way to rectify misconceptions is by assisting students to clearly visualize the phenomenon and grasp the concept (Choi and Chang, 2004). As engineering education has moved from didactic instruction to more learner-centered methodologies (Bransford, Brown and Cocking, 2000), innovative and interactive technique such as web based (Dollar and Steif, 2009; Yahaya, 2002), simulations (Jaakkola *et al.*, 2011) and demonstration (Pearce, Schmidt and Beretvas, 2004) are being used to teach engineering student (Cameron; Felder and Brent, 2009; Yadav *et al.*, 2011). Furthermore, among significant mistakes committed by teachers is that they fail to add variety to their instructional methods and are unable to motivate students. (Felder and Brent, 2009). There are good reasons to believe that educational technologies have the potential to improve teaching and learning, but to utilize technology effectively to overcome specific content difficulties is challenging (Zhou *et al.*, 2011).

Research in the field of learning electricity has not been restricted to bringing learning difficulties to light, it also addresses these difficulties in order to improve teaching and learning (Holton, Verma and Biswas, 2008). Key to understanding electric circuits is the creation and interpretation of electric circuits diagrams (Marshall, 2008). However, students generally fail to grasp the fundamental concepts and have a poor understanding of the qualitative effect of the circuits (McKittrick, 2007). As a result, students have persistent conceptual difficulties that must be explicitly addressed with multiple challenges in different contexts (McDermott, 1996).

Traditional classroom pedagogies entail students listening to a lecture for about an hour and lecturers focusing on transmitting conceptual knowledge to students; students are rewarded for rote learning rather than for conceptual understanding (Brooks and Koretsky, 2010; Yeung, 2009). However, rote learning lacks flexibility, resulting in nonsensical errors and other difficulties in learning (Gowin and Alvarez, 2005; Mintzes and Quinn, 2007). Learning that is meaningful, rather than rote, requires students master fundamental concepts (Prince, Vigeant and Nottis, 2011b), enabling students to better understand new ideas whether presented in traditional contexts or in educational technology facilitated learning situations (Gowin and Alvarez, 2005).

Conceptual understanding is a prerequisite for students' ability to transfer what they have learned in the classroom to new settings (Prince *et al.*, 2011b). Having learned concepts, students can manage information far more efficiently than would be possible in their absence. Therefore, course material that is constructed on the basis of conceptual understanding of principles would not suffer from difficulties during the procedure of acquisition and will enable learners to monitor their own performance and to detect and correct their own errors (Afra, Osta and Zoubeir, 2009).

When students understand a concept, they do so along a continuum that can be characterized as extending from shallow to deep knowledge (Chen, 2007a; Taraban *et al.*, 2007b). The most prominent outcomes of deep knowledge are longer-term retention of information due to more elaborate cognitive representations of the knowledge and ability to transfer knowledge to novel situations because the knowledge is not tied to specific rote situations and procedures (Taraban *et al.*, 2007b). However, when learning new concepts that do not fit their schema of understanding, students choose to memorize the difficult concepts rather than try to understand them (Afra *et al.*, 2009; Chen, 2007b). Lack of conceptual understanding severely restricts the students' ability to solve new problems since they do not have the functional understanding of how to use their knowledge in new situations (Brooks and Koretsky, 2010).

Many students majoring in Electrical Engineering have problems grasping concepts associated with basic electric circuits' behavior. Even though these concepts has been taught during a Basic Electrical Circuits (BEC) course in an earlier semester, learning difficulties still exist and misconception persist when transferring the concepts to other advanced electrical courses in the following semester. There should be an instructor's ideal goal to teach for the minimum of relational understanding so that students would exhibit fewer misconceptions in their understanding and have more faith in their own knowledge (Mason *et al.*, 2008) However guiding students all the way in conceptual understanding for every concept to be learned may not always be practical.

Grasping concepts associated with electrical circuits and basic electricity is not easy for many students, and they often demonstrate learning difficulties around these topics (Choi and Chang, 2004; Pearce *et al.*, 2004). This is due to the fact that they cannot see electric charge carriers or electrons move through an electric wire

(Pearce *et al.*, 2004; Pfister, 2004). Therefore, conceptual difficulties can be attributed to the fact that electric quantities cannot be directly observed. Such problem will continue to persist if traditional teaching methods are continuously being adopted in class (Choi and Chang, 2004).

To improve student learning, instructors should identify concepts that are difficult for students to understand (Longino, Loui and Zilles, 2006). Lecturers can then change course material or teaching methods to focus on these difficult concepts (Zilles, Longino and Loui, 2006). However, many engineering lecturers emphasize student problem-solving skills almost to the exclusion of understanding the underlying concepts (Brooks and Koretsky, 2010). Conceptual or declarative knowledge is what students know in terms of definitions, facts, and concepts; while procedural knowledge is how they use that knowledge to solve problems (Taraban *et al.*, 2007a).

There should be some corrective methods for the students to grasp concepts and gain deep understanding by helping them to gain conceptual understanding and intuition about the circuits rather than just applying formal analysis (Hudson and Goldman, 2007; Taraban *et al.*, 2007b). The teaching and learning of electricity has been the object of investigations, books and conferences for example Ogunfunmi & Rahman (2011), Smaill *et al.* (2011) and Streveler *et al.* (2006). Previous works by researches show that students encounter deep-level conceptual and reasoning difficulties in understanding introductory electricity (Engelhardt and Beichner, 2004; Getty, 2009; Holton *et al.*, 2008; McDermott, 1996).

Engineering colleges nationwide are urged to transform their pedagogical paradigm from a predominantly lecture-based to an inquiry-based teaching approach (Bernold, 2007) as this method promotes conceptual learning relative to traditional instruction (Prince *et al.*, 2011b). Inquiry-based instruction can be defined as pedagogy whereby students are engaged in fundamentally open-ended, student-centered, hands-on activities (Nelson *et al.*, 2011). Inquiry-based learning is a process in which a student poses a question, develops an experiment, collects and analyzes data, answers the question, and presents the results; this process encourages ‘‘information processing’’ rather than ‘‘information scanning’’ (Buch and Wolff, 2000). In an inquiry-based classroom, the idea is to expose and directly confront misconceptions, not with a lecture but with real-world experience (Prince and Vigeant, 2006).

A simulation was able to improve students’ learning outcomes in electrical engineering compared to laboratory work and was beneficial for students with lower prior knowledge and educative ability (Jaakkola and Nurmi, 2004). Simulations are visualization activities used to integrate theory and practice, they are significant yet enabling students to make connections between concepts (Scalise *et al.*, 2011). Conditions for learning encompasses the atmosphere that the teacher creates in the classroom, through good relationships with students and contents; and stimulating materials with an aim that students will enjoy as well as achieve (Inglis and Aers, 2008).

The main aim of science and engineering curriculum is to help students understand and become able to use the accepted explanations of the behavior of the natural world (Biernacki and Wilson, 2011) while developing students’ understanding of the scientific approach to inquiry (Gowin and Alvarez, 2005). It is projected that in classrooms where there is inquiry-based instruction, students may use more meaningful learning strategies, such as direct investigations and hands-on experiences, because such instruction encourages them to structure meaning from these experiences (Nelson *et al.*, 2011).

1.3 Statement of the Problem

Students are seen to have difficulties in learning electricity concepts which hinders their scientific conceptualization. One of the difficulties is not being able to solve problems due to only shallow understanding of basic electrical concepts. This study is the first step towards addressing student misconceptions with open circuits and short circuits concepts. It is important not only to know what these alternative conception are, but it would be useful to identify a possible source for these conceptions. The step that should be taken after this study is to develop teaching and learning activities to address these alternative conceptions. Alternative conception and misconception are used interchangeably which carries the same meaning.

Alternative conceptions that are resistant to change through traditional teaching methods are obviously of particular interest to educators, especially when misconceptions concern a critically important concepts related to core engineering courses (Prince, Vigeant and Nottis, 2010). This research investigated the possibility that students have misconceptions in both open circuits and short circuits concepts. If this is indeed the case, it suggested possible path for teaching and learning activities.

There are reasons for this research to investigate student misconception with open and short circuits concepts. Imagine students attempting to understand total resistance in a circuit without first having an understanding of open and short concepts; or attempting to explain the working of a circuit without knowing how open circuits and short circuits has an effect on a circuit; therefore they were not only failing to imagine the case of the problems given, but also unable to analyze and evaluate how the circuits works. The concept of open and short are fundamental concepts in a basic electric circuits course in an electrical engineering programme. Although most texts treat the concepts as hidden concept, but this topic should have its own topic in the texts.

The concept of open and short circuits is an essential concept for many later concepts such as total resistance, node analysis, mesh analysis, especially when dealing with Thevenin's theorem and Norton's theorem. Even first order and second order transient circuits involve with open and short circuits. Although open and short circuits are such important concept, students' misconceptions with both concepts have been largely neglected. There has been a study of students' misconceptions of other concepts such as thermal and heat (Prince, Vigeant and Nottis, 2009a), energy and temperature (Prince and Vigeant, 2011), and physics (McDermott, 1996) concepts. However, there is not much research of specific concepts related to basic electric circuits (Ogunfunmi and Rahman, 2010; Sabah, 2007). Misconceptions are robust and pervasive therefore understanding the incorrect models that underlie these basic misconceptions is the first step to correcting them (Smaill *et al.*, 2011).

The concepts of open circuits and short circuits are among the most important and difficult concepts taught in first-year of electrical engineering programme. This research will address first-year concepts and hope that students will succeed in their consecutive courses. Circuit simulator also will be used to demonstrate the working of a circuit. By tackling their learning difficulties through the use of simulators, students' learning difficulties will be overcomed and hence, improved their conceptual understanding. This justifies the importance of formulating the teaching and learning activities to assist students' concept learning.

This study focuses on identifying and investigating changes in students' conceptual understanding through the use of simulation-supported approach on open and short circuits concepts through an inquiry-based incorporated with predict-observe-explain task. This research argues that simulations alone do indicate that students cannot verbalize their conceptual understanding. Therefore, an inquiry-based approach is incorporated with simulation-supported and predict-observe-explain tasks to enable students to visualize basic electric circuits' behavior, analyze findings, and verbalize the explanation about the working of the circuits with reasoning. By incorporating simulation-support with inquiry-based approach, statement that claims simulation alone can help electrical engineering students achieved deep understanding in the subject matter is being refuted. This research contributes to the knowledge is assisting students' concepts understanding in open and short circuits concept of electric circuits using simulation-supported approach with inquiry-based approach incorporated with predict-observe-explain tasks.

1.4 Research Objectives

This research attempts to investigate the understanding of basic electric circuits' concept among first-year electrical engineering diploma students at one local public university. This research explores the students' conceptual understanding of open and short circuits concepts. In addition, this research explores the use of an inquiry-based simulation-supported approach incorporate predict-observe-explain task to assist students' conceptual learning. The findings of this research will guide the development of an effective teaching and learning activity.

The research objectives (RO) can be further detailed as follows:

1. To investigate students' conceptual understanding of basic electric circuits concepts.

2. To develop an inquiry-based simulation-supported approach to assist students' conceptual learning of basic electric circuits concepts.

3. To evaluate students' performance in basic electric circuits concepts after learning with the approach.

1.5 Research Questions

To achieve the above research objectives, the following research questions (RQ) are used.

Objective 1: To investigate students' conceptual understanding of basic electric circuits concepts.

RQ1. What are students' conceptual understandings with regards to open and short circuits concepts?

Objective 2: To develop an inquiry-based simulation-supported approach to assist students' conceptual learning of basic electric circuits concepts.

RQ2. Can students' conceptual learning be assisted through the use of an inquiry-based simulation-supported approach?

Objective 3: To evaluate students' performance in basic electric circuits concepts after learning with the approach.

RQ3. What are students' performances on open and short circuits concepts after learning with the approach?

1.6 Conceptual Framework

A conceptual framework can be represented in graphical form or written in narratives form (Miles and Huberman, 1994; Svinicki, 2010). A conceptual framework can assist the researcher in deciding the types of data to collect and the variables to examine (Miles and Huberman, 1994; Svinicki, 2010). In addition, it guides the researcher during the data interpretation phase (Svinicki, 2010).

Students' grade for Electric Circuits, DDE1103 was also gathered and analyzed. The result was as shown in Appendix D. This university has a policy whereby students who obtained a grade C- or below must repeat the course as this course is prerequisite for Circuits Theory I, DDE2113. Table 1.1 shows students grade for DDE1103.

The grades show that a total of 31.5% of students have to repeat the course in the next semester. This data is used as the starting point to start out the research where one-third of students failed Electric Circuits. Based on work by Streveler (2006) which states that there are both difficult and important concepts that need to be investigated in electric circuits. This research investigated further into students' alternative conception.

Table 1.1: Electric Circuits grade

Section	% Passed (Grade C and above)	% Failed (Grade C- and below)
06	69.8	30.2
07	75.0	25.0
09	68.6	31.4
10	63.4	36.6
11	46.8	53.2
12	51.9	48.1
14	87.2	12.8
15	85.1	14.9
Total %	**68.5**	**31.5**

The conceptual framework for this research is shown in Figure 1.1. The framework is based on the ROs that need to be considered when investigating the concepts and designing the teaching and learning activities. The focus of this research is to investigate students' concept and assist them with inquiry-based simulation-supported approach for conceptual learning in BEC course. The components of teaching and learning activities include simulation, inquiry-based approach and assessment.

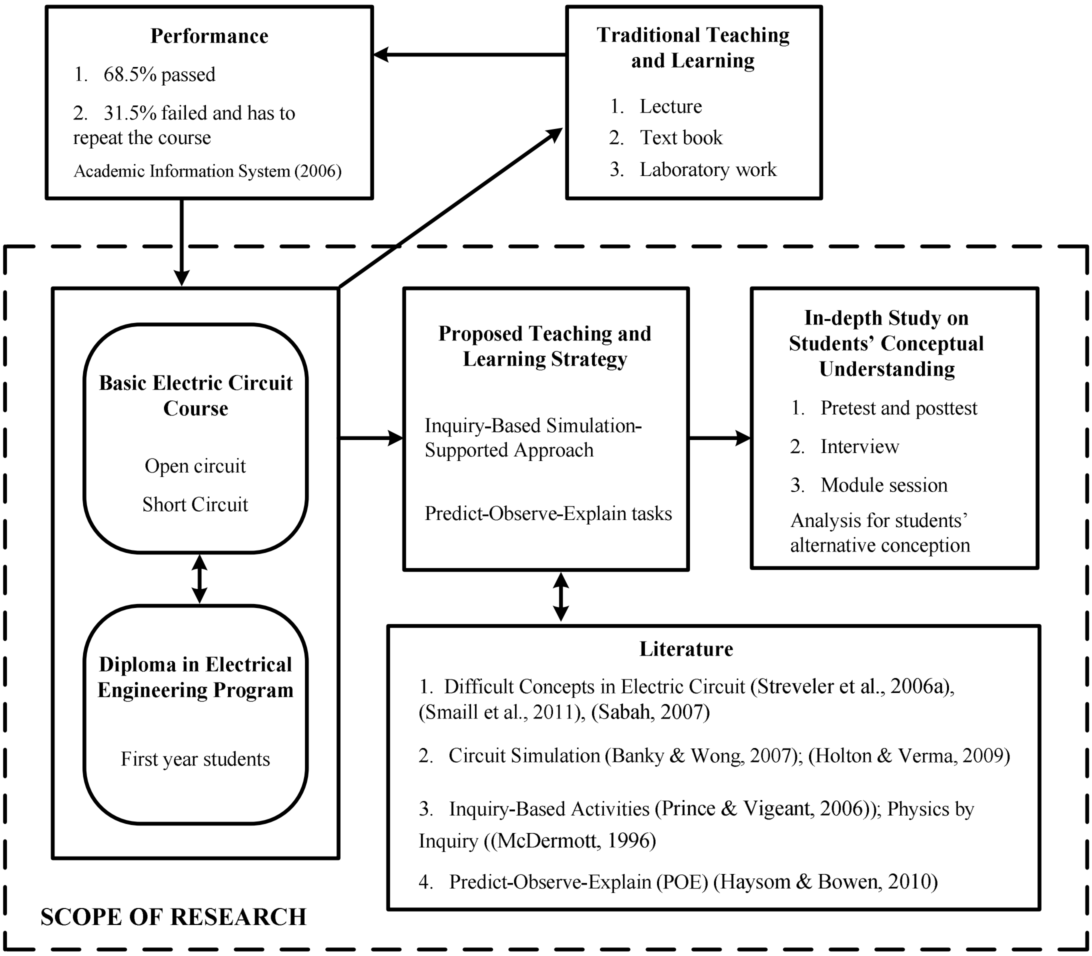

Figure 1.1 Conceptual framework

Students were found to have learning difficulties with important concept in electric circuits course (Streveler *et al.*, 2006) as will be discussed in detail in section 2.2. This is due to a lack of conceptual understanding of basic concepts gained in these courses (Prince *et al.*, 2010). This research adapts one basic electric circuit concept test from Sabah (2007) to investigate students' conceptual understanding is discussed in detail in section 2.3. The reliability and validity of the adapted concept test was performed in this research.

The intervention is an inquiry-based simulation-supported approach incorporated predict-observe-explain (POE) tasks as discussed in detail in section 2.3. The data gathered is analyzed to gain insight into students' understanding. Interviews were also conducted to gain greater insight into students' thinking. The analysis will see the changes in students' conceptual understanding. Findings about students' alternative conception in a BEC will be discussed.

1.7 Significance of the Research

This research offers detail investigation about students' conceptual understandings of open and short circuits concepts in a BEC course. The findings of this research is a significant contribution to enhancing electrical engineering students' conceptual learning in a BEC. Students will understand better the concepts of basic electric circuits and overcome their own difficulties by participating in inquiry-based activities. By verbalizing their conceptual understanding, they will have better retention of their conceptual knowledge. Students become active learners when the learning is incorporated with predict-observe-explain (POE) tasks. Students will have direct interaction and involvement with the learning process which will increase their interest and enable them to acquire scientific knowledge. Overall students will be better equipped with deep conceptual knowledge.

Significant contribution to pedagogy was highlighted in term of identifying an effective approach for teaching and learning activities for open and short circuits concept in BEC. The developed inquiry-based simulation-supported approach will assist students' conceptual understanding especially on willingness of students taking part on inquiry learning which indirectly enhanced their conceptual understanding. The lecturers and university has to be aware of pros and cons when indulging in teaching and learning activities with simulation-supported through inquiry-based approaches. The developed approach will assist lecturers in teaching and learning approaches in a student-centered environment. Through the simulation, several abstract concepts about electricity can be explained and discussed by lecturers easily. The developed approach and lesson plan will serve as a guide for other researchers who are interested in designing an instructional approach for assisting students grasp better conceptual understanding.

1.8 Scope and Limitation of the Research

This research investigates students' concept understanding in a BEC for first-year students taking Diploma in Electrical Engineering programme at one local public university. This research examines the conception that students have of open and short circuits concepts only. This research did not investigate the current teaching and learning strategies used by lecturers and students. Also the researcher did not investigate the methods of assessment used by lecturers.

This research is limited to first-year students who have just entered their second semester of study. They have just finished taking BEC course during their first semester at this university. To meet the purpose of evaluating students' conceptual understanding, the students to be sampled must have taken an Electric Circuits course before. However, grades obtain in the Electric Circuits course will not be used as a selection basis. This research also will not cover other factors such as students' interest, gender, and social background. In fact, students are chosen on a voluntary basis. Also due to space and time constraints, the research was conducted during the students' free time outside their normal class schedules.

The laboratory involved in this research has all the computers installed with Multisim. Also it was confirmed that all the students had used Multisim as their tool for studying BEC during their first semester. This helped this research that the introduction to circuits' simulator software can be kept simple.

1.9 Definition of Terms

This research uses some terms from electrical engineering and education. Listed below are some terms that are used in this work.

1. Concept understanding

   Understanding concepts mean the ability to (Anderson and Schonborn, 2008):

   i. Memorize knowledge of the concept in a mindful manner, as distinguished from rote learning.
   ii. Integrate knowledge of the concept with that of other related concepts so as to develop sound explanatory frameworks.

iii. Transfer and apply knowledge of the concept to understand and solve (novel) problems.
iv. Reason analogically about the concept.
v. Reason logically and globally about the concept (system thinking).

2. Multisim

This research made use of electronic circuits' simulation software, Multisim from Electronics Workbench (EWB). Multisim provides an intuitive drag-and-drop user interface which students can use to build a circuit, insert measuring devices such as voltmeters and ammeters, and simulate the circuits, and observe the results (National Instrument, 2007).

3. Inquiry-based approach

A student-centered environment where the lecturer established the task and support or facilitate the process, but the students pursue their own lines of inquiry (ask questions); draw on their existing knowledge; and identify or interpret the outcomes of learning activities (Kahn and O'Rouke, 2005; McDermott, 1996; Scanlon *et al.*, 2011).

4. Misconception / Alternative conception

A misconception is an idea about or an explanation for a phenomenon that is not accurately supported by accepted physical principles; a mistaken thought, idea, or notion; a false idea or belief; a misunderstanding (American Heritage Dictionary, 2000). There two terms were used interchangeably because they carry the same meaning.

5. Predict-observe-explain (POE)

Developed by (White and Gunstone, 1992) to uncover individual students' prediction and their reasoning about a specific event. POE tasks is to facilitate students' learning conversations in a meaningful way during their engagement with the tasks and to foster student inquiry and challenge existing conceptions that students bring to the classroom (Haysom and Bowen, 2010; Kearney, 2004).

1.10 Organization of the Thesis

Figure 1.2 summarizes the flow of thesis organization. Chapter 1 provides the introduction and background of the research. The objectives of the research and conceptual framework which guide the research are also presented.

Chapter 2 is a review the literature related to the research such as conceptual understanding, teaching and learning activities which are simulation-supported and use an inquiry-based approach incorporated predict-observe-explain tasks. The discussions on the research findings by other researcher are also presented.

Chapter 3 provides the research methods. The details of the participating students, data collection methods, data analysis and issues related to the reliability and validity are described in this chapter.

Chapter 4 presents the development of the inquiry-based simulation-supported approach. The preliminary study that guides the development is discussed. The lesson plans of the developed approach are presented.

The results and discussion of the research are provided in Chapter 5. The results, analysis and discussion related to students' concept understanding are elaborated in this chapter.

Chapter 6 presents the conclusions and reccomendations of the research findings. The achievement on students' conceptual understanding together with several recommendations to improve the current teaching and learning activities are also presented. Lastly, recommendations for further research are also offered.

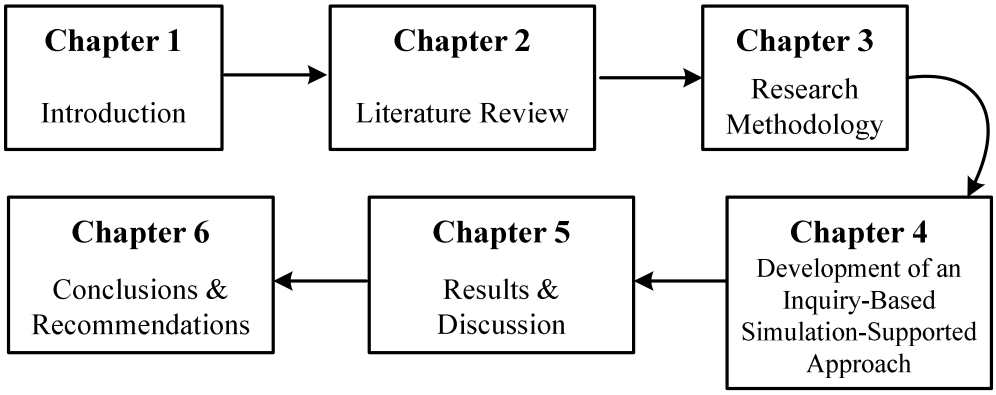

Figure 1.2 Thesis organization

1.11 Summary

This chapter discussed the current teaching and learning issues related to conceptual understanding research in electrical engineering education. The outcome of teaching and learning activities on students' conceptual understanding were also provided. Students have difficulties learning BEC (Ogunfunmi and Rahman, 2010; Smaill *et al.*, 2011; Streveler *et al.*, 2006). The focus of the discussion was on students' conceptual understanding in one local public university in Malaysia. The current teaching and learning activities depends on slide presentations, passive learning, and lecture. Moreover, the students themselves act as passive listener.

To tackle the problem of learning difficulties, this research attempts to assist students' conceptual learning by inducing teaching and learning with simulation-supported activities (Banky and Wong, 2007) incorporated with POE tasks (Kearney, 2004) together with inquiry-based approaches (Prince *et al.*, 2009b). The challenge is to gain deep conceptual understanding. The literature review related to this research is discussed in Chapter 2.

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