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

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A thesis submitted in fulfilment of the
requirements for the award of the degree of
Doctor of Philosophy (Engineering Education)

School of Graduate Studies
Universiti Teknologi Malaysia

OCTOBER 2012

DEDICATION

To my family:

Husband : Zainudin Abdul Razak … for always caring

Mother : Hajjah Siti Fatimah Hj Idris … for always listening

Children : Farah, Hadi, Amir, Anis … for always believing

And in loving memory of:

My father : Haji Hussain Man … for always being a motivator

My daughter : Nur Ain …

Thank you for your loving support of my dream

ACKNOWLEDGEMENTS

In the name of Allah, the Most Beneficent and Most Benevolent. Thank you Allah for bestowing me good health, endurance and perseverance to complete this study. I would like to express my sincere appreciation to those who have made this research and the completion of this thesis possible. My sincere gratitude to “Sisters in EE” who had shared ideas, experience and motivate each other through discussion and get-togethers. The experience of going through this academic journey together was indeed very memorable.

Thank you to my supervisors Assoc. Prof Dr Liza Abdul Latiff and Assoc. Prof Dr Nazli Yahaya for their supervision, support, advice, understanding and continuous encouragement. Thank you to all the professors and senior lecturers who had conducted courses and workshops for the EE group of students. My sincere gratitude also goes to all the lecturers, technicians and students of College of Science and Technology who gave their full support and cooperation in this research.

My gratitude to Assoc. Prof Elliot P. Douglas of University of Florida, Assoc. Prof Dr Rosilah Hassan of UKM, Assoc. Prof Dr Norashidah Md. Din and Dr Yasmin Hanum Md Thayoob of UNITEN for commenting and validating the instruments of my research. Thank you to Dr Kamilah Radin Salim and Ms Arbaiah Inn of UTM Kuala Lumpur for validating my English translation.

Last but not least, my deepest appreciation and sincere gratitude to my beloved family members: my husband, my parents, my children and my siblings for their prayers, support and understanding and prayers throughout this precious time. I dedicate this thesis to my loving family.

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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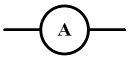
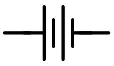
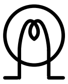
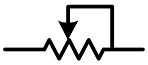
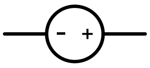
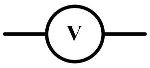
LIST OF ABBREVIATIONS

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.

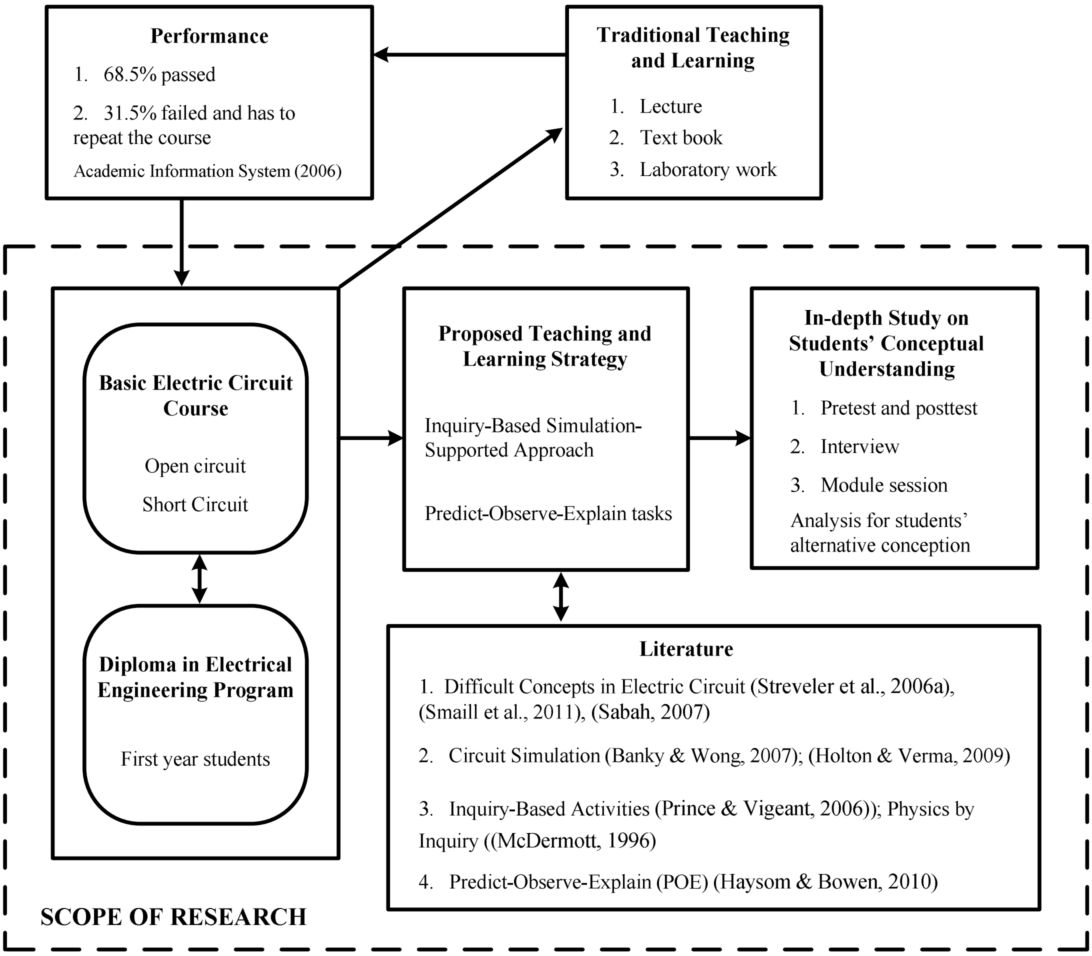


Figure 1.1 Conceptual framework

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.

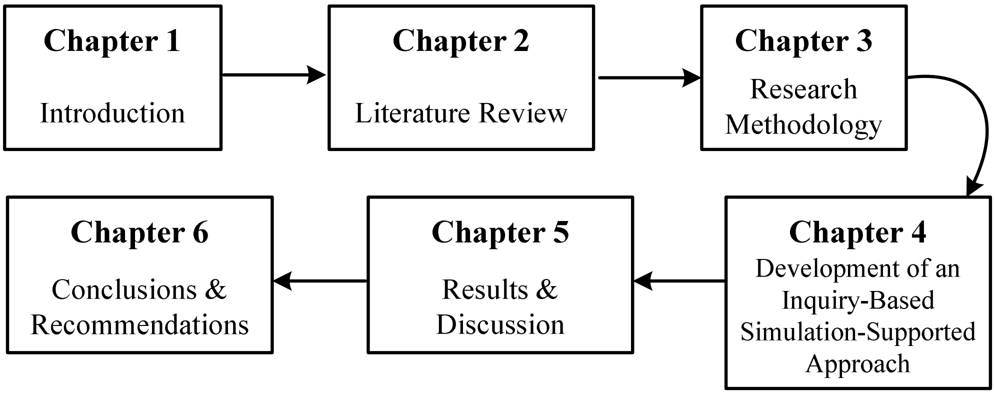


Figure 1.2 Thesis organization

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.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter discussed about the literature related to the study that is being carried out. Several aspects such as students' learning difficulties, alternative conceptions, conceptual learning and understanding will be reviewed. The discussion focuses on the studies carried out by previous researchers.

The discussion starts with students' conceptual understanding related to BEC and its relation to learning difficulties and alternative conception. The discussion proceeds to the teaching and learning approaches globally and in Malaysia and the various methods of enhancement in the BEC teaching and learning activities.

The use of computers and simulations in the process of teaching and learning is also reviewed, especially for BEC to support the research being carried out. The characteristics of inquiry-based and POE tasks to be incorporated into the approach are also discussed.

Finally this chapter describes the BEC course at one local public university in Malaysia. Since the samples of the research are from this institution, the relation between BEC in Malaysia was made with worldwide issues.

2.2 Issues of Teaching and Learning

Engineering knowledge is complex. Therefore discipline concepts cannot usually be introduced to students all at once because building conceptual understanding is a long-term process (Belski, 2008). Research in learning and instruction claims a central role for the concept of knowledge where two most well-known knowledges are declarative or conceptual and procedural knowledge (De Jong and Ferguson-Hessler, 1996; Mayer, 2008). Conceptual knowledge may enhance procedural knowledge and performance as conceptual knowledge may help students identify key features of a problem based on deeper understanding of the domain, as opposed to surface understanding, leading students to properly encode the problem and generate a successful solution (Rittle-Johnson, Siegler and Alibali, 2001). Interaction between students-teachers through the interaction of thinking, feeling, and acting ensure that educating to occur (McDermott, 1993).

Meaningful learning requires that students master fundamental concepts (Prince, Vigeant and Nottis, 2011a). Meaningful learning, or learning for understanding occurs when students try to make sense of the materials presented to them, and is distinguished from rote learning, or learning by memorizing (Gowin and Alvarez, 2005; VanDijk and Jochems, 2002). In rote learning, material presented is not well integrated with existing knowledge which results in good retention but poor transfer; while meaningful learning is manifested by good retention and also good transfer performance (Mayer, 2008).

Conceptual knowledge is an understanding of concepts, operations and relations of principles governing a domain and the interrelations between units of knowledge in a domain which elaborate the question but does not really answer it (Streveler *et al.*, 2003). Understanding a concept means the ability to memorize knowledge of the concept in a meaningful manner, integrate knowledge, transfer and apply knowledge of the concept to understand and solve a problem, reason analogically; and reason locally and globally about the concept (Anderson and Schonborn, 2008). Conceptual understanding has been achieved when students know and understand a concept, and when can elaborate into generalization

(Milligan and Wood, 2010). Different terms are used in the literature to refer to students' conceptual understanding such as alternative conception and misconception (Bransford *et al.*, 2006; Engelhardt and Beichner, 2004; Prince *et al.*, 2009b; Smaill *et al.*, 2011; Streveler *et al.*, 2006; Treagust, 2006).

Level of learning is characterized either deep or surface (Houghton, 2004). Deep learning promotes understanding as it involves the critical analysis of new idea, linking them to already known concepts and principles. This leads to understanding and long-term retention of concepts so that they can be used for problem solving in unfamiliar contexts (Houghton, 2004). Surface learning, which does not promote understanding, is the tacit acceptance of information and the memorization of isolated and unlinked facts (Houghton, 2004).

Students' preconceptions play an important factor in determining their deep understanding (Streveler *et al.*, 2008). Failure to grasp prerequisite concepts will leave students poorly prepared for more advanced study (Vigeant, Prince and Nottis, 2009). If students fail to engage key conceptual knowledge to determine the deep features of a problem, then they will ultimately fail to solve the problem accurately (Streveler *et al.*, 2008). Therefore it is really important for students to have deep understanding of fundamental concepts. Students' face difficulties in conceptualizing difficult concepts thus leading to misconceptions (Turkmen and Usta, 2007) due to lack of deep understanding of fundamental concepts in their fields (Miller *et al.*, 2006; Streveler *et al.*, 2006). One reason for misconceptions is a mismatch between the understanding of a basic science concept and students' cognitive level.

Identification of a misconception is the first step to bringing about change. The process of identification will highlight specific erroneous ideas that students hold (Carle, 1993). Correcting misconceptions requires firstly that learners be both aware of the misconception and dissatisfied with it, and secondly that a replacement concept be available that is intelligible, plausible, and applicable (Turkmen and Usta, 2007).

Educators have observed that today’s students exhibit shorter attention spans and are less tolerant of static media (Millard and Burnham, 2003) and make them passive learners. Instructors should design instructional activities that allows learners of every learning style to engage in active learning during the semester and that have positive effects on learning outcomes and satisfaction (Millard and Burnham, 2003). Therefore, as a solution to shorter attention span, one approach that incorporates simulation-supported will be developed as a method for engaging students in visualizing the outcome of the simulation.

Teaching for conceptual understanding has been heralded as an effective approach within many curriculum frameworks internationally (Milligan and Wood, 2010; Streveler *et al.*, 2008; Taraban *et al.*, 2007a). Teaching of conceptual understanding lies in the linkages between contexts, ideas, and information which enables students to make connection (Milligan and Wood, 2010). It is beneficial for lecturers to initially elicit students’ conceptual understanding to properly address students’ alternative conceptions during the learning process (Gonzales, 2011). However, conceptual understandings are better understood as transition points rather than endpoints (Milligan and Wood, 2010). As a result, it is important to investigate and assist students in overcoming concept difficulties.

As suggested by Scott *et al.* (1998), that there are pedagogical decisions; firstly, the teacher needs to foster a *learning environment* which will be supportive of conceptual change learning. Such an environment would, for example, provide opportunities for discussion and consideration of alternative viewpoints and arguments. A second level of decision-making involves the selection of *teaching strategies,* in terms of overall plans which guide the sequencing of teaching within a particular topic. Finally, consideration must be given to the choice of specific *learning tasks*, which fit into the framework, provided by the selected strategies and must address the demands of the particular science domain under consideration (Scott, Asoko and Driver, 1998). To ensure that fundamental knowledge is acquired and that students have been exposed to the key content on which later courses are built, attempts to develop the mode of course delivery towards a more student-centered approach should be encouraged (Ambikairajah and Epps, 2011).

Concept inventories have been developed for a variety of disciplines such as heat transfer (Prince *et al.*, 2009a); physics (Engelhardt and Beichner, 2004; Hestenes, Wells and Swackhamer, 1992); and electric circuits (Ogunfunmi and Rahman, 2010; Smaill, Rowe and Godfrey, 2008). These evaluate students' fundamental understanding of topics or courses within specific discipline at the conceptual level.

Concept tests aim to assess how well students understand key concepts; prior to instruction through the revelation of the prior knowledge they bring to the class; during the instruction by measuring the conceptual gains; and after instruction by identifying the concepts that are weak understood (Zeilik, 1998). Concept tests are not a test of intelligence; rather they probe of belief systems and are ideally used as pretests and posttests (Hestenes *et al.*, 1992). For the purpose of this research, one concept test is adapted from Sabah (2007) with items in a multiple-choice or short answer format and reasoning that has been designed with common misconceptions in mind.

Therefore, the goal of students' learning is not just only for students to be successful at selecting the right answer. It is for them to achieve real conceptual understanding.

2.3 Conceptual Understanding in Basic Electric Circuits Courses

Basic electric circuit courses are the gate to the electrical engineering discipline. These courses serve to educate engineering students about the fundamental behavior of the active and passive elements of a circuit, and advance into the basic concepts and laws in a circuit or system (Ogunfunmi and Rahman, 2010). In these courses, students are introduced to the application of physical laws: Ohm's, Faraday's, and Kirchhoff's; to electrical engineering fundamental elements: resistors, inductors and capacitors; and their responses: voltage, current and power in direct current (DC) and alternating current (AC) for their behavior in transient and steady state.

Students need to have conceptual understanding of many details of electric circuits beyond just solving equations so that they are able to formulate proper equations from the given information or vice versa (Ogunfunmi and Rahman, 2010). It was proven that engineering students who are academically successful often lack deep understanding of basic and fundamental concepts in their field (Miller *et al.*, 2004; Streveler *et al.*, 2008). This indicates that students' achievement on examinations does not reflect their deep understanding of a specific discipline concept.

2.3.1. Learning difficulties

In teaching electric circuits' course, there are some key concepts that are important and need to be tested so as to ensure student learning and comprehension. The teaching and learning of electricity has been the subject of many investigations, book and conferences (Banky and Wong, 2007; Duit and Treagust, 2003; Psillos, 1998) and are the same across countries (Marshall, 2008; Smaill *et al.*, 2011). Some researches show that students encounter deep-level conceptual and reasoning difficulties in understanding introductory electricity (Psillos, 1998; Sabah, 2007). The development of teaching sequences (Psillos, 1998) and instructional strategies (McDermott, 1993; Prince and Vigeant, 2006) should concern important issues in match students' learning difficulties with concepts to be delivered.

Concept of basic electric circuits is selected based on work by Streveler *et al.* (2006) that was identified as both difficult and important concepts. They ranked 27 difficult concepts where one of the identified concepts in the list was Thevenin and Norton equivalent circuits. However, which concepts require further investigation is still not clear (Streveler *et al.*, 2006). Nevertheless, Thevenin and Norton equivalent circuits understanding builds upon many other concepts as shown in Appendix E. Therefore, in order to master Thevenin and Norton, many prerequisite concepts need to be master first.

The Thevenin and Norton equivalent circuits requires understanding of the total resistance, current and voltages distribution in the circuits during open and short conditions, applying mesh and node analysis; and sometimes performing source conversion (Agarwal and Lang, 2005; Boylestad, 2004; Dorf and Svoboda, 2004; Irwin, 2002). In addition, the open and short circuits concept chosen as an important concepts was proven by researchers' preliminary study (Hussain, Latiff and Yahaya, 2009) as will be discussed in detail in section 4.2. The data were also gathered through document analysis and informal discussion in class and in laboratory. Furthermore, the concept of open circuits and short circuits are also required when understanding transient analysis in the AC circuits (Agarwal and Lang, 2005; Boylestad, 2004; Dorf and Svoboda, 2004; Irwin, 2002). Therefore this research attempts to investigate students' understanding of the open and short concept of BEC (Afra *et al.*, 2009).

One concept inventory for electric circuits has been developed by (Ogunfunmi and Rahman, 2010). Their questions measures students' understanding of different aspects of DC circuits' analysis. However, the concepts involved do not address open and short circuits concepts extensively since only one circuit is used to test both concepts. Persistent conceptual difficulties must be explicitly addressed by multiple challenges in different contexts (McDermott, 1993). Therefore, this research has made an initiative to delve more into open and short circuits concept.

The knowledge inventory instrument called Determining and Interpreting Resistive Electric circuits Concepts test (DIRECT) (Engelhardt and Beichner, 2004) considers electric circuits from a Physics point of view. The instrument, with 29 questions, was used to study several groups of university-level physics students. The adapted concept test from Sabah (2007) is based on DIRECT but was upgraded to a two-tiered concept test called DIRECT-TTC which consists of 15 questions. Two-tier items compensate for the limitation of simple multiple choice items that cannot measure the reason for selection on alternatives. For this research, the researcher also amended the adapted concept test as shown in Appendix G. It includes 12 questions.

2.3.2. Alternative conception

Alternative conception or misconception is generally defined as something a person knows and believes but does not match what is known to be scientifically correct (American Heritage Dictionary, 2000). When misconceptions are interwoven into learning, they interfere with reception of new information (Svinicki, 2008). One way to rectify misconceptions is by assisting students to clearly visualize the phenomenon and grasp the concept. For electric circuits, visualization can be accomplished via simulation. Therefore, in this research study, a simulation approach was developed to bring about visualization and understanding of the abstraction of electricity by pointing to similarities in the real world.

Among alternative conceptions in electric circuits found by Streveler *et al.* (2006) are students believe that voltage and current is a substance that has location, and is able to be consumed or contained. Also students talk about voltage as being a property of a particular location, not the charge difference between two locations (Streveler *et al.*, 2006).

Research done by McDermott (1993) suggests several steps to be taken as an instructional strategy for BEC courses. Firstly is by introducing concept of complete circuits, secondly is by introducing concept of current, thirdly is by introducing concept of resistance and equivalent resistance, and fourth, is by introducing ammeters, voltmeters, and concept of potential difference; and finally, introduce concepts of energy and power. Therefore this research will align the approach according to McDermott suggestion with the intention of reducing difficulties faced by students.

Some research have identified students' understanding of important and difficult engineering concepts. Among these are current flow, closed circuits and current division (Engelhardt and Beichner, 2004; Nelson *et al.*, 2005); and the notion that a light bulb "uses up" current (Pfister, 2004; Zeilik *et al.*, 1997). The results of the study will help lecturers repair student misconceptions so that students can develop a deep understanding of the most basic concepts of engineering (Nelson *et* *al.*, 2005; Streveler *et al.*, 2008). Therefore, this research will attempt to identify alternative conceptions held by Diploma in Electrical Engineering students at one local public university.

2.4 Teaching and Learning Approaches

Many researchers aimed to create teaching and learning activities focused on active participation for improved students' learning process and consequently achieve better understanding. These include activities which were inquiry-based (Prince *et al.*, 2011b), technology-assisted (Abdullah and Shariff, 2008; Aziz, 2011), cooperative task-based (Benson *et al.*, 2010), problem-based (Akçay, 2009; Khairiyah *et al.*, 2005), and project-based (Ambikairajah and Epps, 2011). Students' learning achievements were then assessed to see the outcome of the activities. The information provided through examinations can be used by lecturers to evaluate their instructional methods and the progress and conceptual problems of their students (Engelhardt, 1997; Prince *et al.*, 2010).

Traditional instruction based upon "telling" and heavy reliance on theory and computation is not highly effective at developing accurate conceptual knowledge (Bransford *et al.*, 2000). In traditional pedagogy, the teacher is at the center of the learning process and determines what the students learn and how they learn it. The primary method of learning was to have students memorize and taking notes. This research seeks to adapt the inquiry-based model to assist students in learning concepts in basic electric circuits.

Good teaching is open to change and it involves constantly trying to find out what the effects of instructional practice are on learning, and modifying that instruction in light of the evidence whether it is effective changing student learning (Akhtar, 2007). The consensus which has been achieved gradually among researchers concerning students' learning difficulties has not brought about the consensus on pedagogy (Duit and Rhoneck, 1998; Streveler *et al.*, 2003). Thus, this research attempts to incorporate simulation-supported with inquiry-based to allow students become the owner of the learning process.

Even though there are few teaching and learning activities available for enhancing conceptual understanding, this research attempts to identify the most suitable strategies for the facilities available in the university under study. Therefore, it is very important for the researcher or lecturer to obtain the status of what the university or the institution has when planning for teaching and learning activities. Traditional teaching-and-learning environments often do not address the learning needs of today's "millennial" generation of students who prefer team work, experiential activities, structure and the use of technology (Albuquerque *et al.*, 2010). In fact, students nowadays view technology as a necessity, both in life and in learning and highly regard "doing rather than knowing", making interactive experiential learning a necessity for their educational success. (Albuquerque *et al.*, 2010). Therefore, everybody needs to acknowledge the increasing role and impact of technology on education and training.

2.4.1. Inquiry-Based Teaching and Learning

Inquiry-based teaching theory is a pedagogical approach that invites students to explore academic content by posing, investigating, and answering questions (Guo and Lu, 2011). Inquiry-based classroom is characterized as ‘‘teacher-student verbal exchanges that take place in classroom settings where students learn science by posing questions, proposing and revising evidence based explanations and solutions, and using the language of science processes’’(Ash and Kluger-Bell, 1999). These activities provide an alternative theoretical foundation for rethinking and redesigning teaching practices (Guo and Lu, 2011).

It is widely accepted by (Apedoe, Walker and Reeves, 2006; Donath *et al.*, 2005; Friedman *et al.*, 2010; Kephart and Ieee, 2008; Motschnig-Pitrik *et al.*, 2007; Oliver, 2007; Prince *et al.*, 2011b) that in the higher education a student-centered approach is pedagogically superior to a teacher-centered approach. Students’ conceptual understanding can be dramatically enhanced through a paradigm shift in teaching that incorporates inquiry-based methods (Prince and Vigeant, 2011; Vigeant *et al.*, 2009). Inquiry is closely connected to scientific questions where students must inquire using what they already know and the inquiry process must add to their knowledge (National Research Council, 2000).

An inquiry-based method is an inductive and collaborative teaching and learning method where students are placed in carefully designed situation where reality, rather than the lecturer, can dispute their preconceptions (Guo and Lu, 2011; Vigeant *et al.*, 2009). Inquiry-based instructional practices particularly instruction that emphasizes student active thinking and drawing conclusions from data are favorable (Minner, Levy and Century, 2010). Therefore, lecturers must assist students to reflect on the characteristics of the processes in which they are engaged so that experience and understanding of scientific knowledge go together (National Research Council, 2000). Inquiry-based approach improved depth of understanding, reduced misconceptions and increase longer-term recall of the principles (McDermott, 1996). However, whether it is the scientist, student, or teacher who is doing or supporting inquiry, the act itself has some core components because this approach focused on the process of learning rather than outcomes (Guo and Lu, 2011).

Table 2.1 summarized the definition about inquiry-based teaching and learning in classroom proposed by the National Research Council (2000) viewed from learner’s perspective. This research will comply with all the criteria mentioned:

Table 2.1: Essential feature of classroom inquiry

- ✓ Learners are engaged by scientifically oriented questions.
- ✓ Learners give priority to evidence, which allows them to develop and evaluate explanation that address scientifically oriented questions.
- ✓ Learners formulate explanation from evidence to address scientifically oriented questions.
- ✓ Learners evaluate their explanations in light of alternative explanations, particularly those reflection scientific understanding
- ✓ Learners communicate and justify their proposed explanations.

The teaching and learning approach for this research is designed to incorporate simulation-supported inquiry-based approach with an aim to assist students’ understanding of circuits to clarify the conceptual understanding of open and short circuits. This approach may not be a problems solving technique, but offers an alternative to teaching and learning activities. The inclusion of inquiry strengthens an engineering curriculum and complements the active-learning approach of increased class interaction (Buch and Wolff, 2000). Students’ scientific knowledge is deepened as they developed new understanding through observation and manipulation of conditions in the natural world (National Research Council, 2000).

As students work through the inquiry process, the instructors (Alberta Education, 2004):

motivates students to locate, analyze and use information.
assists students to clarify thinking through questioning, paraphrasing and talking through tasks.
provides students with opportunities to record information.
provides students with opportunities to focus on steps required to complete their inquiries.
individualizes teaching.
evaluates student progress in content and process areas.
models inquiry behaviours (e.g., demonstrating and modelling the inquiry-based learning process).
facilitates and models questioning behaviours (e.g., providing opportunities for students to develop and ask questions).

One inquiry-based methods called guided-inquiry is popular in science learning where students are asked to pose questions, develop experiments to try to answer those questions, analyze information obtained from those experiments and draw conclusions (Edwards and Recktenwald, 2008). Guided-inquiry tries to focus the discussion a little more narrowly through questions posed by the instructor to help the students to develop a deeper understanding of core principles (Edwards and Recktenwald, 2008; Moog, 2012). Therefore, this research incorporates simulation-supported with inquiry-based approach and specifically guided-inquiry approach.

Guided-inquiry approach provides instructors with instant and constant feedback about what their students understand and misunderstand (Moog, 2012). Students quickly pick up the message that logical thinking and teamwork are prized above simply getting “the correct answer.” This emphasized that learning is not a solitary task of memorizing information, but an interactive process of refining one’s understanding and developing one’s skill (Kussmaul, 2011; Moog, 2012). Guided inquiry is a student-centered strategy with a learning cycle of exploration, concept invention and application; as the basis of the carefully designed materials that students use to guide them to construct new knowledge. This approach develops communication through cooperation and reflection, helping students become lifelong learners (Hu and Kussmaul, 2012).

2.4.2. Circuits Simulation

An educational simulation can be defined as a model representing some phenomenon or activity that users learn from by interacting with the model (Alessi and Trollip, 2001). Computer simulation gives student imaginary elements such as coaching, feedback, hints, tools to make complex phenomena easier and more comprehensible to learners while giving the unique opportunity of experiencing and exploring learning environments, and real life phenomenon in a classroom or anywhere else (Alessi and Trollip, 2001).

Students prefer simulations to lectures, textbooks or other passive methods which are more motivating and enhance transfer of learning and also more efficient in enhancing thinking (Alessi and Trollip, 2001). A computer simulation can increase interactivity, individualization, and independent learning (Banky and Wong, 2007). With simulation, students can visualize complicated and even hard-to-imagine abstract scientific concepts, conveying complex ideas that are difficult to convey with static images (Dollar and Steif, 2009). The developed approach gaves the opportunity to students to actively investigate problems using computer simulations, combined with activities that encouraged students to directly consider their prior experience, and encourage students to construct more robust view of BEC.

Popular simulation software tools used by electrical engineering students are Pspice, MATLAB, Multisim and Labview. However due to the facilities available for this research and students' exposure to simulation software, only Multisim is used. Students can further comprehend the structure and working of electric circuits through simulations. In engineering education, simulations of experiments are aimed at preparing students for engineering experience practice by exposing them to relevant engineering fields.

Students learn best when they can address knowledge learned in ways that they trust. The simulation-supported approach encourages students to learn by doing, not just listening, and to improve student understanding of difficult concepts (Thomassian and Desai, 2008). A simulation will be able to improve students' learning outcomes compared to laboratory work and benefit students with lower prior knowledge and educative ability (Jaakkola and Nurmi, 2004). The advantages of using simulators include (Banky, 2005; Banky and Wong, 2007):

1. Allowing the users to modify system parameters and observe the outcomes without any harmful effects.
2. Eliminating component or equipment faults that affect outcomes.
3. Support user paced progress in discovery and understanding of issues.
4. Facilitating deep learning.

Multisim software is an easy to use tool that enables design and simulation of electric, electronic and digital circuits with built-in large databases, schematic entry and simulations that gives users an opportunity to create interesting didactic education examples with friendly interfaces (National Instrument, 2007). Multisim equips educators, students, and professionals with the tools to simulate and analyze circuits' behavior.

Different models of teaching and learning suggest that the best strategy is to use a variety of teaching approaches in different courses and even in different stages of the same course (Guizhu, 2005). It seems that lecturing alone is not sufficient if the quality of teaching and learning is to improved. Lecturers should use a multi facetted approach that integrates technology with effective learning and teaching practices (Turkmen and Usta, 2007). One student simply noted *"Demo can help students to understand the concepts … more than explaining could ever do"* (Pearce *et al.*, 2004). Therefore the developed approach integrating inquiry-based with simulation is implemented to students as a tool for an effective teaching and learning approach.

2.4.3. Predict, Observe, Explain (POE) Tasks

Understanding and experience can be gained through numerous instructional strategies. Social constructivism is the theoretical perspectives used in this study (Kearney, 2004; Kearney and Treagust, 2001). Constructivism emphasizes integrated curricula and having teachers use materials in such a way that learners become actively involved (Schunk, 2009). Consequently, students are considered to learn science through a process of construction, interpreting and modifying their own representations of reality based on their own experience (Kearney, 2004). Language plays a key role in the social constructivist perspective where students verbalization of rules, procedures and strategies can improve students learning (Schunk, 2009).

One of the strategies is predict-observe-explain tasks which facilitate students' 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). Many responses gathered by Haysom and Bowen, (Haysom and Bowen, 2010) mentioned among others were *"POEs have given me more insight into the misconceptions students bring with them into a science class,"* also *"They have shown me that it is important for all students to reflect on their understanding of concepts and to verbalize it before and after the POE experience."* Therefore, this research involves incorporation of POE tasks into simulation-supported approach in order to elicit students' conception of open and short circuits concepts and encourage discussions about their understanding. The POE tasks approach design starts with developing teaching and learning activities that enhance students' understanding of important scientific concepts (Liew and Treagust, 1998).

The basic POE procedure follows three steps: first, students make ***p**redictions* about an upcoming event; second, instructors present a demonstration for ***o**bservation*; and finally students ***e**xplain* the outcome (Haysom and Bowen, 2010; Kearney, 2004). The POE sequences have provided an important way to enhance students' understanding of important scientific ideas. The detail task sequences are:

Step 1: Orientation and Motivation

The POE usually begins by drawing on students' past experiences or previous understanding and raises a challenging question that can be addressed through the experiment that follows. A few minutes of full-class discussion provide the students with the opportunity to reflect on their past experiences and understanding.

Step 2: Introducing the Experiment

Introduce the experiment. Linking it to the previous discussion will help make it meaningful.

Step 3: Prediction: The Elicitation of Students' Ideas

Before doing the experiment, ask students to write down on a worksheet what they predict will happen, along with the reasons for their predictions. This exercise is valuable for both the students and the teacher. Making their reasons explicit helps the students become more aware of their own thinking. It also provides lecturers with useful insights and an opportunity to plan ahead. Hence, while students are writing, lecturers might stroll around so as to get ready for the discussion that will follow.

Step 4: Discussing Students Predictions

This is a two-stage process. First, ask students to share their predictions in discussion. This needs to be handled with sensitivity as some students' will feel anxious about seeming "wrong." Hence, lecturers need to be supportive and encourage as many students as possible to express their viewpoints. There are no poor ideas! All ideas are valued because students represent their best efforts to make sense of the world. Explain that making predictions explicit helps us learn.

After this is done, one might invite the class to discuss which predictions and reasons they now think are best. When students reconsider their reasons, some may begin to change their minds and reconstruct their thinking. Immediately prior to the experiment, it is often fun and illuminating to have a straw vote about the outcome.

Step 5: Observation

If you demonstrate the experiment, invite the students to help out whenever appropriate. Ask students to write down their observations.

Step 6: Explanation

Students often reshape their ideas through talking and writing. That was frequently found that it is useful for students to discuss their explanations of what they observed with peers or in small groups before formulating a written explanation. Students seem to find this action reassuring. Invite a full-class discussion of these as appropriate.

Step 7: Providing the Scientific Explanation

Introduce the scientific explanation by saying, “This is what scientists currently think,” rather than, “This is the right explanation.” Students write the explanation in their activity record sheets. The students might then be invited to compare their explanations with those of scientists, looking for similarities and differences (another opportunity for them to reconstruct their ideas).

Step 8: Follow-Up

Researchers have found that students’ idea often are resistant to change and there is no guarantee that a POE will do the trick, even though it might provide a valuable beginning. This often is designed to help the students reconsider or apply the scientific ideas they have just encountered and begin to appreciate how useful they are for explaining natural phenomena.

POE procedures will enable lecturers to focus on facilitating learning by responding to students needs. A major strength of POEs is that they can continuously provide lecturers with insights into students' thinking: Steps 1 through 4 probe students' initial conceptions, Steps 6 and 7 enable lecturers to monitor students' efforts to reconstruct their thinking, and Step 8 provides lecturers with feedback on students' progress (Haysom and Bowen, 2010). POEs thus can offer lecturers "authentic responses" from students, provided that judgment and assessment do not come into play. For this research students' are encouraged to verbalize their thinking because their responses are very valuable to their conceptual learning.

From a social constructivist perspective, the collaboration use of the POE strategy offers students the opportunity to articulate, justify, debate and reflect on their own and peers' science views and negotiate new and shared meanings (Kearney, 2004). The developed simulation-supported approach for this research combines POE tasks and with an inquiry-based approach to investigate students' conceptual understandings. The interplay between POE and inquiry-based approach is the best match for making predictions about the abstraction of circuits operation; observing simulated output; and explaining simulation output. These POE tasks force students to see multiple perspectives that result in knowledge acquisition through authentic demonstrations which require exploration of thought processes that lead to specific predictions (Treagust, 2006).

2.5 Basic Electric Circuits at One Local Public University

Students taking Diploma Electrical Engineering at one local public university are from four main fields: electronic, communication, mechatronics and power. It is mandatory to take all three circuits courses where the earlier one is the prerequisite to the later one. The courses are Electric Circuits in semester 1, Circuits Theory 1 in semester 3, and Circuits Theory 2 in semester 4 as shown in Table 2.2. The courses learning outcomes are as shown in Appendix A, B and C.

Table 2.2: Circuits courses for Diploma in Electrical Engineering

Circuits Course	Course Name	Credit Hour	Semester Offered
DDE1103	Electric Circuits	3	1
DDE2113	Circuits Theory 1	3	3
DDE2123	Circuits Theory 2	3	4

Students are taught the fundamental concepts of Electrical Engineering in the first semester followed by advanced concepts during following semesters. The aim of these courses is to enable the students to understand the basic rules and methods of analysis and so provide a solid basis for students pursuing their study. There are many important and difficult concepts that are taught in these courses that need to be understood conceptually. The concepts taught are continually built upon one to complexity (Chen, 2007a). Unfortunately, many students find it difficult, boring, full of formulae, many new concepts, and the content too broad and too complicated. The most important teaching factor contributing to student boredom is the use of PowerPoint slides (Mann and Robinson, 2009).

Inquiry-based activities have not been systematically developed for engineering education (Vigeant *et al.*, 2009) or more specifically in electrical engineering. This work seeks to fill the gap of developing inquiry-based activities for electrical engineering students at one local public university in Malaysia. Two concepts in basic electric circuits have been targeted to be explored. To assess the effectiveness of this approach, a concept test has been adapted and given as a pretest and posttest to the students.

Learning precedes most effectively if (Olson and Hergenhahn, 2009):

1. Small steps: The information is exposed to learners in small amounts and proceeds from one frame or one item of information to the next in an orderly fashion. This is what is meant by linear program.
2. Overt responding: Required so that students' correct responses can be reinforced and their incorrect responses can be corrected.

3. Immediate feedback: The learners are given rapid feedback concerning the accuracy of their learning (they are shown immediately after the learning experience whether they have learned the information correctly or incorrectly).
4. Self-pacing: The learners are able to learn at their own pace.

With the integration inquiry-based, simulations and POE tasks produced an effective teaching and learning practices.

2.6 Scope and Finding from Other Research

Literature on ranges of teaching and learning activities in electrical engineering, inquiry-based, simulations and POE tasks are reviewed. Various studies were analyzed and the researcher has identified the specific teaching and learning activities related to each of the research objectives. Table 2.3 shows literature on identifying and investigating important and difficult concepts in BEC and its' relation to students' conceptual understanding.

Table 2.3: Identifying and investigating difficult concepts

Author/Year	Scope/Field	Findings
(Streveler *et al.*, 2006)	• Identifying and investigating difficult concepts • In engineering mechanics and electric circuits • Delphi study	• Students who are academically successful often lack a deep understanding of fundamental concepts in their field. • Must help students to create accurate mental models. • Produce list of important and difficult concepts in electric circuits and engineering mechanics

Author/Year	Scope/Field	Findings
(Streveler *et al.*, 2008)	• Learning conceptual knowledge • Most common conceptual difficulties • Possible sources of those difficulties	• Difficulties from three domain: mechanics, thermal science and direct current electricity • Students come to classes with conceptual knowledge that is under development and is likely to contain incorrect information

The discussion proceeds to the teaching and learning approaches and the various methods of enhancement in the BEC teaching and learning activities as shown in Table 2.4. The use of computers and simulations in the process of teaching and learning is also reviewed, especially for BEC to support the research being carried out. The characteristics of inquiry-based and POE tasks to be incorporated into the approach are also discussed.

Table 2.4: Teaching and learning of BEC

Author/Year	Scope/Field	Findings
(McDermott, 1993)	• Physic by Inquiry • Learning and teaching physics • Innovative reforming of introductory course	• Traditional instruction • Generalization about learning and teaching • Improving match between learning and teaching • Meaningful learning requires that students be intellectually active
(Kearney, 2004)	• Predict-Observe-Explain • Multimedia-supported Learning environment • Learner control	• Students' learning conversation • POE as diagnostic tool to elicit conception and understanding • POE as the basis for initiating students conversation • Technology can mediate learning process

Author/Year	Scope/Field	Findings
(Kearney *et al.*, 2001)	• Design and construction of POE tasks • Constructivism	• Enhance students' engagement • Students' learning conversation during their interaction with the computer program
(Banky and Wong, 2007)	• Electronic Circuits • Simulation software • Troubleshooting exercise • Deep Learning • In the laboratory	• Simulation promotes understanding of device and understanding of concepts • Motivate students' interest in the course • Simulation assists a learning process
(Holton and Verma, 2009)	• AC/DC circuits • Concept inventory • Simulation • Instructional Strategy	• Confuse between variables (V and I) • Lack of distinction between components (C and L) • Circuits configuration (Series and Parallel) • Ignore the sources type (DC and AC)

Table 2.5 shows technique used in assessing students' conceptual understanding. The use of diagnostic instruments or concept inventory was further reviewed. Since the samples of the research are from this institution, the relation between BEC in Malaysia was made with worldwide issues.

Table 2.5: Concept inventory on BEC

Author/Year	Scope/Field	Findings
(Engelhardt and Beichner, 2004)	• DC resistive circuits • Developed diagnostic instrument named DIRECT	• Students hold multiple misconceptions even after instruction

Author/Year	Scope/Field	Findings
(Treagust, 2006)	• Importance of assessment • Diagnostic instruments	• The use of two-tier diagnostic tests can help identify students' alternative conceptions in limited and clearly defined areas • Two-tier multiple-choice
(Sabah, 2007)	• Using DIRECT to develop DIRECT-TTC • Resistive DC circuits	• Validated questionnaire using Rasch analysis • Two-tiered
(Ogunfunmi and Rahman, 2010)	• Electric Circuits Concept Inventory (ECCI) • Electric circuits course • Rational for developing • Concepts covering overall course	• To measure students' understanding • The ECCI do not test problem solving steps but test major concept and ability of students to understand the problem and apply the required methods to solve the problem
(Smaill *et al.*, 2011)	• DC circuits • Diagnostic test • Misconception	• Identify level of preparedness of first-year student • Misunderstanding occurs in basic subject • Same across countries • Follow sequential thinking • Can be corrected by appropriate course intervention

2.7 Summary

The literature review in this chapter guided the researcher to carry out the study effectively. Some literatures pertinent to this research were reviewed. This practice was followed through the research. The review starts with an analysis of students' conceptual understanding and learning difficulties. Students' alternative conceptions found by others were also reviewed.

Reviews also were made of teaching and learning approaches. The common approaches to integrating teaching and learning instruction in the curriculum known as traditional method and inquiry-based instructions where reviewed in this chapter. Several example of teaching and learning instruction in the course were discussed with reference to the reviewed literature. A discussion of the advantages of using computer simulation was also presented. In particular, students' understanding in BEC is discussed and the instruments used to determine students' concept were elaborated. In addition, review on BEC at the university involved was also presented. The common difficulties encountered by students in BEC concepts understanding were also presented.

In relation to the above discussion, teaching and learning approaches emphasizing on inquiry-based simulation-supported approach were proposed. The design of teaching and learning instruction in the course should be able to develop and enhance students' conceptual understanding. Similarly, the design and implementation of teaching and learning instruction should be able to assist students' conceptual learning in basic subject. Since these teaching and learning instructions are important to be formulated, a review of scope of the research finding by others was also provided.

CHAPTER 3

RESEARCH METHODOLOGY

3.1 Introduction

This chapter describes the research methods used in this research. An explanation of the research design and data collection method to address the RO and answer the RQ in Chapter 1 will be provided. The following described only the research design, the operational framework that guides the research and the instruments used in this study. The study setting is also explained. The data collection method and data analysis processes are also elaborated. The steps taken to ensure the validity and trustworthiness of the findings are discussed.

3.2 Research Design

Several researchers suggested that a quasi-experimental research design is most appropriate when it is not possible to randomly assigned participants to groups; which is a strong requirement of experimental research (Fraenkel and Wallen, 2007; Johnson and Christensen, 2008; Punch, 2009). The researcher had to conduct the study by making use of the existing natural setting (Punch, 2009). This research employed a quasi-experimental non-equivalent control group design approach to gain an in-depth exploration of the basic electric circuits' conceptual understanding among Electrical Engineering students. Non-equivalent control group design involves giving a pretest and posttest to an experimental group and a control group;

the control group and the experimental group come from naturally assembled setting (Campbell and Stanley, 1963). The research was carried out at one local public university. The participants of the research were first-year diploma students enrolled in Diploma in Electrical Engineering. The samples were not randomly selected; they were based on the classroom setting.

The data for this study were gathered using pretest, interview, intervention and then posttest. Qualitative data, including interviews and document analysis, were used to investigate and describe students' conceptual understandings of the basic electric circuits' behavior. The quantitative data were from pretest and posttest. The rationale for using both qualitative and quantitative data is because a useful survey of student experience could best be developed only after a preliminary exploration of student is obtained (Creswell, 2003). Data obtained will increased in credibility and validity if the data collected are merged as these sources provide rich information and deep understanding about the study (Johnson and Christensen, 2008; Merriam, 1998). Triangulation process of merging the qualitative and quantitative data can increase the validity of a study.

All the qualitative data, in the form of words need to be transcribed (Miles and Huberman, 1994) and analyzed to form descriptions and patterns (Johnson and Christensen, 2008). Table 3.1 summarizes the research questions, data collection methods and data analysis techniques employed in this study.

Table 3.1: Research method and data analysis

Research Objective	**Research Question**	**Data Collection**	**Data Analysis**
To investigate students' conceptual understanding of basic electric circuits concepts.	What are students' conceptual understanding with regards to open and short circuits concepts?	**Qualitative** Interview: students	Constant-comparative method*

Research Objective	Research Question	Data Collection	Data Analysis
To develop an inquiry-based simulation-supported approach to assist students' conceptual learning of basic electric circuits concepts.	Can students' conceptual learning be assisted through the used of inquiry-based simulation-supported approach?	**Quantitative** Inquiry-based verbalization Document: answer sheet	Constant-comparative method
To evaluate students' performance in basic electric circuits concepts after learning with the approach.	What are students' performances on open and short circuits concepts after learning with the approach?	**Mixed method** Document: pretest and posttest Interview: students	Paired-sample t-test** Constant-comparative method

* Constant-comparative method is used to identify common theme and categories from the interview and document analysis. It is performed by identifying and comparing the categories in all transcribed data. The explanation is available in section 3.6.2.

** Paired-sample t-test is available in SPSS. This analysis is used when comparing mean score for the same group of people on two different occasions. The explanation is available in section 3.6.1.

The above research methods and data analysis techniques were used to develop the operational framework for conducting this research. The disadvantage of quantitive data can be balanced out with the advantages of qualitative data and vice verse (Fraenkel and Wallen, 2007).

3.3 Operational Framework

Table 3.2 shows the operational framework for the research. It describes the sequence of work to accomplish the research objectives. The research work began with a preliminary study. A body of literature on the concepts difficulties of electric circuits, the teaching and learning activities, and students' concepts understanding were reviewed. The data obtained from electrical engineering students taking BEC were gathered to investigate the students’ conceptual understanding.

Table 3.2: Operational Framework

Time	Method	Instrument	Sample
One semester prior of the study begin	Preliminary study	Document – exam papers, lecture notes, informal discussion, open-ended test.	109 students
First week of the semester	Pilot testing	12 two-tiered concept test multiple-choice questions	86 students for pilot testing. Cronbach Alpha of 0.721
	Pretest		47 students as treatment group 33 students as control group
Before the intervention	Interview 1	Semi-structured interview	27 students
Within the semester that is after the pretest and prior of the posttest	Intervention. Using computer installed with Multisim	Inquiry-based simulation-supported approach incorporate predict-observe-explain tasks (had content validated by experts)	12 students for pilot testing
			47 students as treatment group
Final week of the semester	Posttest	12 two-tiered concept test multiple-choice questions	47 students as treatment group 33 students as control group
After the posttest	Interview 2	Semi-structured interview	15 students

3.3.1. Preliminary Study

Prior to the actual research, one preliminary study was conducted to determine university students' understanding of electric circuits concepts. Previous classroom discussions, students' verbal responses, and students' examination answer scripts were analyzed and group into several descriptions of learning difficulties. The result of students' achievement on written test was reported in Hussain *et al.* (2009). These raw data were supported by results from a preliminary test comprised of open-ended conceptual questions as shown in Appendix F. This preliminary test was used to examine students' understanding about the behaviour of electric voltage and current in open and short circuits. The result of the problem identification guided the development and formulation of the research objectives (RO) and research questions (RQ) of this research.

The three preliminary test questions were administered to students' during the final week of their first semester. There were 109 students' who are taking BEC took the test. Students' responses were analyzed and the findings provided the basis for content selection and design of teaching and learning approaches.

3.3.1.1 The Findings on Simple Circuits

There were three questions on the preliminary test. Figure 3.1 show Question 1 for simple circuit.

Q1. A simple DC circuit in Figure 1 is referred.

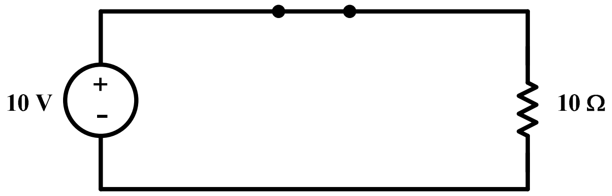


Figure 1

a. Redraw the circuit in Figure 1 to show how to measure the voltage drop across 10 Ω resistor.

b. Name laws, rules or theorems that can be used to calculate the voltage drop across 10 Ω resistor.

c. Redraw the circuit in Figure 1 to show how to measure the current flows through 10 Ω resistor.

d. Name laws, rules or theorems that can be used to calculate the current through 10 Ω resistor.

Figure 3.1 Question 1

For question 1a, 76.9% of the students answered correctly when they drew the position of the voltmeter in parallel with the resistor. However, 30.8% of students drew the same configuration to measure current for question 1c. This showed that the students understood the concept of measuring voltage across a resistor. However, they did not understand how to measure current through a resistor in a circuit. The ammeter should be placed in series with the resistor when the current is to be measured. Practically, if the ammeter is placed in parallel with the resistor, it will be damaged. To avoid damage to the instrumentations, a simulation was chosen for students to construct the circuits. The first part of the approach was concentrated on connecting devices to the circuits.

There were 50.6% and 64.3% of students who correctly answered Ohm's Law for questions 1b and 1d respectively although the responses by 23.1% respondents on Kirchhoff's Voltage Law (KVL) for 1b and responses by 14.3% respondents on Kirchoff's Current Law (KCL) for 1d were also correct. These gave the percentage of respondents answering correctly for question 1b and 1d to 73.7% and 78.6% respectively. However there were 26.3% students who answered Voltage Divider Rule (VDR) for 1b and 21.4% of students answered Current Divider Rule (CDR) for 1d. Both of these answers were wrong because these rules apply to circuits with more than one resistor. This shows that students lack deep understanding of fundamental concepts in their field as mentioned by (Streveler *et al.*, 2006).

3.3.1.2 The Findings on Open Circuits

Figure 3.2 shows Question 2 which focuses on an open circuits where the switch is used examine the concept of open and short circuits. Students frequently make mistakes in open and short circuit analysis especially when current and voltage are to be determined (Duit & Rhoněck, 1998).

Q2. Referring to Figure 2;

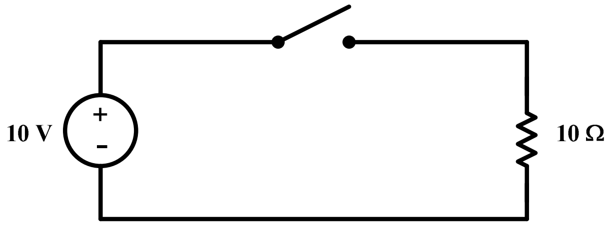


Figure 2

a. Circle the answer for the voltage drop across 10 Ω resistor.

   i. 0 V because of open circuit
   ii. 10 V by using KVL or Ohm's Law

Explain your answer : ____

____

b. Circle the answer for the current flowing through 10 Ω resistor.
   i. 0 A because of open circuit
   ii. 1 A by using KCL or Ohm's Law

Explain your answer :____

____

Figure 3.2 Question 2

There were 27.8% student who answered 10V for question 2a. They explained that there was voltage drop across the resistor although the circuits is an open circuits. Their answer is wrong because the circuits is not complete, therefore the voltage drop across the resistor should be zero. The answer is 10 V if the voltage to be measured is at the open circuits.

For question 2b, 88.7% students answered correctly with an explanation that there will be no current flow in an open circuit. This shows that students can visualize that current flow in a complete circuits. However, 33.7% of the students gave wrong explanations to their correct answers. Therefore, the question on concept of open circuits is suitable to be included in the approach.

3.3.1.3 The Findings on Open And Short Circuits

Question 3 is as shown in Figure 3.3 where the question tests students' conceptual understanding of total resistance in an open and short circuits.

Q3. Referring to Figure 3;

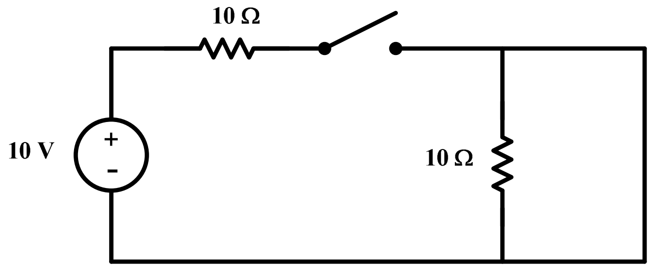


Figure 3

a. Calculate the total resistance of the circuit when the switch is opened.

b. Calculate the total resistance of the circuit when the switch is closed.

Figure 3.3 Question 3

There were 53.8% and 43.2% of students who made mistakes regarding total resistance of an open circuit as in 3a, and in short circuits as in 3b, respectively. 21.3% of students gave the answer of 10Ω for question 3a, and 36.1% gave the answer of 20Ω for question 3b, where both answers were actually wrong. Students failed to notice the effect of an open versus short circuits when measuring resistance.

Total resistance is measured from the source. When the switch is open, the total resistance from the source is zero because the resistors are not fully connected in the circuits. When the switch is closed, then the effect of a short circuits is noticeable. The 10Ω resistor that is in parallel to the short circuit can be neglected because the short circuit is more dominant. Therefore, the total resistance for question 3b is only the first 10Ω. Students failed to notice the effect of open and short in this question. Their answers described the fact that they have focused their attention upon one point in the circuits and ignored what is happening elsewhere (Duit & Rhoněck, 1998).

The concept test administered proved that students do not have a deep understanding of their field. Even though the questions asked were fundamental, mistakes still persist. Based on the concept test given, it can be concluded that students have difficulties with open circuits, short circuits, total resistance and interpretation of circuits diagrams which are the fundamental concepts in electric circuits analysis. This research will address these concepts collectively in the approach to be developed as these concepts are interrelated.

3.3.2. Research Samples and Setting

Once RO and RQ have been formulated, the research setting was identified. Samples involved were first-year students taking Diploma in Electrical Engineering at one local public university were chosen. The students had just finished taking the Electric Circuits course during their first semester. In the second semester they are not taking any circuit courses. The timing for investigation during their second semester on their conceptual understanding was just right. Student's participation in the research was voluntary.

The laboratory selected has 40 computers each with Multisim installed. The purpose of having one student to a computer is that they can practice the simulation on their own. This is in line with other research that demonstrates the importance of students' taking ownership of the task which engaged students in identifying or sharpening questions for inquiry (National Research Council, 2000).

3.3.3. Pilot Study of Concept Test and Pretest

One concept test on basic electric circuits was adapted from Sabah (2007). Some modifications have been made from the original test when there were not sufficient questions on a particular concept of interest (Vigeant *et al.*, 2009). The concept test was content validated by experts in the field. The instrument was piloted with 86 students and assessment of reliability was made. The SPSS internal consistency of Cronbach Alpha reliability coefficient was 0.721. This value shows the that the inferences made from the result of an alpha above 0.7 is normally considered to indicate a reliable set of items and indicates acceptable reliability (Johnson and Christensen, 2008; Pallant, 2007).

3.3.4. Pretest and Interview after Pretest

The concept test is used for pretest and posttest. Pretest was conducted during their first week of the semester. After the pretest, the researcher proceeded with the interviews. The interviews were conducted in small focus groups (Johnson and Christensen, 2008) of two or three. They were called to the researchers' room to be interviewed about their answers in the pretest. Each of them were asked to verbalize the reasoning behind wrong answers in pretest as a method to gain further insights into students thought processes (Smaill *et al.*, 2011). The verbal explanations by students were constant-comparatively analyzed to form themes on conceptual understanding. The researcher function more as a moderator or facilitator, and less as an interviewer (Punch, 2009). The data were recorded for later transcription. All the interviews were conducted before the intervention in the lab.

3.3.5. Approach Development

Concurrently the inquiry-based simulation-supported approach incorporate POE tasks was developed based on the work of McDermott (1996), Kearney (2004), and Prince and Vigeant (2006). Originally there were four questions developed as shown in Appendix H, but after pilot testing one question had to be dropped because of redundancy as will be discussed in 4.2. The approach was content validated by experts in the field as shown in Appendix L. Once validated, the approach was pilot tested. After some refinement of the approach, the intervention in the lab was scheduled using computers installed with Multisim. Students were asked to come to the lab during their free time by choosing a time slot allocated for the intervention. Therefore the intervention session did not conflict with their normal class schedules. The researcher took advantage of naturally occurring treatment groups in the research situation (Punch, 2009).

3.3.6. Intervention

During the intervention, a PowerPoint presentation of the questions was displayed on the screen. The approach answer sheet was given to the students for them to write their answers. Students' simulated result had to be approved by researcher. They had to verbalize their understanding before preceded to the next question. The lab session was incorporated with inquiry-based activities and POE tasks. The researcher acted more like a facilitator than a lecturer. Their explanations were recorded for later transcription.

3.3.7. Posttest and Interview after Posttest

The posttest was given during the final week of the semester. Again small group interviews were conducted after the posttest to investigate students’ verbalized explanation. The data was again recorded for later transcription.

3.4 Respondents

In this research, the researcher had some control over when to measure outcomes of this natural setting (Punch, 2009). The respondents of this study were first-year students who had taken the basic electric circuits’ course for their electrical engineering discipline. The electrical engineering students were majoring in electronic, power, mechatronics and communication of Electrical Engineering programme at one local public university. They were purposively sampled to suit the research objectives and research questions (Punch, 2009).

For validity purposes, 86 students were involved while 12 students were sampled for the pilot testing of the simulation-supported approach. During the pretest, lab session and posttest, 47 students were involved as the treatment group. There were 33 students who volunteered to be in the control group. Therefore, the real data for transcribed, constant-comparative method of analysis and triangulation were obtained from 47 students. There are 27 students who took part in the interviews after pretest and 15 who attended the interviews after the posttest. The number of participants were enough for both quantitative and qualitative data collection (Johnson and Christensen, 2008). Posttest was conducted during their final week of the semester with the same students. Therefore, paired-sample t-test can be used to analyze quantitative data (Pallant, 2007).

3.5 Research Instruments and Data Collection

The researcher used pretest and posttest, small focus-group interviews, document analysis, concept test questionnaires and intervention with inquiry-based simulation-supported approach. In some cases, open-ended question were used especially during the intervention.

3.5.1. Concept Test for Pretest and Posttest

A concept test was used to test the students' conceptual understanding regarding the course material before and after the use of the approach developed. Concept test was used in the preliminary study to find basis of students' common learning difficulties, and to test their prior knowledge on the topics. Concept test on basic electric circuits is adapted from Sabah (2007). Some modifications were made to the original test and the reviewed concept tests have 12 two-tier multiple choice questions as shown in Appendix G. The test was used for pretest and posttest. The concepts tested are shown in Table 3.3.

The content and the concepts to be tested and the structure of the questions were changed by rearranging the sequence of the questions and rephrasing the English to suit the level of students in Malaysia which use Malay as their main language. The concept test was content validated by experts in the field as suggested by Engelhardt & Beichner (2004) as shown in Appendix L. The concept test was pilot tested to check for internal consistency. This adapted concept test, with the main aim to measure students' conceptual understanding, was used for the pretest and posttest of this research. The concepts selected were among the 27 concepts identified as important and difficult concept for students to master in electric circuits (Streveler *et al.*, 2006).

Table 3.3: Concept tested

Question No.	Concept Tested
1	Current in a complete circuits
2	Voltage sources in series and parallel
3	The effect of short circuits
4	Total resistance in an open circuits
5	Total resistance in a switched circuits
6	Effect of a switch in a circuit
7	The effect of variable resistor
8	Resistance in a switched short circuits
9	Voltage in a switched parallel circuits
10	Distribution of voltage source in an open circuits
11	Distribution of current in parallel circuits
12	The effect of doubling the resistance

3.5.1.1 Pretest

Table 3.4 shows the schedule of the pretest. The allocated time was one hour; however, few students finished earlier. The pretest was conducted in the first week of the semester. Students answered the pretest wholehearted, showed that they are really aware about their understanding on electric circuits. This concept test was valuable as a “wake-up call” and led to students monitoring their understanding from previous semester (Smaill *et al.*, 2008).

The test for the four sections was conducted at different time. There are no interaction effects since the test was planned without students knowing it. The students expected their own lecturer to enter the class. As the researcher explained about the test they have to take, they were really surprised and afraid that they might not retain well on understanding of electric circuits.

Table 3.4: Pretest schedule

Pretest	Time	Number of students	Classroom
15 July 2010	9 am	14	H106
15 July 2010	10 am	13	H104
15 July 2010	2 pm	7	DK1
15 July 2010	3 pm	13	DK2
		Total = 47	

3.5.1.2 Posttest

Table 3.5 shows the schedule for the posttest. The posttest was conducted during the final week of the semester.

Table 3.5: Posttest schedule

Posttest	Time	Number of students	Classroom
14 Oct 2010	9 am	14	H106
14 Oct 2010	10 am	13	H104
14 Oct 2010	2 pm	7	DK1
14 Oct 2010	3 pm	13	DK2
		Total = 47	

3.5.2. Interviews

The objective of the interviews was to gain insight about things that could not be observed (Merriam, 1998) where respondents' thoughts and perspectives in their own words could be acquired through the interviews (Punch, 2009). Interviews are used to provide rich and detail insight to the investigation of the study. Interview was also used to reinforce the information obtained from the concept test. Students were interviewed to gain insight into their learning and experiences before and after the intervention. The researcher aimed to explore in-depth the students' conceptual understanding.

In conducting the interviews, the interviewee should be experienced and knowledgeable in the area to be interviewed (Rubin and Rubin, 2005). The participants were selected from among those who could provide the most information and important insights about the topic being studied (Merriam, 1998; Rubin and Rubin, 2005). The interviewees selected for this research were students who were involved in learning about electric circuits the previous semester before this study began.

Prior to the interview, the students were contacted by phone. The objective of the interview and estimated time of the interview was explained. The students were asked to come in groups of three or four. Then face-to-face structured interviews were conducted in the researcher room. The role of the researcher changes in a group interview, functioning more as a moderator or facilitator, and less as an interviewer (Punch, 2009).

The interview began with a personal introduction of the researcher at the beginning of each interview session. The interviewees also introduced themselves briefly. The researcher explained the purpose and confidentially of interview as stated in the Explanatory Statement and Consent Form as shown in Appendix K. The students has to read, agreed and signed before the interview. The students were also informed about the audio-recording of the interview. The best and most common way to record the interview data is by audio-taping the interview (Merriam, 1998; Rubin and Rubin, 2005). The students were also informed that they might be contacted again should there be any further justification needed. All the interviews were conducted in the researchers' room. During the interview, the researcher also wrote ideas for follow-up questions to be used as the guiding questions in the interview.

The structured interview questions were based on the wrong answers given during pretest and posttest. Students were also requested to give their views on current conceptual understanding that they have on the topic. The difficulties encountered while studying related courses were also obtained. Follow-up questions were raised to elicit more information from the participants.

The questions that were asked during pretest, posttest, intervention and interview do not need mathematical problem solving steps but rather the questioning were designed to test students' ability to verbalize major concepts of the problem and explain the required methods to solve the problems. Students' interview comments and the researchers' own reflections were also given. The written data were also obtained and analyzed from the answer option "Other" in the concept test. Some students are brave enough to choose this as their reason, and they try to write down their understanding. Their answer clearly show their alternative conceptions which will be discussed in this chapter.

The recorded interviews were transferred to the researchers' computer for transcribing and coding purposes. All transcribing processes were done by the researcher to allow the researchers to recall the interview and become familiar with the data (Punch, 2009).

The central issue of interview aspects is on language used (Punch, 2009). However, all students were comfortable in answering the interview in Malay. Luckily, most common technical terms of electrical engineering were mentioned in English such as "open circuits", "short circuits", "current flow" and "voltage drop". Therefore, the interview transcriptions combined a mixture of both languages. It should be noted that the quotations which appear in Chapter 5 were translated into English and the translations were verified by an expert as shown in Appendix M. The original sentences and the grammatical mistakes were maintained to retain the originality of the sentences by respondents.

Ethical requirements were followed by the researcher among other are to obtain students consent and kept their identity confidential (Punch, 2009; Rubin and

Rubin, 2005). Identification codes were assigned to each participant to maintain their confidentiality. At the end of session, a momento was given to each student as a token of appreciation.

3.5.2.1 Interviews after Pretest

There were 27 students who came for the interview sessions. Most interviews lasted for one hour. Table 3.6 shows the interview after the pretest schedules that were conducted in the researchers' room. The interview was conducted face-to-face and in groups of two or three students. There were nine interview sessions. The rational for grouping in three was for conveniences; there are only three chairs available in the room. Among other reason was students were not willing to talk much if there were alone with the researcher. Students were willingly talking about their mistakes in front of friends as that were their way of doing discussion in group work.

Table 3.6: Interview schedule after the pretest

Pre-Interview	**Number of students in the morning**	**Number of students in the afternoon**
15 July 2010	3	3
16 July 2010	3	3
22 July 2010	3	3
28 July 2010	3	
10 August 2010	3	
11 August 2010	3	
	Total students = 27	

3.5.2.2 Interviews after Posttest

Only 15 students came to the interview sessions after the posttest. The interview was conducted during study week. Table 3.7 shows the interview after the posttest schedule that was conducted in the researcher room. The interview was conducted face-to-face and also in small groups of two or three students. There were ten interview sessions. The reason why fewer students volunteered was because they were busy preparing for their final exams.

Table 3.7: Interview schedule after the posttest

Post-Interview	Number of students in the morning	Number of students in the afternoon
14 Oct 2010	2	2
18 Oct 2010	2(1)*	0
19 Oct 2010	2	2
20 Oct 2010	2(1)*	0
21 Oct 2010	1	2
	Total students = 15	

* called for re-interview due to unclear and inadequate data

In some cases, the explanation given by the participants were unclear and inadequate based on the transcribed data (showed in the parenthesis). This prompted the researcher to conduct a second post-interview. Again the students were contacted by phone and dates and times were set. Interview assisted the researcher understanding the participants perceptions at a deeper level (Rubin and Rubin, 2005).

3.5.3. Documents

Documents provide rich sources of information that can be used to support the data collected through interviews (Johnson and Christensen, 2008; Merriam, 1998). The document obtained and prepared for this research are:

i. Answer sheet as shown in Appendix I
ii. Pretest (in the open written responses)
iii. Posttest (in the open written responses)

By examining these documents, the researcher was able to analyze the conceptual understanding that the students had and compare them with the verbalized answers given from interviews. In addition, once students have deep conceptual understanding, they should be able to verbalize it during interview session. However, students had problems verbalizing their understanding even though they can put into writing very well as will be discussed in Chapter 5.

3.5.4. Inquiry-Based Simulation-Supported Approach

This research investigates an inquiry-based simulation-supported approach with simulation incorporated predict-observe-explain tasks. The preliminary work on interview and document analysis was to identify students' alternative conception in basic electric circuits' course.

The approach is developed based on concepts associated with open and short circuits. The PowerPoint presentation of this approach is shown in Appendix H. The software to be used is electronic circuits' simulation software, Multisim from Electronics Workbench (EWB).

3.5.5. In the Lab Intervention

Each student was assigned to one station with a computer installed with Multisim. Each student has to do computer simulation for all three questions on their own. The researcher started the lab session by highlighting the purpose of the session and the scope of the lesson as shown in Appendix H. Also the students were asked to familiarize themselves with the tools in Multisim which they have used in the earlier semester. The approach developed is presented in Chapter 4.

The researcher acted as facilitator only. The researcher's role was to guide the students, walking around the room and probing questions to check their understanding. The data was collected during inquiry-based simulation-supported approach intervention session by audio recording. Then the recorded audio was transferred to the researchers' computer for data analysis. The purpose of audio recording was to gather extra information about students' verbalization of learning especially when they using the simulation software.

The computer laboratory scheduled was arranged with the technician and the time slots to be used were obtained. Students were asked to sign up for allocated time slots which did not conflict with their other courses in that semester. Table 3.8 shows the schedule of intervention sessions. Figure 3.4 shows students during the intervention in the lab session.

Table 3.8: Intervention session schedule

Lab Session	**Number of students**
15 July 2010	4
19 July 2010	4
21 July 2010	4
21 July 2010	5
22 July 2010	6
26 July 2010	6
28 July 2010	4
29 July 2010	4
2 August 2010	3
4 August 2010	7
	Total = 47

At the end of the lab session, a door gift was distributed to each student to show appreciation. They were also informed that there would be another session for the posttest and post-interview. The date of appointment will be informed later. Appendix N and O were used for each lab session as a guidance for the researcher not to missed anything important.

Figure 3.4 Lab session

3.6 Data Analysis

As mentioned in the previous sections, the data in this study were gathered through interviews, approach intervention sessions, documents, pretests and posttests. All of the interviews and intervention session data were fully transcribed by the researcher as the researcher is more familiar with the terminologies used during the interviews. By transcribing the interviews on her own, the researcher could also familiarize herself with the keywords used by the participants, which is the starting phase for data analysis (Merriam, 1998). The gathered data were analyzed via a constant comparative method and triangulated to produce themes of students' conceptual understandings (Merriam, 1998; Rubin and Rubin, 2005).

Students’ marks from the pretest and posttest were analyzed quantitatively with SPSS using a paired-sample t-test (Johnson and Christensen, 2008; Pallant, 2007). The data gathered in this study were analyzed by looking at alternative conceptions that the students had on the concepts of open circuits and short circuits. Students’ alternative conceptions can be concluded after triangulation.

All the findings were then compared to the literature to characterize students’ conceptual understanding of open and short circuits. The criteria can be used as guidance for future teaching and learning activities. The common alternative conceptions were then gathered to determine the similarities and differences with the literature (Engelhardt and Beichner, 2004; Holton *et al.*, 2008; Smaill *et al.*, 2011).

3.6.1. Paired Sample T-Test

The T-test is the parametric statistics that can be used to find out whether there is a significant difference among two groups (e.g. males and females) or two sets of data (before and after) (Pallant, 2007). Paired sample t-test (also called repeated measures) is used to see changes in test scores tested at Time 1, and then again at Time 2 (often after some intervention or event) within the same group of samples (Pallant, 2007). A total of 47 students from treatment group and 33 students from control groups took the pretest and the posttest. Therefore, paired sample t-test was suitable to detect differences in this study.

A parametric version needs to have normal distribution. Therefore, normality test was applied for the data from pilot test, the pretest and posttest as shown in Appendix P.

The pretest and posttest were graded and analyzed statistically. The grading are dichotomous data which states right is 1 and wrong is 0. There are 12 two-tiered questions, namely answer and reason for that answer. So there were 24 questions which gave the highest total marks of 24.

One way to assess the importance of the findings is to calculate the effect size, also known as ‘strength of association’. This statistic indicates the relative magnitude for the differences between means (Pallant, 2007). Cohen’s *d* is used to compare groups in term of standard deviation units.

Effect size defined by *d* is the difference between the means, M_1 - M_2, divided by standard deviation, δ, of either group. Cohen argued that the standard deviation of either group could be used when the variances of the two groups are homogeneous (Cohen, 1992).

$$\text{Cohen's } d = \frac{M_{post} - M_{pre}}{\sqrt{\frac{\delta_{post}^{2} + \delta_{pre}^{2}}{2}}}$$

Cohen proposed the following interpretation: 0.2 is small effect; 0.5 is moderate effect and 0.8 is large effect (Cohen, 1992). Power analysis is carried out using GPower software using Cohen’s d value. Power analysis gives power for a specific effect size. The statistical power of a test is the probability of getting a statistically significant result (Faul *et al.*, 2009). The higher the number of samples used compare to sample size required will show the better the effect size.

3.6.2. Constant Comparative Method

Qualitative data analysis begins with coding where codes are assigned to each data set (Rubin and Rubin, 2005). This process is important for identifying the data set during the analysis and write-up (Merriam, 1998). The interview and lab session transcripts were coded according to students coding number with S1 up to S47 according to the number of students involved.

Comparative method was used to analyze the interview transcripts and intervention session where the data sets are constantly and continuously compared among them to find the regularities in the data (Merriam, 1998). The researcher also referred to the research questions when analyzing the data and determining the categories (Johnson and Christensen, 2008). The interview transcripts were analyzed to identify patterns in the data that offer insight into students' conceptual understanding. The translation from Malay to English was validated by experts in the field as shown in Appendix M.

The data set is analyzed according to first level and second level analysis. The first level is called descriptive codes and the second level is called categories (Johnson and Christensen, 2008; Punch, 2009) which are summary for each data set that link together (Merriam, 1998). The coding were further analyzed by interpreting, interconnecting and conceptualizing to find categories (Johnson and Christensen, 2008). This is done by grouping the descriptive codes into similar themes then the identified codes are reviewed to further verify the categories obtained. The analysis focused on identifying the alternative conceptions that students held on open circuits and short circuits as presented in Chapter 5.

3.7 Reliability and Validity

Establishing reliability and validity of the research findings is very important in any quantitative research. Reliability means consistency (Punch, 2009). Validity means the extent to which an instrument measures what it claims to measure. An indicator is valid to the extent that it empirically represents the concepts it propose to measure (Johnson and Christensen, 2008; Pallant, 2007; Punch, 2009). Experts in electrical engineering field were consulted as content experts for validity purposes.

This research has concluded to use Cronbach alpha about for internal reliability. The concept test was pilot tested to 86 students to check for its reliability. The reliability coefficient of Cronbach alpha was found to be 0.721 which shows strong internal consistency (Johnson and Christensen, 2008; Pallant, 2007).

3.8 Credibility and Transferability

Qualitative researchers need to demonstrate that their studies are credible by engaging and employing member checking, triangulation, thick description, peer review and external audits (Creswell and Miller, 2000). Credibility refers to internal validity of the qualitative research (Creswell, 2003). Reliability is concerned with the data recorded by the observers compared to the events that actually happen in the study setting (Punch, 2009). On the other hand, validity of the qualitative research is concern with the truth of research findings or the closeness of the research findings to the reality (Merriam, 1998). Qualitative research seek to generalize called transferability which refers to which the results of qualitative research can be transferred to other contexts (Borrego, Douglas and Amelink, 2009).

To ensure the transferability and credibility of the findings, this research applied triangulation and peer examination methods. The purpose of triangulation is to seek convergence, corroboration, correspondence of results from different methods (Johnson and Christensen, 2008). To accomplish data triangulation, the data from interviews, lab session intervention and documents were collected to gain a comprehensive understanding of the case being studied. Triangulation is important because findings that were based on several data sources will be more accurate and convincing (Merriam, 1998).

Also peer examination was used where the identified categories were given to be reviewed and commented on by other researchers (Merriam, 1998). In this research, experts in electrical engineering, qualitative and quantitative research acted as peer examiners. Also supervisors of the research do helped to examine the categories.

3.9 Summary

This chapter highlights the research design to justify the reasons behind this research being conducted and how the samples and the research setting were selected. The summary of the research procedures were presented using the operational framework that guides the research was discussed in detailed.

The description of the instruments and data collection methods and their contributions in obtaining a comprehensive and in-depth data on students' conceptual understanding were also discussed. The method employed to run the approach intervention were also discussed. The formative evaluation of the approach was also explained during the pilot study.

The qualitative data analysis using constant comparative method to determine the descriptive codes and categories were also highlighted. The data analysis using paired sample t-test was used for the quantitative data. Lastly, the strategies adapted by the researcher to ensure reliability and validity; also credibility and transferability of the study were also presented.

Based on the discussion about the research methods, the study was conducted systematically and concisely with holistic and good research characteristics.

CHAPTER 4

DEVELOPMENT OF AN INQUIRY-BASED SIMULATION-SUPPORTED APPROACH

4.1 Introduction

This chapter discusses the development of the inquiry-based simulation-supported approach. The preliminary study that guides the development of the approach is discussed. The approach developed was pilot tested to check for content and flow of the approach. The developed approach will be used as learning intervention.

4.2 The Approach Development and Pilot Testing

The findings from the preliminary study were used as the basis for developing the inquiry-based simulation-supported approach. The questions in the lesson plan of the approach were shown in Table 4.2 until Table 4.5 and also the PowerPoint presentation for the approach as shown in Appendix H. Students' simulated circuits are shown in Appendix J.

Formative evaluation is carried out to gather data for the development of the approach. The developed approach was content validated by experts in the field as shown in Appendix L. The pilot testing was run to check for the content and the flow of the approach. The feedbacks obtained from students during pilot testing were evaluated.

Originally there were four questions. The approach was pilot tested in the first week of the semester with 12 students. However, after pilot testing, one question was dropped due to redundancy as shown in Appendix R. The reason behind this deletion was that the deleted circuits had the same concept as asked in exercise 1. The redundancy caused confusion among students during pilot testing. Therefore after discussing the issue with supervisors and consulting with the content validator, that question was omitted, leaving only three questions. The improved version of the final approach was ready to be implemented. The approach developed has been validated by the expert from University of Florida that the principles of guided inquiry have been used appropriately in this study as shown in Appendix L.

The outcome during pilot testing also showed that the lab session has to be reduced from three hours to two hours. This is because students already familiar how to use Multisim, which reduces simulation programming time. However, more time was spent on inquiry-based approach to allow students to explain each exercise verbally.

4.3 The Developed Approach

The developed approach thereafter only has three questions as shown in Table 4.2 until Table 4.5. The sequence flow of the exercises is as shown in Figure 4.1.

Exercise 1. Simple circuits.
Exercise 2. Short circuits.
Exercise 3. Open circuits.

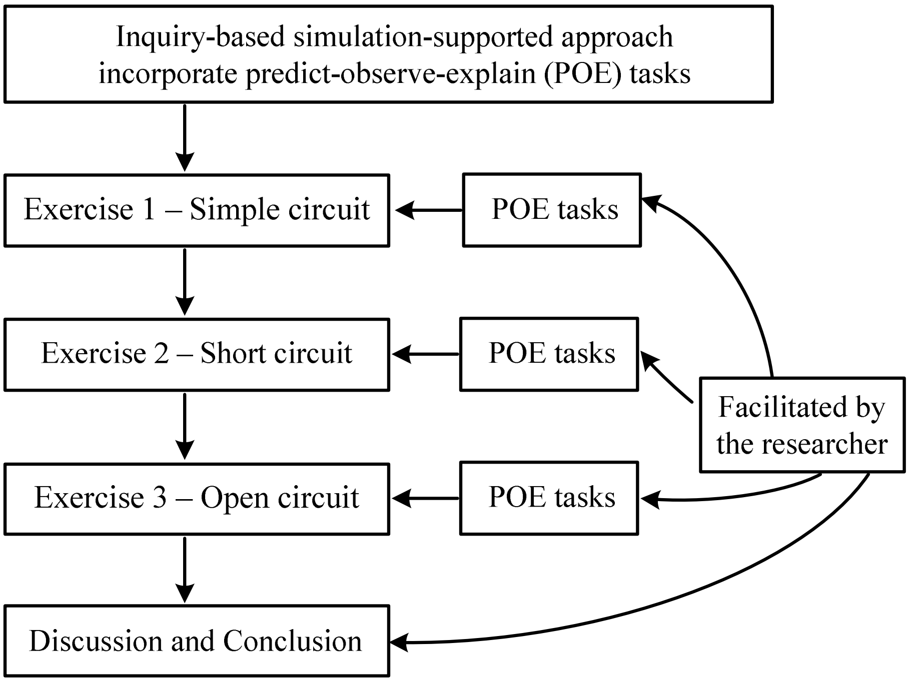


Figure 4.1 Sequence flow of the exercises

The discussion and conclusion is the final section where student has to reflect what they have learned and acquired from the inquiry-based simulation-supported approach intervention session. The approach incorporates POE tasks with simulation. Inquiry-based approach is incorporated throughout the approach intervention sessions. Table 4.1 shows the lesson plan for the approach.

Table 4.1: Lesson plan of the approach

Exercise	**Task**	**Teaching and Learning Activities**
3 different circuits	SETUP – students draw the circuits using Multisim.	Students work individually on their own computer.
POE tasks	**PREDICT** – students predict outcome of the simulation.	Individual prediction. Facilitated by the researcher.
	OBSERVE – students observe the outcome of the simulation.	Performed with social interaction. Small group discussions. Inquiry-based approach. Facilitated by researcher.
	EXPLAIN – students explain any differences between their prediction and observations.	

The intended learning outcome from the inquiry-based simulation approach with POE tasks incorporated was to allow students to reflect their own alternative conceptions and become aware of rectifying them. The researcher displayed the PowerPoint presentation of the questions as shown in Appendix H. Students drew the circuits on the computer using Multisim and then predict the operation of the circuits. The sequence flow of activities is shown in Figure 4.2.

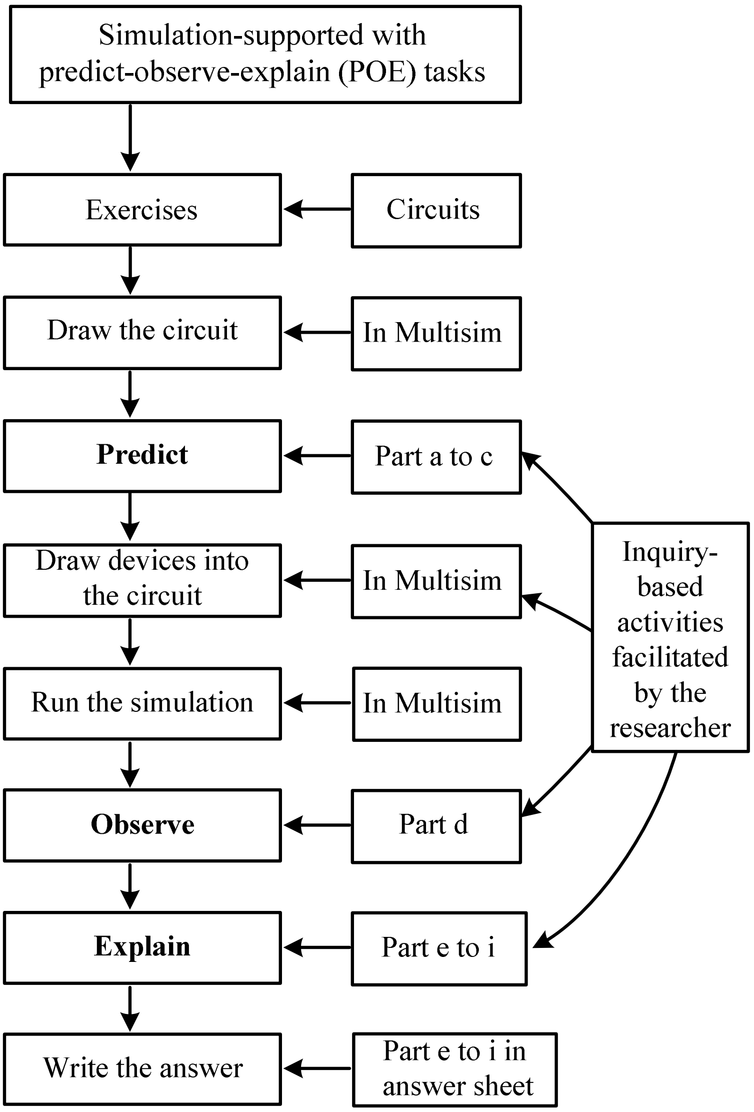


Figure 4.2 Sequence flow of activities

The exact circuit was displayed on the screen, which students' drew using Multisim. The simulation was run and the output was obtained. Students have to explain verbally the circuit operations to the researcher. Students had to compare their observed output with their prediction earlier on. They have to critically evaluate their own alternative conceptions. Once the researcher confirmed that their simulated output and verbalization of the circuits was correct, then they had to answer the questions at the end of each exercise on an answer sheet. As mentioned in Chapter 2.4.3, the POE task was incorporated in this approach, therefore the equential flow of this approach is organized according to the POE tasks.

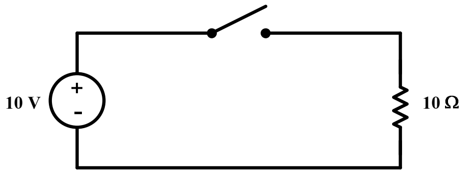
The steps involved in this guided inquiry-based simulation-supported approach using POE task are, first they have to **predict** the characteristics of the circuits as asked in part a, b, and c. Then, after simulated circuits are working, they have to **observe** the working of the circuits as displayed on the computer as asked in question d. Finally they have to **explain** verbally the working of the circuits to the researcher who only acts as facilitator and to peers sitting next to him/her.

Rather than the researcher conduct lectures and explain the concepts to the class, the researcher uses leading questions to generate student responses, such that the students will provide as many answers to their own questions as possible. The researcher assists the students in constructing or correcting their knowledge. Once their explanation satisfies the researcher and the correct answers according to the concept are explained, they can answer Q1 parts e until i. The same process is repeated with Q2 and Q3. The researcher will try to probe students' understanding by asking contradicting questions. This will enhance data obtained from students' conceptual understanding as will be discussed in detail in Chapter 5.

4.3.1. Lesson Plan for Exercise 1

The lesson plan for Exercise 1 of simple circuits is shown in Table 4.2. When first using the simulation software, students take a little time to re-familiarize themselves with the software. Their previous knowledge of Multisim did help them to master the software quicker. Once the circuits is drawn on their computer, they have to answer parts a to c, which is the prediction task.

Table 4.2: Lesson plan of Exercise 1

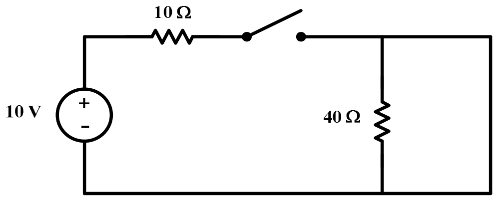
Exercise	**Teaching and Learning Activities**
Exercise 1:  a. Can this circuit works? b. Give reasons to your answer in a. c. What devices can you use to make sure that the circuit really works? d. Draw all circuits containing the devices as mentioned in c. e. Explain the working of each circuit as drawn in d.	**Predict:** For question a-c **Observe:** Simulation output for question d **Explain:** Verbalize circuits operation for question e

Later they have to simulate the circuits and observe the output as to answer part d. Each student has to explain in writing the operation of their circuit for part e. The process of explaining and verbalizing activates the question and answer session.

4.3.2. Lesson Plan for Exercise 2

The lesson plan for Exercise 2 is a circuit consisting of a short circuit as shown in Table 4.3.

Table 4.3: Lesson plan of Exercise 2

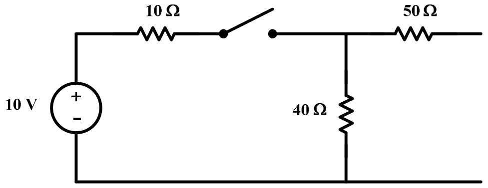
Exercise	**Teaching and Learning Activities**
Exercise 2:  a. Can this circuit works? b. Give reasons to your answer in a. c. What devices can you use to make sure that the circuit really works? d. Draw all circuits containing the devices as mentioned in c. e. Explain the value of current flow through each resistor. f. Explain the value of voltage drop across each resistor. g. Explain the working of the circuits according to the bulbs lighted. h. Explain the steps needed to measure the total resistance. i. What is the total resistance of the circuit?	**Predict:** For question a-c **Observe:** Simulation output for question d **Explain:** Verbalize circuits operation for question e-i.

By now students should have already mastered the use of the software. Once the circuit is drawn on their computer, they were ready for the prediction task. Once the prediction is done and they have written their answer for a to c, they have to draw the circuits with the mentioned predicted devices. Then they have to simulate the circuits and observe the output as in part d. Each student has to explain out loud to the researcher the operation of each circuit for part e to i. Once the explaining session ends, they have to write their answer based on what they have understood from the question and answer session.

4.3.3. Lesson Plan for Exercise 3

The lesson plan for Exercise 3 is a circuit consisting of open circuits and a switch is shown in Table 4.4.

Table 4.4: Lesson plan of Exercise 3

Exercise	Teaching and Learning Activities
Exercise 3:  a. Can this circuit works? b. Give reasons to your answer in a. c. What devices can you use to make sure that the circuit really works? d. Draw all circuits containing the devices as mentioned in c. e. Explain the value of current flow through each resistor. f. Explain the value of voltage drop across each resistor. g. Explain the working of the circuits according to the bulbs lighted h. Explain the steps needed to measure the total resistance. i. What is the total resistance of the circuit?	**Predict:** For question a-c **Observe:** Simulation output for question d **Explain:** Verbalize circuits operation for question e-i.

The same POE is used for the three different circuits. Once the prediction is done in part a to c, they have to draw the circuits with the mentioned predicted devices. Then they have to simulate the circuits and observe the output as in part d. Each student has to explain out loud to the researcher the operation of each of the circuit in part e to i. Once explaining session ends, they have to write their answer based on what they have understood from the question and answer session.

4.3.4. Lesson Plan for Discussion and Conclusion

The lesson plan for Discussion and Conclusion is shown in Table 4.5. At the end of lab session, students were asked to recall and generalize what they had learned from the inquiry-based simulation-supported approach.

Table 4.5: Lesson plan of Discussion and Conclusion

Exercise	Teaching and Learning Activities
Discussion and Conclusion: 1. What are the behaviors of short circuits? 2. What are the behaviors of open circuits? 3. What are the methods of measuring total resistance? 4. How to interpret the working of a circuit?	**Reflection:** Making conclusion for all the simulated exercise based on concepts learned. **Explain:** Verbalize circuits operation for discussion and conclusion.

The four parts in the Discussion and Conclusion section required each student to make generalization on their own of what they have learned in this lab session. This lab session is not graded. This takes the pressure off the students to be "right" and gives them more freedom to really express what they are thinking. Furthermore, the researcher is not the lecturer of their class, so they can feel free to comment and express the status of their understanding.

4.4 Summary

This chapter explained the rationale for the development of the inquiry-based simulation-supported approach. The justification for the questions included in the approach was based on the findings from a preliminary study conducted in an earlier semester was explained. The questions selected are aimed at examining students' understanding of circuits operations in the condition of open and short circuits. The open and short is activated by having a switch.

The method employed to develop the approach was also discussed. Circuits simulator is chosen as the media for students to construct and simulate the circuits. Simulation can help students to visualize the operation of a circuit. The POE tasks incorporated with an inquiry-based approach help students verbalize the operation of a circuit. The developed approach addressed open and short circuits concepts collectively with total resistance and interpretation of circuit diagrams as these concepts are interrelated. Lesson plans for each exercise were presented.

Discussion about pilot testing that was organized to check the flow and that the content of the approach also presented. The developed approach is ready to be administered to students. Intended learning outcome of the inquiry-based simulation approach incorporate POE tasks was also discussed.

CHAPTER 5

RESULTS AND DISCUSSION

5.1 Introduction

This chapter provides results and discussion of the data obtained from pretest, posttest, interviews, and intervention sessions. The main interest of the study is to focus on identifying alternative conceptions that can hinder students' learning. Marks obtained from pretest and posttest were analyzed and discussed quantitatively according to themes of concept tested.

The results from interviews and inquiry-based simulation-supported approach were analyzed qualitatively according to themes. There are four concepts tested. Students' verbalizations were analyzed to identify themes about students' alternative conception. The identified themes of students' alternative conceptions are discussed in this chapter. Finally, comparisons were made between before, during, and after the intervention to see changes on how students verbalize their conceptual understanding which will determine how the intervention has assisted their understanding.

5.2 Students' Achievement from Pretest and Posttest

The total marks obtained for pretest and posttest were analyzed using paired-sample t-test. The full results of paired-sample t-test are shown in Appendix Q. Results showed that the inquiry-based simulation-supported approach intervention session as teaching and learning activities has a strong positive impact in assisting students learning concepts. All questions have answer choice "Other" which was graded accordingly as right or wrong based on their written answer.

5.2.1. Results of Pretest and Posttest for Control Group

Table 5.1 shows the paired-sample t-test for the posttest score and the pretest score. There is significant evidence that their mean are not the same with a gain of 2.06. The probability value *p* of 0.024 gave significant improvement from pretest to posttest. To prove the significant changes, the effect size was calculated using Cohen's *d* which gives the value of 0.65 which indicated medium to large effect size in the differences of mean (Cohen, 1992).

Table 5.1: Paired-sample t-test of posttest and pretest (control group)

Test	**N**	**Mean**	**Standard Deviation**	**P**	**Cohen's *d***
Posttest	33	15.85	3.73	0.024	0.65
Pretest	33	13.79	3.11		

5.2.2. Results of Pretest and Posttest for Treatment Group

Table 5.2 shows the paired-sample t-test for the posttest score and the pretest score. There is significant evidence that their mean are not the same with the gain difference of 2.44. The probability value *p* of 0.000 gave significant improvement from pretest to posttest after learning with the inquiry-based simulation-supported approach. To justify the significant changes, the effect size was calculated using Cohen's *d* which gives the value of 0.79 which indicated a large effect size in the differences of mean (Cohen, 1992).

Table 5.2: Paired-sample t-test of posttest and pretest (treatment group)

Test	**N**	**Mean**	**Standard Deviation**	**p**	**Cohen's *d***
Posttest	47	16.70	2.53	0.000	0.79
Pretest	47	14.26	3.53		

5.2.3. Result for Themes of Concept Tested

As mentioned in Section 3.6.1, the 12 questions were grouped into four themes accordingly to the concept tested as shown in Table 5.3. Therefore the paired-sample t-test was also conducted for treatment group on the four themes to check for significant improvement of conceptual understanding after having intervention with an inquiry-based simulation-supported approach.

Table 5.3: Result paired-sample t-test for themes

Themes	**Test**	**N**	**Mean**	**Standard Deviation**	**p**	**Cohen's *d***
Complete circuits	Posttest	47	8.47	2.09	0.004	0.65
	Pretest	47	7.17	1.88		
Open circuits	Posttest	47	3.62	0.87	0.000	2.81
	Pretest	47	1.09	0.93		
Short circuits	Posttest	47	2.87	1.45	0.116	0.32
	Pretest	47	2.47	1.04		
Resistance	Posttest	47	3.26	0.82	0.000	1.36
	Pretest	47	1.89	1.15		

5.2.3.1 Complete Circuits

From the paired-sample t-test of complete circuits in Table 5.3, the mean between pretest and posttest showed significant difference of 1.30. The probability value of 0.004 indicates significant improvement from pretest to posttest of complete circuits after learning with the inquiry-based simulation-supported approach. To justify the significant changes, the effect size calculated using Cohen's *d* gaves the value of 0.65 which indicated a medium to large effect size in the differences of mean (Cohen, 1992).

5.2.3.2 Open Circuits

From the paired-sample t-test of open circuit in Table 5.3, the mean between pretest and posttest showed significant difference of 2.53. The probability value of 0.000 indicates significant improvement from pretest to posttest of open circuits after learning with an inquiry-based simulation-supported approach. To justify the significant changes, the effect size calculated using Cohen's *d* gaves the value of 2.81 which indicated a large effect size in the differences of mean (Cohen, 1992).

5.2.3.3 Short Circuits

From the paired-sample t-test in Table 5.3, the mean between pretest and posttest showed significant difference of 0.40. The probability value of 0.116 indicated no significant improvement from pretest to posttest of short circuits after learning with the inquiry-based simulation-supported approach. To justify the significant changes, the effect size calculated using Cohen's *d* gaves the value of 0.32 which indicated a small effect size in the differences of mean (Cohen, 1992).

5.2.3.4 Resistance

From the paired-sample t-test in Table 5.3, the mean between pretest and posttest showed significant difference of 1.37. The probability value of 0.000 indicates significant improvement from pretest to posttest of short circuits after learning with the inquiry-based simulation-supported approach. To justify the significant changes, the effect size calculated using Cohen's *d* gaves the value of 1.36 which indicated a large effect size in the differences of mean (Cohen, 1992).

5.3 Students' Alternative Conception from Interview

Based on the 12 questions in the concept test as shown in Appendix G, the questions are grouped together according to concepts tested as shown in Table 5.4. There are four main themes of concepts administered during pretest and posttest.

Coding was given to the student and researcher as S referring to student and R for the researcher. The students are numbered from S1 up to S47 accordingly. The shaded answer is the correct answer and correct reason to the concept test questions.

Table 5.4: Concepts tested and related questions

Concept Themes	Concept Test Question no.	Scope
1. Complete circuits	1, 2, 7, 11, 12	Series and parallel circuits
2. Open circuits	6,10	Open circuits and circuits with a switch
3. Short circuits	3, 8, 9	Short circuits and circuits with a switch
4. Resistance	4, 5	Total resistance in an open, short and switched circuits

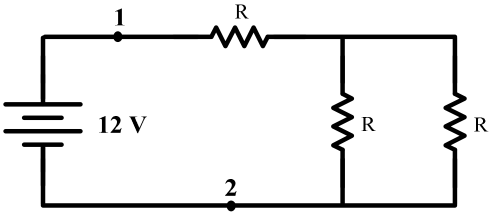
5.3.1. Complete Simple Circuits

Investigations on students' conception were analyzed by reviewing each question. Complete simple circuits theme is composed by questions 1, 2, 7, 11 and 12. The circuits involved are series and parallel where both are simple circuits. The interview data can detect students who had alternative conceptions. The in-depth analysis of alternative conceptions is tabulated later after the interview data is analyzed as will be discussed in detail in Chapter 6.

5.3.1.1 Question 1: Concept Test

Figure 5.1 shows Question 1 for complete circuit. Students were asked to analyze current flow in a circuit.

1. Compare the current at point 1 with the current at point 2. Which point has a larger current?



a. Point 1.
b. Point 2.
c. They are the same

Reason:

a. Current travels in two directions around the circuit.
b. Current from the battery goes to the circuit and then comes back to the battery.
c. The resistors use up a little of the current.
d. Others (Please specify): ____

Figure 5.1 Question 1

5.3.1.1.1 Concept Test Response

Table 5.5 shows students response for Question 1. The shaded answer and reason is the correct response for this question.

Table 5.5: Analysis of Question 1

Concept Tested	Answer & Reason	% Pretest Response Frequency	% Posttest Response Frequency	Analysis of Response
Circuits must be complete for current to conduct.	aa	2.1	4.3	This circuit is a complete and simple circuit. 63.8% and 76.6% students understand that current conducts in a complete circuit.
	ab	6.4	8.5	
	ac	6.4	6.4	
	ba	2.1	2.1	
	bb	2.1	0	
	ca	4.3	2.1	
	cb	**63.8**	**76.6**	
	cc	12.8	0	

However, students who gave reason c *(the resistors used up a little of the current)* in pretest and posttest showed that they assume the current is consumed by the resistors in the circuits. There are also students who gave answer a *(point 1 has larger current)* which shows their alternative conception of the current flow in the circuits where students assume that the current is consumed and sink at the resistors in the circuits (McDermott, 1996).

5.3.1.1.2 Interview Response

The following were reasoning made by students to explain for their wrong answer where more in-depth meaning of their conception was obtained.

R: *Can you explain which point has the higher current?*
S1: *Point 1*
R: *Why point 1?*
S1: *Because the current has not taken up by any R yet*
S2: *Yes, I have the same reason as her.*

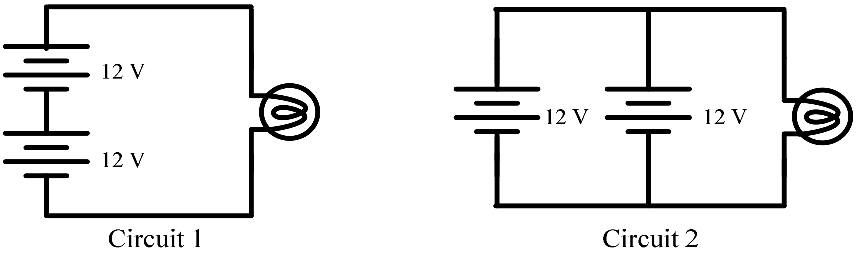
R: *What is your answer for question 1?*
S3: *Point 1*
R: *You said point 1 has higher current, can you explain your reason why?*
S3: *I thought the current has to divide into two, because of parallel, therefore the current coming out is less.*

S1 and S3 understanding was point 1 has higher current than point 2 because the resistor consumes a little current. The conclusion that can be made is that students do analyze circuits with sequential reasoning as agreed with (Engelhardt and Beichner, 2004), one element after the other; rather than taking the circuits as a whole (Smaill *et al.*, 2011). Such students believe that current travels around a circuit and are influenced by each element as it is encountered (Engelhardt and Beichner, 2004; Smaill *et al.*, 2011). Students who gave reason C *(the resistors used up a little of current)* do not understand the concept of the resistor and current which will be discussed in detail in section 5.3.4.

5.3.1.2 Question 2: Concept Test

Figure 5.2 shows Question 2 for complete circuit. Students were asked to analyze brightness of the bulb which relates to current flow in a circuit.

2. Compare the brightness of the bulb in Circuit 1 with that in Circuit 2. Which bulb is brighter?



a. The bulb in Circuit 1.

b. The bulb in Circuit 2.

c. They are the same

Reason:

a. Because two batteries in the Circuit 1 provide more voltage.

b. Because two batteries in the Circuit 2 provide more voltage.

c. Because 24 V is applied across the bulb in each circuit.

d. Others (Please specify): ____

Figure 5.2 Question 2

5.3.1.2.1 Concept Test Response

Table 5.6 shows students response for Question 2. The shaded answer and reason is the correct response for this question.

Table 5.6: Analysis of Question 2

Concept Tested	Answer & Reason	% Pretest Response	% Posttest Response	Analysis of Response

Arrangement of devices affects current and voltage distribution.	**aa**	**74.5**	**83.0**	83% of students can differentiate between series and parallel circuits. However students who answer B and C cannot understand that the arrangements of devices in a circuit affect current and voltage distribution.
	ab	2.1	4.3	
	ac	4.3	2.1	
	bb	8.5	2.1	
	bc	2.1	8.5	
	cb	2.1	0	
	cc	6.4	0	

The major alternative conceptions that students held were shown when they gave reason b *(because two batteries in the Circuits 2 provide more voltage)* or c *(because 24V is applied across the bulb in each circuit).* This shows that they cannot see the effect given by series and parallel connection on the distribution of currents and voltages (Engelhardt and Beichner, 2004; Yahaya, 2002). The written data were also obtained and analyzed from the answer option "Other".

5.3.1.2.2 Interview Response

The following were reasoning made by students to explain for their wrong answer where more in-depth meaning of their conception was obtained.

R: *Can you explain to me which circuit is brighter?*
S4: *Circuit 1*
R: *Can you give reason?*
S4: *Circuit 1 is in series so add up become 24V, but circuit 2 …I thought the current are the same in both circuits.*

R: *Can you explain to me which circuit is brighter?*
S5: *Circuit 2*
R: *Can you explain the reason for circuit 2?*
S5: *I am a bit confused. Two sources in parallel can be added up, but if in parallel, what happened? I am not sure…*

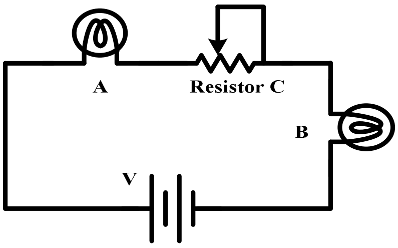
Based on these conversations, S4 and S5 were confused about series and parallel connections. Even though they have already taken BEC during their first semester, but they still rely on their surface understanding.

5.3.1.3 Question 7: Concept Test

Figure 5.3 shows Question 7 for complete circuit. Students were asked to analyze brightness of the bulb when there is a variable resistor.

7. If you increase the resistance of Resistor C, what happens to the brightness of bulbs A and B?

   a. A and B increase.
   b. A stay the same, but B decrease.
   c. A and B decrease.
   d. A and B remain the same.



Reason:

a. The battery supplies a constant current to the circuit.
b. Increasing Resistor C will decrease the circuit current.
c. Because Resistor C consumed some current.
d. Others (Please specify): ____

Figure 5.3 Question 7

5.3.1.3.1 Concept Test Response

Table 5.7 shows students response for Question 7. The shaded answer and reason is the correct response for this question.

Table 5.7: Analysis of Question 7

Concept Tested	Answer & Reason	% Pretest Response	% Posttest Response	Analysis of Response
Increasing or reducing the value of a resistor will affect the total current.	aa	0	2.1	When students have varieties of answer shows that strong alternative conception does hinder their scientific thinking. Even though this is simple series circuits but the variable resistors is a factor in
	ab	2.1	0	
	ac	2.1	2.1	
	ad	2.1	0	
	ba	4.3	0	
	bb	48.9	31.9	
	bc	8.5	8.5	

	bd	4.3	2.1	determining students' conception.
	ca	0	2.1	
	cb	**21.3**	**27.7**	
	cc	0	4.3	
	cd	2.1	10.6	
	da	4.3	6.4	
	db	0	2.1	

There were 48.9% from pretest and 31.9% from posttest showed a poor understanding about the effect of total resistance in a circuit. Their answers of b *(A stay the same, but B decrease)* and reason of b *(increasing resistor C will decrease the circuits current)* showed about students' alternative conception. Students again assumed that the current is consumed in the element as the current passes through (Engelhardt and Beichner, 2004). However, the percentage of correct answers of cb increased from 21.3% to 27.7%.

Reasons for the improvement are the intervention using inquiry-based simulation-supported approach. Many combinations of answers and reasons were chosen due to alternative conceptions they hold about the effect of a variable resistor in a series circuits.

5.3.1.3.2 Interview Response

The following were reasoning made by students to explain for their wrong answer where more in-depth meaning of their conception was obtained.

R: *Can you give reason to your answer in question 7?*
S10: *I understand like this. When the current flow, bulb A lights up, when the current flow through variable resistor, the current after that is lower.*

R: *Which concept that you don't understand here?*

S5: *I = V/R, so when the resistance increase, the current at bulb B drop, but not at bulb A. Because there is no resistor at A.*

R: *Can you explain your reason?*
S5: *I thought like this. When the current flows through variable resistor, the current after that is lower.*

R: *How many current flows in series circuits?*
S5: *One*
R: *Can you explain your reason?*
S11: *Before this there is no resistor, so Bulb A takes original current, when pass through variable resistor, the current after that is lower. When the current is reduces, therefore bulb B will be less bright compare to bulb A.*

Among the written answers obtained from the answer option "Other", were b *(bulb A stay the same but bulb B decrease)* in brightness with the reasons of *(bulb B will receive less voltage, current flow to bulb A without any resistance while current flow to bulb B with resistance, increase the resistor of C caused the current through bulb B is decrease)*; and *(voltage supply provide current to bulb A without any resistance).* These answers show that the students assumed bulb A consumed a little current with the remaining left to bulb B, causing bulb B to be less brighter than bulb A. Students alternative conceptions was that current is consumed by a component and the later component receives less current (Engelhardt and Beichner, 2004).

5.3.1.4 Question 11: Concept Test

Figure 5.4 shows Question 11 for complete circuit. Students were asked to analyze the current in a parallel branch.

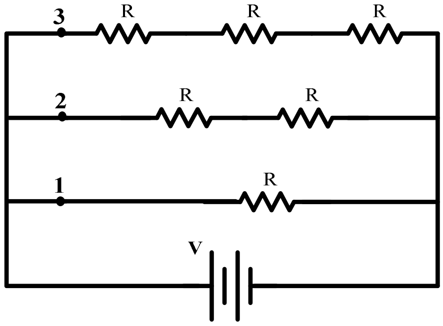
11. At which branch the magnitude of current is the lowest?

a. 1

b. 2

c. 3

d. They are the same



Reason:

a. Because the farthest away the branch from battery will get the least current.

b. Because the current will be divided equally between the branches.

c. Because more current will pass through the low-resistance branch.

d. Others (Please specify): ____

Figure 5.4 Question 11

5.3.1.4.1 Concept Test Response

Table 5.8 shows students response for Question 11. The shaded answer and reason is the correct response for this question.

Table 5.8: Analysis of Question 11

Concept Tested	Answer & Reason	% Pretest Response Frequency	% Posttest Response Frequency	Analysis of Response
Voltage source supplied directly across parallel branch. Current in the branch depends on value of elements in that branch	ab	2.1	2.1	Simple parallel circuits was observed as less alternative conceptions provided there is no open or short and no switch to make students confused
	ac	8.5	0	
	ca	12.8	6.4	
	cb	10.6	14.9	
	cc	**55.3**	**72.3**	
	db	10.6	2.1	
	dc	0	2.1	

Students seem to understand that current in a branch depends on the value of elements in that branch as shown from their answer where 55.3% from pretest and 72.3% from posttest gave response correctly. However, there are students (10.6% from pretest and 14.9% from posttest) who gave reason b *(because the current will be divided equally between branches)* where they were thinking that current is the same in parallel circuits (Smaill *et al.*, 2008).

5.3.1.4.2 Interview Response

The following were reasoning made by students to explain for their wrong answer where more in-depth meaning of their conception was obtained.

R: *In parallel circuits, is the current the same?*
S16: *Different*
R: *Which branch is the lowest now?*
S6: *Branch 3*
R: *Give reason*
S9: *Hmmmm A…because the branch is farthest from the battery*

R: *Can you give your answer?*
S10: *The more resistors will give lesser current*
R: *And the reason?*
S10: *Because the branch is the farthest from the source*
S13: *Yes, I have the same reason as him.*

However, the interview data was contradicted from the answer and reason given in the pretest and posttest. The unexpected finding was that students thought that the farther the branch was from the source the less current it will get. This alternative conception need further research on students understanding.

5.3.1.5 Question 12: Concept Test

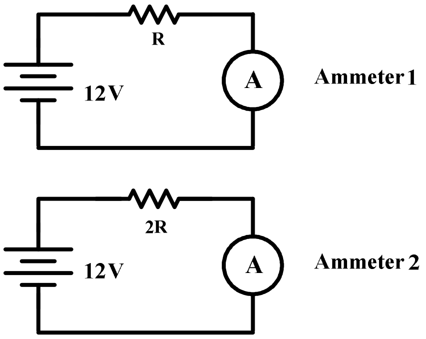
Figure 5.5 shows Question 12 for complete circuit. Students were asked to analyze the ammeter reading.

12. Compare the readings of Ammeter 1 and Ammeter 2 in the circuits shown below, which one has higher reading?

a. Ammeter 1.

b. Ammeter 2.

c. They are the same.



Reason:

a. Because the voltage is the same in both circuits.

b. Because the greater the resistance, the lower the current for the same voltage source.

c. Because the resistance does not affect the current.

d. Others (Please specify): ____

Figure 5.5 Question 12

5.3.1.5.1 Concept Test Response

Table 5.9 shows students response for Question 12. The shaded answer and reason is the correct response for this question.

Table 5.9: Analysis of Question 12

Concept Tested	Answer & Reason	% Pretest Response Frequency	% Posttest Response Frequency	Analysis of Response
Change in total resistance cause the change in total current, but not the voltage source.	aa	2.1	0	With complete circuits, students have no alternative conception.
	ab	**83.0**	**93.6**	
	ac	4.3	0	
	bb	8.5	2.1	
	bc	0	2.1	
	cc	2.1	2.1	

Students understand that change in total resistance causes a change in total current, but not the voltage source. Students heavily depend on ohm's law which makes their explanation easier for the complete circuits. Students' alternative conception is dominant when they encountered a circuit with a switch, open or short as will discussed in section 5.3.2. and 5.3.3.

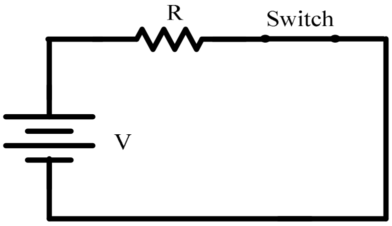
5.3.2. Open Circuits

Based on conclusions made in 5.3.1.5.1 earlier, students had alternative conceptions when a circuit has a switch, be it open or closed. The two questions grouped under open circuits which are questions 6 and 10 where both circuits contained a switch. These circuits can be used to determine what their alternative conceptions are for open circuits. Open circuits situation occur when a branch is not part of a closed circuit.

5.3.2.1 Question 6: Concept Test

Figure 5.6 shows Question 6 for open circuit. Students were asked to analyze a circuit having a switch.

6. After the switch is opened, what happens to the resistance of resistor R?



a. Increases.
b. Stay the same.
c. Goes to zero.

Reason:

a. The value of resistance depends on the applied voltage.
b. Since there is no current, the resistance of the resistor will go to zero.
c. The electrical resistance does not depend on current or voltage.
d. Since there is no current, the resistance of the resistor will increase.
e. Others (Please specify): ____

Figure 5.6 Question 6

5.3.2.1.1 Concept Test Response

Table 5.10 shows students response for Question 6. The shaded answer and reason is the correct response for this question.

Table 5.10: Analysis of Question 6

Concept Tested	Answer & Reason	% Pretest Response Frequency	% Posttest Response Frequency	Analysis of Response
Switch will define which elements active or inactive in a circuit.	ac	4.3	2.1	This circuit asks for resistance during open circuits. Strong alternative conceptions about resistance and open circuit.
	ba	4.3	0	
	bb	2.1	0	
	bc	**48.9**	**85.1**	
	be	2.1	4.3	
	ca	2.1	0	
	cb	29.8	6.4	
	cc	4.3	0	
	cd	0	2.1	
	ce	2.1	0	

The major alternative conception in the pretest was the answer of c *(goes to zero)* and reason of b *(since there is no current, the resistance of the resistor will go to zero)* where they assumed that when switch is open, current goes to zero, hence the resistance also goes to zero. From their reply, it can be concluded that they are taking current as the prime concept which drives the circuits; where they really rely on Ohm's Law to interpret circuits operation (Smaill *et al.*, 2008). However from the interview data, where students have to explain their reasoning for their wrong answer, more in-depth meaning was obtained. Many combinations of answers and reasons were chosen as their answer because of strong alternative conception of resistance and open circuits.

5.3.2.1.2 Interview Response

The following were reasoning made by students to explain for their wrong answer where more in-depth meaning of their conception was obtained.

R: *When there is no current, what happen to R?*
S9: *Hmmm we have to use V=IR?*
R: *Ok…if you think you have too*
S9: *If there is no current, and we want to find the value of R, so R is 0 isn't? Because there is no current.*

R: *What is your answer?*
S3: *When there is open and closed, I am confused…*
R: *So you have problem with switched circuits…*
R: *When the switch is opened, is there any current flow?*
S1: *No*
R: *If no current, is there any voltage?*
S1: *No, since cannot use ohms law.*

R: *Is the circuits operates when the switch is opened?*
S1: *No*
R: *Then what is the value of the resistance?*
S1: *Same as original value.*
S4: *Why?*
S1: *If there is no current….hmmm I don't know….*

R: *When the switch is opened, is there any resistance value?*
S5: *I thought when the switch is opened, no current flow, therefore the resistance is also zero.*

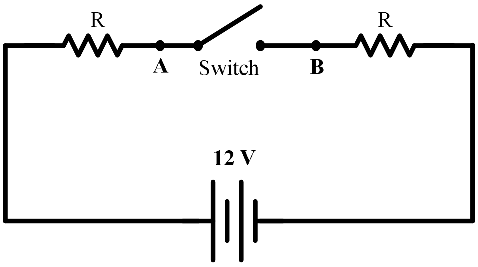
From the “Other (Please specify)” section, students wrote that *cannot apply ohm’s law because no current; and switch open no current therefore no resistance.* The analyzed data confirms that the students depend heavily on ohm’s law as their main rule to analyze circuits; where current is the prime concept (Smaill *et al.*, 2008).

5.3.2.2 Question 10: Concept Test

Figure 5.7 shows Question 10 for open circuit. Students were asked to analyze the voltage at a point in the circuit.

10 What is the voltage between points A and B?

a. 0 V
b. 12 V
c. Less than 12 V



Reason:

a. There is no voltage since there is no current flowing.
b. Because some of the voltage of a battery has dropped across the resistors.
c. If there is no resistance, there will be no voltage dropped.
d. Others (Please specify): ____

Figure 5.7 Question 10

5.3.2.2.1 Concept Test Response

Table 5.11 shows students response for Question 10. The shaded answer and reason is the correct response for this question.

Table 5.11: Analysis of Question 10

Concept Tested	Answer & Reason	% Pretest Response Frequency	% Posttest Response Frequency	Analysis of Response
Voltage persists, but current does not, in an open circuits.	aa	55.3	40.4	The question asked for open circuit's voltage. Varieties of answer are given.
	ab	2.1	0	
	ac	10.6	19.1	
	ad	2.1	4.3	
	ba	0	2.1	
	bb	0	4.3	
	bc	4.3	2.1	
	bd	**0**	**4.3**	
	cb	17.0	23.4	
	cc	8.5	0	

The majority of the students (55.3% of pretest and 40.4% of posttest) responded with an answer of a *(increases)* and reason a *(the value of resistance depends on the applied voltage).* They do not understand the concept of open circuits and the affect of voltage in an open circuit. In addition students still have only a surface understanding on the concept of resistance. However from the interview data, where students have to explain their reasoning for their wrong answer, more in-depth meaning was obtained. They do not notice that voltage persists, but current does not, in an open circuits (Yahaya, 2002). Again this shows that students apply the ohm's law to the analysis of any circuits without considering open or short circuits effect.

5.3.2.2.2 Interview Response

The following were reasoning made by students to explain for their wrong answer where more in-depth meaning of their conception was obtained.

R: *Can you explain to me about this question?*
S14: *Now the switch is open, no current flow, therefore no voltage at A-B.*

R: *Why 0 Volt at A-B?*
S3: *Because of open circuits.*
R: *Is there any voltage drop at each resistor?*
S3: *No, because of no current.*

R: *Is the circuits operates during open circuits?*
S4: *No.*
R: *Is there any voltage at A-B?*
S4: *No. How come got any voltage if there is no current.*

R: *Can you explain your answer and reason?*
S10: *There is no voltage since there is no current flowing.*

R: *Can you explain?*
S12: *I am not confident with open and short. My answer is A, because when there is no current, the voltage also zero.*

All data from the interview above shows that students assumed that when current flow, it shows the existence of voltage. They really assume current as the main concept, not the voltage. Therefore they perceived the battery is a current source not a voltage source (Yahaya, 2002).

R: *Can you give me reasons for question 10?*
S14: *Can we measure V at a place with no R?*
S2: *Cannot*
R: *Then what is the answer?*
S16: *Because there is no resistor, so there is nothing to be measured.*

R: *What do you understand about this question?*
S8: *If switch is open, there is still a voltage. When the voltage pass through resistor, there is a voltage drop.*
R: *Means that the value of V at A-B is less that 12 V?*
S8: *Yes because has been taken by the first R.*

Based on these conversations, S14 really relies on Ohm's law, therefore all values are zero. This final response shows what S8 understands about voltage drop at a component; however the effect of open circuits is neglected. Furthermore, S8 assumes that there is voltage drop at first R though the circuit is open. The conclusion based on conversations on open circuit was students do not visualize the operation because the current is the prime concept that students hold.

The written data were also obtained and analyzed from the answer option "Other". Among the answers written by many students were a *(0 Volt)* with the reasons *no voltage drop since the switch is open; not a complete circuits and there is no voltage across open circuits.* A few that answered b had reasons d with their written reasons as *in open circuits, there are voltages but no current; and same as put the voltmeter in parallel with the voltage source.* All the answers show that the students assume with that an open circuit nothing will happen or nothing is affected (Streveler *et al.*, 2008).

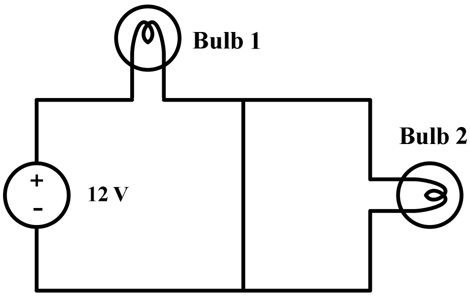
5.3.3. Short Circuits

The previous two questions were about open circuits. These next three questions (3, 8 and 9) refer to circuits with shorted arms or a switch can be used to determine students' alternative conception about short circuits. A short circuit occurs when there is no resistance between the two terminals of interest. The outcomes are discussed below.

5.3.3.1 Question 3: Concept Test

Figure 5.8 shows Question 3 for short circuit. Students were asked to analyze the brightness of the bulb in a combination circuit.

3. Compare the brightness of Bulb 1 and Bulb 2 in this circuit, which one is brighter?



a. Bulb 1.

b. Bulb 2.

c. They are the same.

Reason:

a. Because the bulbs are connected in parallel.

b. Because no current will pass through Bulb 1.

c. Because no current will pass through Bulb 2.

d. Others (Please specify): ____

Figure 5.8 Question 3

5.3.3.1.1 Concept Test Response

Table 5.12 shows students response for Question 3. The shaded answer and reason is the correct response for this question.

Table 5.12: Analysis of Question 3

Concept Tested	Answer & Reason	% Pretest Response Frequency	% Posttest Response Frequency	Analysis of Response
The voltage and current distribution is affected by the existence short circuits.	aa	2.1	0	Now students started to shows their alternative conception especially when open circuit is existed in a circuit and need to be analyzed.
	ac	**66.0**	**78.7**	
	ad	8.5	6.4	
	bc	0	2.1	
	ca	17.0	8.5	
	cc	2.1	4.3	
	cd	4.3	0	

Regardless of their reasons, students who answered b *(bulb 2)* and c *(there are the same)* totally ignored the effect of a shorted arm in the circuit. However, from the interview data, where students have to explain their reasons for their wrong answer, more in-depth meaning was obtained about students' alternative conceptions of the current flow in short circuits.

5.3.3.1.2 Interview Response

The following were reasoning made by students to explain for their wrong answer where more in-depth meaning of their conception was obtained.

R: *Can you explain to me which bulb is brighter?*
S7: *Bulb 1*
R: *Why bulb 1?*
S7: *Because bulb 1 receive current first.*
R: *Then a little bit of current left?*
S7: *Yes.*

S7 assumed that current flow from one component to another where current is consumed by bulb 1 and the remaining goes to bulb 2. Same explanation obtained from S17 as shown in conversation below. Both S7 and S17 assumed that current still goes to shorted branch.

R: *Can you explain to me which bulb is brighter?*
S17: *The current flow from bulb 1 then to bulb 2, so they both have the same brightness*
R: *So bulb 1 and bulb 2 are in series?*
S17: *Eh no no, they are in parallel, therefore bulb 1 is brighter than bulb 2. Hmmm I am not sure…..*

However the answer given by S18 shows that he totally ignored the effect of short circuits. This wrong answer was given quite frequently on both the pretest and the posttest.

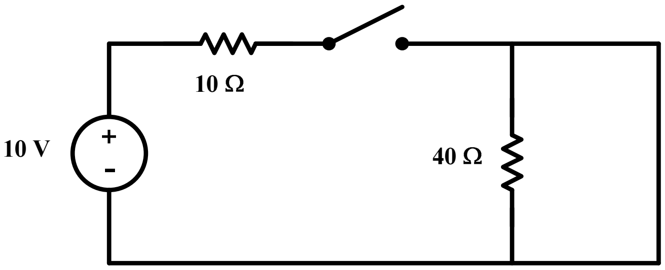
R: *What is your answer and reason?*
S18: *Here there is a short circuit; it is just like no effect to the circuits… just like nothing happen.*
R: *So means that short circuits does not affect the circuits?*
S18: *Yes.*

From the answer option "Other", students answering was c *(they are the same)* had reasons d *(because the bulb are connected in series).* However students who answered a *(bulb 1 brighter)* is the correct answer but gave the wrong reason. Among the reasons were *because bulb 1 is connected in series; bulb 2 being short circuits; bulb 1 got the more voltage;* and *because the current across bulb 1 is higher than bulb 2.* All of the answers show that the students assume bulb A consumed little current which the balance of remaining current will be left for bulb B which caused bulb B to be less brighter than bulb A. All their answers show that they neglected the effect of a shorted arm in a circuit.

5.3.3.2 Question 8: Concept Test

Figure 5.9 shows Question 8 for short circuit. Students were asked to analyze the value of resistance.

8. What is the total resistance of the circuit when the switch is closed?



a. 50 Ω

b. 10 Ω

c. 8 Ω

d. 0 Ω

Reason:

a. The total resistance is the sum of the two resistors.

b. Only the 10 Ω resistor operates in the circuit.

c. The two resistors are in parallel.

d. Because the total resistance equals zero in a closed circuit.

e. Others (Please specify): ____

Figure 5.9 Question 8

5.3.3.2.1 Concept Test Response

Table 5.13 shows students response for Question 8. The shaded answer and reason is the correct response for this question.

Table 5.13: Analysis of Question 8

Concept Tested	Answer & Reason	% Pretest Response	% Posttest Response	Analysis of Response
Switch will define which elements active or inactive.	aa	19.1	8.5	A circuit with switch and short circuits. Varieties of alternative conception showed by students.
	ad	2.1	0	
	bb	**72.3**	**74.5**	
	bc	0	2.1	
	be	0	10.6	
	cb	2.1	0	
	cc	2.1	2.1	
	dd	2.1	2.1	

Students who gave answer of a *(50Ω)* have ignored the effect of short circuits where they understand that both resistors are active in the circuits. While students who answered c *(8Ω)* thought that the circuits is a pure parallel circuits. However from the interview data, where students have to explain their reasoning for the wrong answer, more in-depth data were obtain.

5.3.3.2.2 Interview Response

The following were reasoning made by students to explain for their wrong answer where more in-depth meaning of their conception was obtained.

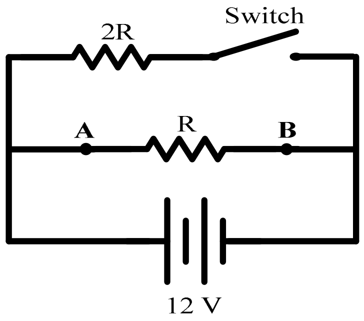
> ***R:*** *What happen to current when it reaches the two branches?*
> ***S12:*** *Divided into two branches because the branch is in parallel*
> ***R:*** *Then the current combine again after that?*
> ***S12:*** *Yes*
>
> ***R:*** *What happened to the current flow at the node (of having shorted branch)?*
> ***S14:*** *Flow into both branches.*
>
> ***R:*** *What happen to the current flow?*
> ***S18:*** *I don't understand concept of short circuits. When the switch is closed, the current flows, when it reaches short…where does it goes? I am not sure which one.*

From the answer option "Other", many answers were written by students. Among given answers were b *(10Ω)* the correct answer but with the wrong reason of *(the two resistors is in series).* Conclusion can be made from these answers are that students assume the short circuits does not have any impact on the operation of circuits.

5.3.3.3 Question 9: Concept Test

Figure 5.10 shows Question 9 for short circuit. Students were asked to analyze the voltage at a point in a circuit.

9. What will happen to the voltage between points A and B if the switch is closed?



a. Increase
b. Decrease
c. Stay the same

Reason:

a. The voltage source will be distributed between the resistors based on the value of the resistance.
b. Closing the switch will increase the total resistance of the circuit.
c. Adding 2R will decrease both the voltage across R and the current flowing through R.
d. Adding 2R resistor affects the battery current only.
e. Others (Please specify): ____

Figure 5.10 Question 9

5.3.3.3.1 Concept Test Response

Table 5.14 shows students response for Question 9. The shaded answer and reason is the correct response for this question.

Table 5.14: Analysis of Question 9

Concept Tested	Answer & Reason	% Pretest Response Frequency	% Posttest Response Frequency	Analysis of Response
Adding another branch in a parallel circuits will not affect the total voltage	aa	4.3	0	Varieties of answer given proved that strong alternative conceptions that they held with a switched circuits.
	ab	2.1	4.3	
	ac	0	2.1	
	ba	4.3	8.5	
	bb	4.3	6.4	
	bc	25.5	6.4	
	bd	0	2.1	
	be	2.1	0	
	ca	4.3	6.4	
	cb	2.1	2.1	
	cc	4.3	4.3	
	cd	**25.5**	**36.2**	
	ce	21.3	21.3	

Answer b *(decrease)* given by students were analyzed. Their surface understanding on concept of parallel circuits hinders their scientific conception. They have convoluted understanding about the dependence of current on terminal voltage only, not the resistor (Yahaya, 2002). Some chose answer a *(increase)* because of alternative conception that voltages in parallel circuit have less resistance.

5.3.3.3.2 Interview Response

The following were reasoning made by students to explain for their wrong answer where more in-depth meaning of their conception was obtained.

R: *What is the concept behind parallel circuits?*
S9: *Same voltage*
R: *What is the reason?*
S9: *I don't know how to explain and give reasons.*

R: *Can you explain to me why the voltage stays the same?*
S13: *I am confused. Is voltage stay the same or have to divide by 2 branches…*
S5: *I don't know about the effect of R and 2R in this circuit….parallel circuits*

From the answer option "Other", among the answers written by students were c *(stay the same)* with the correct reasons of *in parallel voltage is the same.* All the answers show that the students understand the concept of parallel circuits but cannot relate for parallel circuits with resistance.

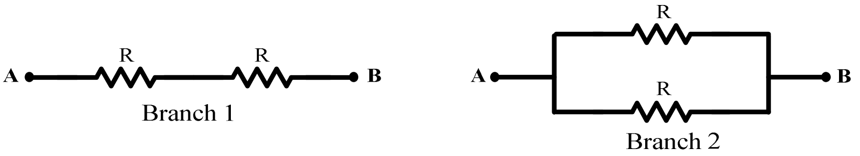
5.3.4. Resistance

Students are very knowledgeable when it comes to calculation which is on procedural knowledge. They are very comfortable of using calculators. Questions 4 and 5 were used to determine students' alternative conceptions of resistances in an open circuit with a switch. However, when it comes to questions that need their conceptual understanding, they become confused as shown in Question 4 as varieties of answers were given.

5.3.4.1 Question 4: Concept Test

Figure 5.11 shows Question 4 for resistance. Students were asked to analyze the resistance value.

4. Compare the resistance of Branch 1 with that of Branch 2 where point A and B are open terminals. The resistance of Branch 1 is ____________________ the resistance of Branch 2.



a. Four times

b. Double

c. The same as

d. Half

Reason:

a. The total resistance of each branch equals the sum of the two resistors.

b. Because the total resistance equals zero in open circuits.

c. Adding a resistor to any circuit will increase the overall resistance.

d. Others (Please specify): ____

Figure 5.11 Question 4

5.3.4.1.1 Concept Test Response

Table 5.15 shows students response for Question 4. The shaded answer and reason is the correct response for this question.

Table 5.15: Analysis of Question 4

Concept Tested	**Answer & Reason**	**% Pretest Response Frequency**	**% Posttest Response Frequency**	**Analysis of Response**
There are values of resistance in an open circuit.	aa	6.4	21.3	Now the concept of resistance with no source connected. Students seem to have varieties of answers interpreting the open circuit effect on the resistance.
	ab	8.5	2.1	
	ac	10.6	17.0	
	ad	**6.4**	**19.1**	
	ba	23.4	12.8	
	bb	4.3	2.1	

Concept Tested	Answer & Reason	% Pretest Response Frequency	% Posttest Response Frequency	Analysis of Response
There are values of resistance in an open circuit.	bc	8.5	8.5	Now the concept of resistance with no source connected. Students seem to have varieties of answers interpreting the open circuit effect on the resistance.
	bd	21.3	10.6	
	ca	2.1	4.3	
	cb	2.1	0	
	cc	2.1	0	
	da	2.1	2.1	
	dd	2.1	0	

Multiple answers and reasons given by students showed that they have many alternative conceptions. Only 6% from pretest, and 19% from posttest responded correctly. Most of them composed the answer themselves.

5.3.4.1.2 Interview Response

The following were reasoning made by students to explain for their wrong answer where more in-depth meaning of their conception was obtained.

R: *Can you explain how do you figure out this question?*

S5: *This is an open circuit, so if open circuits, there is no current, therefore no value of resistance.*

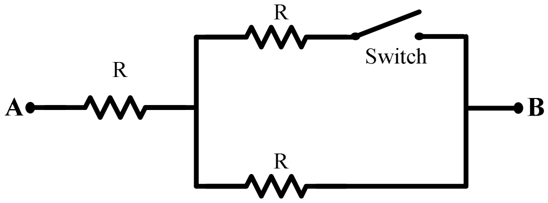
Based on S5 answer, his perception is resistance exists only when current and voltage exist. He strongly relies on Ohm's law regardless of the type of circuits. From the answer option "Other", among written answers were a, b and d. These showed that they can differentiate between series and parallel circuits. However, in d, they cannot give a solid reason such as *in series added up but in parallel have to times and divide.* This is the right reason, but not the reason related to the answer given earlier. Answers b or d shows that they understand the concepts but cannot give reasons to support their answer. It is a bit risky to assume that if students understand about series and parallel circuits that they can apply the concept to any scenario; which is proved to be wrong based on students' answer to this question.

5.3.4.2 Question 5: Concept Test

Figure 5.12 shows Question 5 for resistance. Students were asked to analyze resistance value when a switch is used. Students' alternative conception emerged again in Question 5 for which they provide varieties of answers. This can be concluded that with an open circuit and resistance, their alternative conceptions is high. This is compounded even more if the circuit has a switch.

5. How does the resistance between the terminal A and B change when the switch is closed?

a. Increase by R/2
b. Increase by R
c. Stay the same
d. Decrease by R/2
e. Decrease by R



Reason:

a. Closing the switch will add a resistor in series.
b. The circuit is not affected after closing the switch.
c. Adding a resistance in parallel to any branch decreases its total resistance.
d. Others (Please specify): ____

Figure 5.12 Question 5

5.3.4.2.1 Concept Test Response

Table 5.16 shows students response for Question 5. The shaded answer and reason is the correct response for this question.

Table 5.16: Analysis of Question 5

Concept Tested	Answer & Reason	% Pretest Response Frequency	% Posttest Response Frequency	Analysis of Response
Adding or removing resistor will affect the value of total resistance.	aa	8.5	8.5	Now open circuits is integrated with a switch and resistors. Varieties of answers were given which show that they have many alternative conceptions. They cannot visualize the effect of switch on resistances.
	ac	10.6	10.6	
	ba	4.3	4.3	
	bc	4.3	4.3	
	cb	6.4	8.5	
	cc	0	4.3	
	da	4.3	4.3	
	dc	**53.2**	**46.8**	
	dd	4.3	4.3	
	ea	0	4.3	
	ec	4.3	0	

Students did not notice the effect of open and closed switch in a circuit which was compounded with their previous alternative conception about resistance in open circuits. Many answers and reasons chosen showed their alternative conception about resistance value in an open circuit when a switch is open or closed.

5.3.4.2.2 Interview Response

The following were reasoning made by students to explain for their wrong answer where more in-depth meaning of their conception was obtained.

R: *When the switch is open, is the current flow to the top R?*
S8: *No*
R: *So if the switch is open, what is the total R?*
S8: *Hmmm open….open circuits I don't understand*

R: *Which R is in this circuit if the switch is open?*
S1: *I forgot about open and closed. During close circuits which R is active, which one is not…*

R: *When the switch is open, is the current flow to the top R?*
S3: *Hmmm not sure…*
R: *So is there any current flow at open branch?*
S3: *No.*
R: *If there is no current, will the top R active?*
S3: *No….*
R: *So what is the total R during open?*
S3: *Is the lower R active during open?*
R: *Good question…think for a while*
S3: *I am not sure….as I understand if the switch is open, the lower R also is inactive…therefore only the first R left….*

The written data from the answer option “Other”, one popular answer is *closing the switch will lower the resistor in parallel.* Based on interview data, many students explain that they cannot notice the effect of switch especially when determining the total resistance in an open circuit. Students are confused about the function of switch. They perceived as opening the switch as disabling the whole parallel arm, therefore no current flow to B; hence ignored both resistors in parallel. These concepts of resistance, open and short were inter-related as their alternative conception. However, after all the interview session finished, an unexpected finding emerged. Students’ explanations are as quoted below.

Interview: Unexpected Findings

R: *Can you explain your understanding by now?*
S6: *I am not really love electric circuits during last semester….because of the lecturer.*

R: *Any other comment?*
S16: *Because the lecturer uses more PowerPoint slides.*

R: *What more?*
S16: *I am really stressed during my final exam especially on topic about Thevenin.*

R: *Anything else?*
S11: *I don’t like mathematical operation….too much.*

There are many internal and external factors that affect student learning. This can be investigated later in future research. S16 commented on Thevenin theorem, the justification of finding students' alternative conceptions on open and short circuits concepts was just right. Furthermore, S11 commented that mathematical operations can be made simpler if the teaching and learning approaches concentrate more on enhancing students' understanding of concepts first before getting into procedural knowledge. With this order, students understand the concept first before applying it in different scenario.

Comments from S16 regarding the use of PowerPoint slides in teaching and learning can be defined in many scopes. He may get bored if he acts only as passive listener. However, PowerPoint slide is beneficial if incorporated in a class where she becomes an active learner. Comments from S6 regarding the lecturer has to be looked into. It is either the student was originally not interested in engineering or the lecturer which caused his interest to decline. Research is required to link engineering education interest with teaching strategies.

5.4 POE with Inquiry-Based Simulation-Supported Approach

An inquiry-based simulation-supported approach was created in an effort to increase student responsibility for learning and to improve teaching in BEC. Results indicated that students and lecturer alike do appreciate the use of virtual simulations but care should be taken to ensure that the simulations are relevant to the course material and that educators are familiar enough with the use of the simulations to assist students should any problems arise (Albuquerque *et al.*, 2010).

The lesson plan for the approach was shown in section 4.3 and Appendix H. The circuits drawn and simulated by student are shown in Appendix J. Findings from the approach intervention sessions suggest that students who initially did not acquire satisfactory understanding of circuits' concepts and common students' alternative conceptions were justified through analysis of inquiry-based session.

However, one improvement shown by students' was when they started to do inquiry for themselves by verbalizing the process of simulation.

The researcher acts more like a facilitator. If one student gave an answer, the researcher will open the conversation and ask his/her friend, "does the answer given is correct" or "do you agree with his answer". He/she has to elaborate on that matter. It looks like everybody will have to answer or else he/she will be asked. This really follows active-learning class with student-centered. By the end of the exercise 1 session, students seem to do more talking, questioning and reasoning than the researcher. This meets the purpose of inquiry-based approach.

Even though they have listened to their friends answers on certain concepts, they still cannot verbalize perfectly about their understanding. The truth about students' understanding can really be displayed by verbalizing the process. This shows that conceptual understanding cannot be plagiarized. Once the explaining session is ended, they have to write their answer based on what they have understood from the question and answer session into the approach answer sheet.

There are three circuits that have to be simulated using Multisim. First exercise is a simple series circuit, second is a short circuit and finally, is an open circuit. Each simulated working circuits has to be explained verbally before answering the next question. All POE steps are followed for each question.

Students should start their observation by first looking at the circuits as a whole and detecting what component, devices and sources are used. Figure 5.13 shows researcher representation flows of concept thinking about the operation of a circuit. Students should use in explaining their exercises. Based on the components, devices and sources, students should be able to define whether a circuit is a DC or AC circuits. The second part is student should be able to define the type of circuits used either series or parallel. Once both are known then the circuits operation can be analyzed. As suggested by (McDermott, 1993), the flow of the questions and answers for this approach intervention session are tailored to method as mentioned in section 2.3.1.

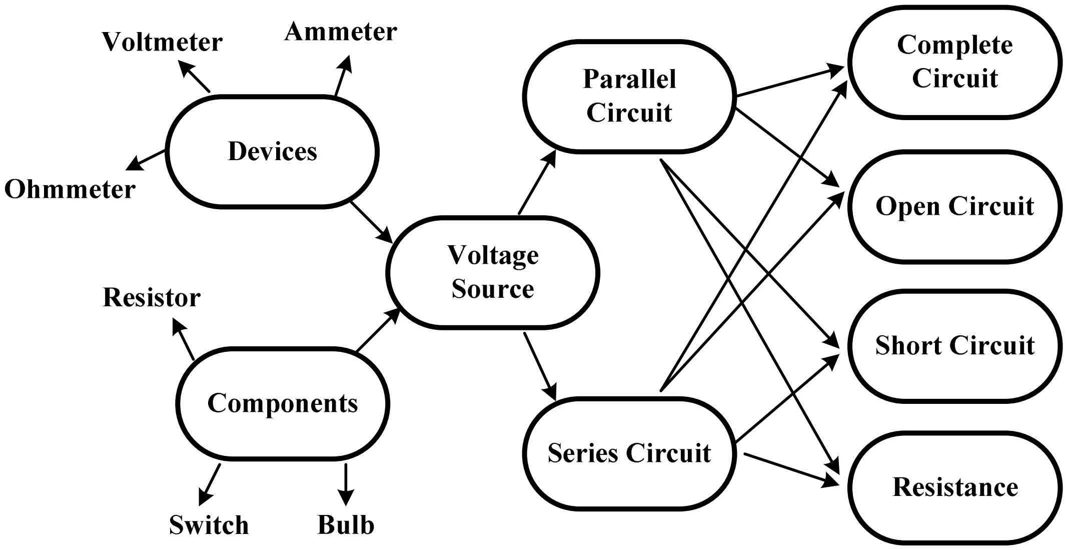


Figure 5.13 Flow of concept thinking about the operation of a circuit

All the data obtained from approach intervention sessions were transcribed and analyzed using constant-comparative method. The categories identified from the analysis of the interviews formed the basis in analyzing the approach intervention sessions. The first and second level of analysis is shown in Tables 5.17 until 5.29.

Based on the flow of concept thinking, students' conversation during approach is analyzed. Even though this simulation-supported is built on POE tasks but students explanations sometimes were diverted because they need further elaboration on certain concepts. Therefore the explanation task took longer compared to predict and observe tasks. Table 5.17 shows an example of the conversations in the laboratory and the descriptive codes and categories that were obtained from the transcript analysis using constant-comparative method. The descriptive codes and categories will be discussed in detail in Chapter 6.

Table 5.17: Example of descriptive codes and categories of analysis

Sample	Descriptive Codes	Categories
R: Now explain about circuits with ammeter. **S16:** Ammeter is connected in series, and then the current is divided into two. **R:** Why the current has to divide into two? **S16:** Yes into R and into short.	See the correct simulation result but cannot verbalize	Verbalize the simulated output
R: You said there is current flowing through 40 ohm resistor? **S16:** *Yes there is current flow…*	Current flow	Circuits operation
R: Ok now look at your same circuit but now with the bulb….*why the bulb is not light up*? **S16:** O yes.... **R:** Any comment?	Students ask question for clarification	Learning by inquiry
S16: *Means that there is no current here (at short circuits)?*	The effect of short circuits	Short circuits
R: How to measure total resistance? **S23:** Remove the source. **R:** Then… **S26:** Remove devices	Students ask question for clarification	Learning by inquiry
R: Then what is your finding? **S25:** Ooops…*Does open circuits has resistance?*	The effect of open circuits	Open circuits
R: Any current or voltage at short circuits? **S1:** No voltage and no current. **R:** Can you explain why? **S1:** *When there is short, current flow through short.*	See the correct simulation result but not confident to verbalize	Verbalize the simulated output
R: If there is current then why there is no voltage? **S1:** Because there is no resistor.	Current flow	Circuits operation
R: How do you justify that? **S1:** *Because when use V=IR, then V is zero.*	Rely on Ohm's Law	Current is the prime concept

5.4.1. POE Tasks on Simple Circuits

The POE tasks for Exercise 1 are quite simple. The circuit's simulation works and the POE tasks fit nicely to students' conceptual understanding. As shown in the data from Concept Test and interview, students did not have big problem in understanding and explaining the simple circuits. Table 5.18 shows students' prediction task for part c. They can predict which devices to use; this shows that they are well versed in basic devices for electric circuits. In fact the same prediction occurred when dealing with part c for exercise 2 and 3. This is because students are simulating a DC circuits. The observation and explanation task is simpler for students to execute. They really can delve into simple series circuits.

Table 5.18: Prediction task

Sample	Descriptive Codes	Categories
R: Question 1.... Can this circuit works? With the switch open. **All:** No **R:** Can somebody give reasons? **S12:** *(Not working) because the switch is open.* **R:** Correct. Ok now turn on the switch. Run and Stop your simulation. Can you SEE the working of the circuits? **S14:** *The circuit works but we cannot SEE it's working.* **R:** How can we see the circuits are working? What devices should we use? **All:** *Bulb, multimeter, voltmeter, bell, buzzer, ammeter.* **R:** Good responses.	Able to predict the devices to be used in the circuits	Circuits operation

Problem arose when they wanted to make use of the apparatus mentioned in the prediction task. They make mistakes as shown from their conversation in Table 5.19.

Table 5.19: Connecting meters

Sample	Descriptive Codes	Categories
R: You want to measure the voltage drop across R? *And you put the voltmeter across switch, is it correct*? **S8:** *Hmmm not sure…* **R:** You want to use multimeter. Ok can you explain how to connect to the circuits? **S10:** *Connect in series of parallel?*	Connect meter to measure value	Circuits operation

Sample	Descriptive Codes	Categories
R: Can you explain the connection of voltmeter and ammeter in a circuit. **S16:** *Voltmeter in parallel and ammeter in series.* **R:** *But look at your connection, Is it right?* **S16:** *Oooo yea …* **R:** *You must be able to verbalize your understanding and reasoning. You can explain in Bahasa Malaysia.*	Understand basic concept but making wrong application Write and verbalize answer in Malay	Surface understanding Deep understanding
R: Your first circuit, can you explain? **S7:** *The first circuit, closed switch, bulb light up. For current…hmmm ammeter is connected in parallel?* **S22:** *No, ammeter in series…but voltmeter?*	See the correct simulation result but cannot verbalize Students ask question for clarification	Verbalize the simulated output Learning by inquiry

As shown by S16, she understands that "*Voltmeter in parallel and ammeter in series*" but that was found only her surface understanding. She did not manage to apply the concept when connecting the devices. Also S7 and S22 were still confused about how to connect the devices.

5.4.2. POE Tasks on Open and Short Circuits

When dealing with Exercise 2, students tended to treat the open circuit as simple series circuits (same as in Exercise 1). Their explanation was similar to Exercise 1. However, the observation task was a bit lengthy because now the circuit has a branch of shorted arm. The findings show that students easily neglect the effect of the shorted arm in a circuit. Their alternative conception persists as was found from the interviews. The conversation in Table 5.20 shows their alternative conceptions about short circuit concept.

Table 5.20: Short circuits alternative conceptions

Sample	Descriptive Codes	Categories
R: Question 3, how much current coming out from the source? **S7:** 1 Ampere. **R:** What happen at the node? **S7:** *Divided into two.).* **R:** Look at your circuit with ammeter…what does it tells? **S7:** *Oooppss… the current is not divided.*	See the correct simulation result but cannot verbalize	Verbalize the simulated output

Based on the conversation above, S7 assumed that the current is divided into two when it reaches the node, even though the node has a shorted branch. This alternative conception confirms that students neglected the effect of short circuits. Their conception is acknowledged by the conversation with S17 as shown in Table 5.21.

Table 5.21: Conception about voltage and current

Sample	Descriptive Codes	Categories
R: Can you explain why there is no voltage drop at short circuits? **S17:** *I don't know…maybe because … hmm I cannot explain. For sure I know there is current flow.*	See the correct simulation result but cannot verbalize	Verbalize the simulated output
R: *There is current flow, so why there is no voltage?* **S17:** *When there is current, there should be voltage also?*	Contradicting questions	Deep understanding

Sources of their alternative conception is sought based on conversation shown in Table 5.22 as mentioned by S12 and S14 where they cannot define the number of branches in circuits, which will affect their prediction of current flow in the circuits.

Table 5.22: Conception about branches

Sample	Descriptive Codes	Categories
R: Can you define how many branches we have in question 2. **S12:** Two branches **R:** Look carefully… two only? **S14:** Yes **R:** Ok let us count….. **S14:** *Ooo yea three branches*	Define the number of branches in a circuit	Circuits operation

One unexpected finding emerged during the intervention sessions was that students cannot verbalize their simulated output. Eventhough they saw the right output, they face problem verbalizing their conceptual understanding. Verbalization can prevent students from copying the simulated output right onto their answer sheet. It will also enhance their deep understanding. This finding shows that they have surface understanding of the basic concept. As shown in Table 5.23, they were worried about their non-lighted bulb instead of worrying why they cannot explain the output.

Table 5.23: Engage in inquiry-based

Sample	Descriptive Codes	Categories
R: What do you understand about your output? **S10:** *Is my circuit right? Why this bulb is not light up?*	Students ask question for clarification	Deep understanding

However, S10 felt comfortable in asking questions, which shows that they are comfortable with the inquiry-based approach. This could enhance their surface understanding. Table 5.24 below show how student as S12 and S16 can become a good inquirer if they were given opportunity. This capability will diminish their surface understanding and develop a deep understanding.

Table 5.24: Inquiry capabilities

Sample	Descriptive Codes	Categories
R: How do you understand about your circuits with the bulb? **S12:** *This bulb is brighter than the second one.* **R:** Any reason for that? **S16:** *Hmm, it cannot brighter?* **R:** Look at your bulb circuits. Any current flowing through 40 ohm? **S16:** *0 A.* **S12:** *What does that mean?* **S16:** *Means that no current at all through 40 ohm branch…understand?*	Current distribution The effect of short circuits	Circuit operation Short circuits

Another finding emerged from the total resistance exercise. They were trying to calculate manually based on their procedural knowledge from the previous course. However, when faced with short circuits, many answers were given. Table 5.25 below shows that S18 assumed all resistors in the circuits were taking part in the operation of the circuit regardless of its connection.

Table 5.25: Conception about resistance

Sample	Descriptive Codes	Categories
R: Is this 40 ohm active in this circuit? **S18:** *Ooo we have to figure it that way? Does for total R we have to consider all R in the circuits?* **R:** Look back and try to figure out from your simulated circuits.	Students ask question for clarification	Learning by inquiry

Therefore, students again were requested to simulate their circuits to obtain the value of total resistance. This part is important in Thevenin and Norton Theorem as mentioned in section 1.3 and shown in Appendix E. Total resistance cannot be calculated if students cannot figure out which resistor is active and which is not in an open or short circuit. Furthermore, where to place the devices in the circuit is important in measuring the desired value as shown in conversation in Table 5.26.

Table 5.26: Individual work with inquiry-learning

Sample	Descriptive Codes	Categories
R: Try to simulate on your own, once done we will discuss together. **S16:** *Where to connect the multimeter?*	Insist on individual work Students ask question for clarification	Own the learning Learning by inquiry

Another finding was students really depend on Ohm's Law to predict circuits operation, the same finding as obtained from interview session. As shown in Table 5.27 below, S26 relied heavily on V=IR. By relying on Ohm's law will caused their alternative conception on open and short circuits concepts higher. This is the reason why they cannot grasp open and short concept even though this concept is a very basic concept.

Table 5.27: Dependent upon Ohm's law

Sample	Descriptive Codes	Categories
R: What is your conclusion about short circuits? **S24:** *No resistance.* **S25:** *No voltage.* **S24:** *Has current.* **R:** How about during open circuits? **S26:** *Short circuits…no voltage, because V=IR because no I, so no R. But why here (short circuits), no R but still got current?*	Students ask question for clarification	Learning by inquiry

There are cases when student know how to explain but is not confident in doing so as shown in Table 5.28. S4 seems to explain well but the final sentence shows that she has only surface understanding.

Table 5.28: Not confident to verbalize

Sample	Descriptive Codes	Categories
R: Can you explain to me **S4:** *Ooopss why this bulb is not light up?* **R:** Try to figure it out…. And explain to me. **S4:** *Current flows, not entering branch with resistor, all go into short circuits* **R:** Are you sure? **S4:** *More or less…(not sure)*	See the correct simulation result but not confident to verbalize	Verbalize the simulated output

Students can execute the POE tasks easily for Exercise 3. This is because too much time was spent on clarifying the POE task on Exercise 2. Furthermore, they did not have any problem in observing and explaining the open circuits operation.

5.4.3. POE Tasks on Discussion and Conclusion

Finally there was session for discussion and conclusion as shown in Table 5.29.

Table 5.29: Reflection for conclusion

Sample	Descriptive Codes	Categories
R: How to interpret the working of a circuit? Try to reflect back what we have done and learned. **S8:** *Make sure the switch is closed.* **R:** For what purpose? **S8:** *Looking into the current in the circuits* **R:** Good…any other suggestion? **S14:** *Just imagine there is a current.* **R:** Great. Assume that there is a current flow…especially when to measure R total.	Insist on reflection for conclusion Doing reflection	Deep understanding Meaningful learning

After the simulation-supported approach intervention session, there was clear evidence that inquiry-based instruction, enriched with computer simulation and collaboration, promoted students' conceptual understanding of BEC concept and understandings of scientific inquiry. Students willingly involved in inquiry learning based on POE tasks. After the lab session, students understood the concept, and can apply the concept as shown in the posttest data as described in sections 5.4.

The descriptive codes and categories were obtained using constant comparative methods by constantly comparing themes obtained. This topic will be discussed in detail in Chapter 6.

5.5 Students’ Verbalizations

Fourty-seven (47) students attended the inquiry-based simulation-supported approach intervention sessions. Students’ conversations provided rich data for analysis. Students’ conceptual understandings were examined through their verbal responses during the intervention sessions and interviews. Only 6 students participated in both interviews. Changes on students’ verbalizations could only be gathered from these 6 students. Data recorded at 3 different times during the study was compared namely during:

i. interview after pretest;
ii. intervention;
iii. interview after posttest.

5.5.1. Student S4

Table 5.30 shows S4 verbalization. S4 relied on Ohm’s law and current as the prime concept to formulate her own explanations. In all three situations, S4 used the concept of no voltage, no current. S4 was not confident of her answer based on this verbalization even after the intervention. However, S4 marks improved from 41% (pretest) to 66% (posttest). But this result confirms that S4 can verbalize her understanding.

Table 5.30: S4 verbalization

Data gathering	Students' Responses / Question related	Analysis
interview after pretest - *for Question 10*	How come has voltage if there is no current?	Understood the application of Ohm's law.
during intervention - *for Exercise* 2*	Can we measure V at a place with no R?	
interview after posttest - *for Question 10*	Voltage is 0V because not measured at R.	

* Exercise 2 is related to Question 10

5.5.2. Student S7

Table 5.31 shows S7 verbalization. Like S4, S7 also relied on Ohm's law. S7 also relied on Ohm's law and the concept of no voltage, no current. S7's explanations did not show improvement from before to after intervention. S7 was not confident in the answers based on this verbalization even after the intervention. However, S7 marks improved from 37% (pretest) to 62% (posttest). This result informed that she cannot verbalize her understanding.

Table 5.31: S7 verbalization

Data gathering	Students' Responses	Analysis
interview after pretest - *for Question 10*	I really don't understand. Voltage between A-B *(at open circuit)*? But there is no current…	The open circuit concept is not well understood
during intervention - *for Exercise 2**	How come there is a voltage *(at open circuit)*?	
interview after posttest - *for Question 10*	Because there is no resistor, so there is nothing to be measured.	

* Exercise 2 is related to Question 10

5.5.3. Student S8

Table 5.32 shows S8 verbalization. S8 showed a different understanding of concepts. S8 verbalized better than S4 or S7. However, S8 also rely on current as the prime concept, where there is no voltage if there is no current. S8 showed a little confident in verbalizing the answers based on these conversations. In addition, S8's marks improved from 58% to 66% pre to post test.

Table 5.32: S8 verbalization

Data gathering	Students' Responses	Analysis
interview after pretest - *for Question 3*	Yes because it *(the current)* has been taken by the first R.	Show understanding on distribution of current flow in a circuit
during intervention - *for Exercise 3**	Because bulb 1 receive current first.	
interview after posttest - *for Question 3*	The more resistors will give lesser current.	

* Exercise 3 is related to Question 3

5.5.4. Student S10

Table 5.33 shows S10 verbalization. Conversations with S10 showed that S10 used inquiry learning frequently. S10 feels comfortable in showing alternative conceptions by inquiry. This will enhance S10's concept learning. S10 also rely on Ohm's law where there is no voltage if the circuit is open. S10's marks improved slightly from 54% to 62% pre to post test.

Table 5.33: S10 verbalization

Data gathering	Students' Responses	Analysis
interview after pretest - *for Question 11*	*(Less current)* because the branch is farthest from the source.	Understand about parallel circuit concept
during intervention - *for Exercise 2**	When the voltage pass through resistor, there is a voltage drop.	
interview after posttest - *for Question 11*	*(The currents)* divided into all branches because the branch is in parallel.	

* Exercise 2 is related to Question 11

5.5.5. Student S12

Table 5.34 shows S12 verbalization. S12 confesssed of having alternative conceptions rather than doing inquiry as S10 did. This method will not help S12's development of conceptual understanding. S12, like others, also rely on Ohm's law where no current, no voltage. S12 had a lost on marks from 70% to 66% pre to post test. It seems like the intervention did not help him grasp the concept.

Table 5.34: S12 verbalization

Data gathering	Students' Responses	Analysis
interview after pretest - *for Question 10*	I am not confident with open and short. My answer is A, because when there is no current, the voltage also zero.	Understand an open circuit concept but cannot verbalize clearly
during intervention - *for Exercise 3**	The circuit is not working because the switch is open.	
interview after posttest - *for Question 10*	I know that there is a voltage at open circuits. But between A-B *(an open circuit)*? I am not sure how to explain	

* Exercise 3 is related to Question 10

5.5.6. Student S14

Table 5.35 shows S14 verbalization. S14 was very confident in verbalizing her concepts. S14 conversed in long sentences that show S14 can verbalize concepts very well. S14 showed improvement from 88% to 90% in the test. Based on pretest marks, S14 had strong conceptual understanding.

Table 5.35: S14 verbalization

Data gathering	Students' Responses	Analysis
interview after pretest - *for Question 3*	The current flow from bulb 1 then to bulb 2, so they both have the same brightness	Understand the effect of a short circuit.
during intervention - *for Exercise 2**	Is my circuit right? Why this bulb is not light up?	
interview after posttest - *for Question 8*	All current goes to short, means that no current at all through 40 ohm branch	

* Exercise 2 is related to Question 3 and Question 8

Data from the intervention session shows that students can engage well in inquiry-based teaching and learning activities. However, based on data from 6 students that were analyzed showed that their verbalization were still not concrete. This is due to the fact that this is the only inquiry-based intervention class that they have gone through. In addition their BEC course before does not insist on students' verbalization. Students' performance in inquiry showed that it can help their conceptual understanding if lecturers incorporate it into the course.

5.6 Summary

This chapter reports and discussed data gathered about students’ conceptual learning obtained from qualitative and quantitative methods. Results were presented and discussed in four parts;

i. Quantitative data from pretest and posttest
ii. Qualitative data from interview
iii. Qualitative data from intervention
iv. Students’ verbalization

Based on the discussion in this chapter, the results and discussion were organized according to the RQ of the study. The first RQ is concerned with determining students’ conceptual understand of open and short circuits concepts. The discussion data were from interview and the pretest and posttest responses. The findings showed that students hold many alternative conceptions on both concepts.

The second RQ were finding whether students’ were being assisted in conceptual learning. The discussions were from the intervention. The findings show that students can engage in inquiry-based learning. They are willing to talk, discuss and explain among their peers and also with the researcher.

The final RQ were discussions on student’s performance in pretest and posttest. The findings showed a significant improvment of the concept test score on complete, open and resistance. However, performance on short circuits is not significant. Data triangulation will be performed to generate finding as will be discussed in Chapter 6.

CHAPTER 6

CONCLUSIONS AND RECOMMENDATIONS

6.1 Introduction

This chapter will discuss conclusion for the research. Findings of the research will be listed and conclusion made on the findings to achieve all the objectives of the research will also be discussed. Recommendation and contribution of the research will also be provided. This is followed bu the highlights on the implications of the research for students' conceptual learning. Lastly, the recommendations for future research will also be discussed.

6.2 Conclusion on Research Findings

Investigation on alternative conceptions and approach to assist students' conceptual learning were conducted resulted in an inquiry-based simulation-supported approach being developed and implemented. Students' conceptions obtained from different data gathering source will be presented.

6.2.1. Students’ Alternative Conceptions

Students’ thoughts and perspectives, as stated in their own words can be acquired through interviews (Punch, 2009; Rubin and Rubin, 2005). Based on the qualitative analysis of pretest and posttest, intervention and interviews, conclusions can be drawn about students’ alternative conceptions. The categories of students’ alternative conceptions as was discussed in section 5.3 were obtained through constant-comparative method of the interview session after pretest and after posttest as shown in Table 6.1.

Table 6.1: Students’ alternative conceptions from interviews

1. Current is consumed by resistor
2. Sources in series or parallel have the same effect
3. Current is the same in parallel circuits
4. The farther the element or branches from the source, the less current is obtained
5. Current is the prime concept
6. Neglect the effect of short circuits in circuits operation
7. Confused about the effect of open circuits
8. Confused about the function of a switch
9. Value of resistance depends on the voltage source
10. Confused about voltage in parallel circuits, and current in series circuits

These results show students’ hold alternative conceptions regarding electric circuits. These alternative conceptions are very basic and will hinder their performance and attainment of advanced conception in later subjects. The conclusions for all the 10 alternative conceptions are elaborated as below.

1. Current is consumed by a resistor. As a result the current flow through later devices is less. The correct concept is that current will flow in a closed loop circuit, and current will not sink across devices or components in the circuits.

2. The farther the element or branch is from the source, the less current is obtained. This strengthened their alternative conception as discussed in 1 above. Again, they thought that the current is consumed and sink along the way the current travels, therefore the farther the branch, the less current it will received at the end.

3. Sources in series or parallel have the same effect. One surface understanding that students hold was that voltage is the same in parallel circuits; and current is the same in series circuits. However, they neglect the effect of the component, devices and branch exist in the circuits during operation.

4. Current is the same in a parallel circuit. Students thought that when current reach a node, the current will be divided equally among the branches. They neglect the effect of components in the branches, especially when there is a short circuits branch.

5. Voltage in a parallel circuit and current in a series circuit cause confusion. Students' can memorize well about these cases, where voltage in parallel is the same and current in series is the same. But a problem arises when it is blatantly applied regardless of the type of the circuits, and the component or devices in that circuit.

6. Current is the prime concept. There is a heavy reliance on Ohm's law, V=IR. Therefore when there is no current, both V and R will become zero. This idea is not always true especially when there are short or open circuit branches.

7. The value of voltage drop depends on the current flow. Students thought that the value of voltage drop only exist if there is a current flow. This conception is not always right. There are conditions under which the voltage exists though current does not, especially in an open circuit. This conception confirms that the main equation applied to electric is always V=IR.

8. The effect of short circuits is neglected when the circuit is in operation. By neglecting a short circuit effect, analysis of the operation of circuit will be incorrect. Students must understand the effect that is experienced by a circuit that has a short circuit before doing any analysis.

9. The effect of an open circuit is confusing. This alternative conception was mainly contributed to finding a total resistance. And again when they relied heavily on V=IR, their finding will give the value of resistance is zero in an open circuits. They do not notice that resistance is a passive element where its value is not contributed by external factor.

10. The function of a switch causes confusion. Solely it is not because of a switch, but because of the open and short circuits concepts that was triggered due to opening and closing of the switch. Therefore, this again confirmed that students have alternative conceptions on open and short circuits concepts.

These alternative conceptions hold by students showed that they do not have deep understanding in electrics courses that they have taken in the first semester. The findings showed that students have not understood the fact that electrical element obey certain intact behavior when they are connected in any circuits; similar to finding by Rahman and Ogunfunmi (2010).

6.2.2. Students' Learning

Investigations about students' learning were gathered during the intervention given to students. The obtained data can be concluded especially during explanation of their simulated output. The obtained data can give conclusion on students' learning on basic electric circuits as defined below:

1. Materials provided for instructional purposes should be given in steps, starting with the very basic concepts. The later concepts should be built upon the previous understood concepts. The inquiry-based simulation-supported approach was tailored to these steps by firstly asking students to do simple predictions on devices to be used in the circuits.

2. The concept should be the introduced first in any instructional approach. Conceptual knowledge will allow students to link knowledge to a bigger perspective. When, where and how the concept should be use can generate their deep understanding of the basic concepts. The prediction tasks incorporated in the approach make students think in a global perspective.

3. Once knowledge on any specific concepts is understood, the instructional approach to deliver procedural knowledge later is easier. The conceptual knowledge will assist the procedural knowledge as there are interrelated. These methods was implemented in the approach as it begins with concepts of simple, open and short circuits first before asking students to do procedural thinking on how to obtained total resistance.

4. The topic of electricity is very abstract and how internal operation of the circuits cannot be visualized. Simulation will help students to visualize the internal working of the circuits which will assist their understanding.

5. Furthermore, hands-on activities can assist students to grasp the knowledge better as they can perform the drawing on their own and simulate the operation of the circuits. Students will be the owner who facilitates their own learning.

6. Inquiry-based activities incorporated in the approach really help students to characterize their own alternative conceptions. The inquiry-based approach is defined by facilitating the questions rather than giving the answer. Therefore student will have to think on their own asked questions. This will make them evaluate and criticize their own thinking.

7. Participation in inquiry-based instruction expects students to verbalize their ideas. These will take away the students' role as passive listener into an active participant. After the approach intervention session, all students seem to enjoy the class where everybody has the chance to talk, communicate and converse among themselves. This indeed aligned with the inquiry-based process of learning that promotes the method of clarifying the situation.

8. The POE tasks help students to enhance their conceptual knowledge. Though from the approach, the tasks do not flow smoothly due to some side verbalization that occurred due to clarifying some students' mistaken thought but this process actually assist students' knowledge by rectifying their alternative conceptions.

9. Reflection at the end of the approach intervention session helped students gather all the knowledge learned and composes a nice discussions and conclusions. They showed confidents in doing reflections as they wrote their answer in Bahasa Malaysia.

10. Social interaction during the POE tasks inquiry-based simulation approach occurred nicely. They can interact well as their peers are from the same line of study. And also the same alternative conceptions also held among their peers.

11. Finally a small gift given at the end of the approach intervention session, after interview, and after the test makes them feel proud. Their participation was acknowledged by the researcher. The thought that counts.

Through inquiry-based teaching and learning, students scientific knowledge is deepened as students developed understanding through observing and connect evidence to knowledge (National Research Council, 2000). A key component of inquiry-based instruction requires students to let real results correct their alternative conceptions (Prince and Vigeant, 2006). Social interactions between students were encouraged as they discuss their observation and explanation with others in the class.

6.2.3. Students' Achievement

The descriptive codes and categories obtained from the data using constant comparative methods by constantly comparing themes confirmed about students' learning as discussed in section 6.2.2. As discussed in section 5.4, Table 5.17 until Table 5.29 shows examples of descriptive codes and categories obtained. All the codes obtained were concluded in Table 6.2 below.

Table 6.2: Students' alternative conception from intervention session

Categories	Descriptive Codes of Students' Alternative Conception
1. Concepts	Current is the prime concept
	Relies on formula V=IR
	Understand basic concept but making wrong application
	Open and short circuits
	Switch in the circuits
2. Inquiry-based approach	Write and verbalize answer in Malay language
	Insist on verbalizing the explanation
	Insist on individual work
	Students ask question for clarification
	Insist to write answer in short and precise after verbalize the result
	Insist on reflection for conclusion
3. Circuits operation	Able to predict the apparatus to use
	Able to connect components and devices to build a circuit
	Not able to connect meter to measure value
	Not able to define the number of branch in a circuit
	Not able to explain procedure needed to measure desired value
	Neglect the effect of short circuits
	Confuse the effect of open circuits
	Not able to define the number of branch in a circuit
	Not able to predict the current distribution

Categories	**Descriptive Codes of Students' Alternative Conception**
4. Simulation	Cannot verbalize the simulation output
	Not confident to verbalize the simulation output

The conclusion for each categories and codes obtained were discussed as follows:

1. Concepts

   Almost all of the alternative conceptions about concepts mentioned in 6.2.1 emerged again during the approach intervention sessions. However, the purpose of the approach intervention session is to assist students. The conversation during the intervention as discussed in sections 5.3 and 5.4 showed how the researcher assisted students in rectifying alternative conceptions. Students' also have alerted about their own alternative conception once they indulged in inquiry-based approach.

2. Inquiry-based approach

   This method is confirmed to have positive effect on students' learning. Students were changed from being passive listeners to active participants. They show comfort when going through the inquiry-based approach. Furthermore being able to verbalize in Malay makes them comfortable in voicing out their ideas.

3. Circuits Operation

   The exercises in the approach were organized in a manner that tackles the concepts from a simpler to a higher level question. These orders do help student visualize and verbalize the output. The researcher acts as facilitator to student in performing the POE task.

4. Simulation

   The output from simulated circuits triggered the students' alternative conceptions. By verbalizing students can enhance their deep understanding. Many questions were asked by students to clarify their problems. However, students or their peers have to answer and discussed about their own questions. These inquiry methods enhanced their conceptual understanding.

This research demonstrated that the benefits of self-explanation can be achieved with a relatively simple simulation approach that can be fit well to any approach. By engaging in verbalize explanation, students acquired better-integrated visual and verbal conceptual knowledge. The effectiveness of the implementation of the inquiry-based simulation-supported approach was assessed. It shows that student achievement for simple circuit, open circuits, and resistance were significantly improved. However, achievement on short circuits was not significantly improved. Therefore, methods of teaching and learning instruction have to be researched in order to rectify this problem.

The gradual improvement in students' knowledge in verbalizing and their positive attitude towards the simulation with inquiry-based teaching and learning approach may indicate that the instructional approach should be developed and implemented more widely in undergraduate studies. Factors that stimulate a good question and answer are engaging problems, and a facilitator at hand to answer questions, to give instant feedback and to discuss with the students.

After students have gone through an inquiry-based approach, the findings show that they have tried to evaluate the circuits first by verbalizing it before trying to find mathematical solutions. As what was also found by Getty (2009) that state that student should be encouraged to develop an ability to qualitatively evaluate electric circuits. Therefore, the implementation of an inquiry-based approach with simulation-supported approach has proved to be significant in improving students' verbalization ability. In addition the use of the simulation helped students visualize the operation of the electric which are very abstract in nature. Seeing the bulbs light has rectify their alternative conceptions on the working of the circuits. As a result, the integration of simulation activities into the classroom provide an innovative learning environment that allows more interactive and effective applications for students to gain valuable experiences through hand-on.

6.3 Conclusion

The objective of the research is to determine and assist students' conceptual understanding of basic electric circuits. The expected alternative conceptions encountered by students were also investigated. The conclusions are presented according to the research objectives as stated in Chapter 1.

The findings from the research state that the alternative conceptions reported in the literature were found among students' at this local public university. Results showed that the implemented inquiry-based, simulation-supported approach was successful in enhancing students' conceptual understanding of open and short circuits concepts. However, findings from students' verbalizations indicate that changes in teaching and learning approaches are required to better support learners in developing scientific inquiry that enable learning of the intended conceptual knowledge.

6.3.1. Conceptual Understanding

Pretest and posttest comparisons indicated significant positive improvement in students' conceptual knowledge scores, but inconsistent performance on an individual basis. As the treatment includes inquiry-based learning opportunities in addition to computer simulations, the findings on students' experiences do support the improvement on verbalization of conceptual understandings.

There are four concepts tested in the pretest, approach and posttest. These four concepts were probed during the interviews to gain in-depth information regarding students' alternative conceptions. The finding from the data gathered can be grouped into two categories: local reasoning and sequential reasoning. The explanations are as below:

1. Local reasoning is indicated when students believe that current divides into two equal parts at every node regardless of what is happening elsewhere in the electric circuits (Engelhardt and Beichner, 2004).

2. Sequential reasoning is indicated when students believe that current travels around an electric circuit and is influenced by each element as it is encountered, and a change made at a particular point does not affect the current until it reaches that point (Engelhardt and Beichner, 2004).

Data obtained from interviews and interventions are tabulated in these two categories as shown in Table 6.3.

Table 6.3: Students' Alternative Conceptions

Categories	**Students' Alternative Conception**
Local Reasoning (Engelhardt and Beichner, 2004; Smaill *et al.*, 2011; Streveler *et al.*, 2008)	Ignore the effect of a short circuits
	Ignore the effect of an open circuits
	Make wrong application of understood concepts like voltage in parallel are the same; and current in series are the same.
Sequential Reasoning (Engelhardt and Beichner, 2004; Smaill *et al.*, 2011; Streveler *et al.*, 2008)	Current is consumed
	Rely on Ohm's law, V=IR
	Confuse about switch
	Current is the prime concept
	Changing the circuits will only affect the later component

It is concluded that students really have alternative conceptions of the concepts tested which relate to open and short circuits. Students make mistakes in the analysis of open and short circuits especially when current and voltage are required to be determined (Duit and Rhoneck, 1998). There found to hinder their conceptual understanding. This shows that students are lacking a deep understanding of fundamental concepts in their field (Miller *et al.*, 2004; Streveler *et al.*, 2006).

Therefore, their surface understanding of concepts will limit their ability to build knowledge of electric circuits. To understand the concepts learned, they must have the ability to predict how circuits operate. An inability to prediction will cause students to be unable to apply concepts. Surface understanding held by students will limit their further trying to understand the deeper concept in later courses.

As proven by this research, verbalization will help students enhance their deep understanding. By enhancing their deep understanding, meaningful learning will take place. However, students' perceptions as obtained in part of the unexpected finding will contribute to their capabilities of learning concepts.

6.3.2. Teaching and Learning Activities

The findings show that when appropriately structured, inquiry-based teaching and learning activities can help students develop critical scientific-inquiry skills. This suggests that inquiry-based learning is essential for teaching concepts at the university level.

Students' conceptual understanding was significantly enhanced by the use of an inquiry-based simulation-supported approach. The use of simulation-supported together with inquiry-based should be encouraged to assist students to enhance conceptual understanding. Students were beginning to ask scientific question regarding the topics which will further deepened their conceptual learning.

Electronic simulations may increase student access to laboratory experiences. However, simulation alone will only produce correct results without helping students to understand the working of the circuits. Therefore an inquiry-based approach into simulation will enhance their understanding through verbalizing and reasoning session. Linking the simulation to the inquiry-based approach does help students visualize how electric circuits work because it enables students to see the abstraction.

The simulation packaged together with the inquiry-based approach enhanced students' conceptual learning through verbalizing their conceptual understandings. Furthermore, the incorporation of POE tasks can further aid the understanding.

6.3.3. Conceptual Learning

Students can verbalize better on the concept during the simulation session. Their written answers show that they can explain the correct situation. The interviews suggested that students have a strong understanding of basic concepts related to series and parallel circuits, have some understanding of the relationship between current flow and resistance, but struggle to interpret a circuit with a switch. The findings also indicate that students can grasp complete circuits, open circuits and resistance; however they have trouble grasping short circuits concepts. The findings suggest that these students were able to be successfully involved in appropriate inquiry practices.

6.4 Contribution

This study has met the objectives of the research. The finding of this research contributes to the body of knowledge on how to enhance electrical engineering students' conceptual learning of BEC. The developed inquiry-based simulation-supported approach can be used with modification in other courses that are similar in nature.

This research revealed that students held many alternative conceptions about short circuits and open circuit concepts. The developed inquiry-based simulation-supported approach assisted in developing students' conceptual understanding especially when students willing take part in inquiry learning. Therefore, lecturers should adapt inquiry approaches. Students' verbalization of concepts must be encouraged as verbalizing is an approach to enhancing students' deep understanding.

6.5 Implications

1. Teaching and learning strategies must be adopted to satisfy different students' needs. With the proper alignment of content, pedagogical design, tasks, assessment strategies, and lecturer and student roles at the university level, inquiry-based learning environments can be created in which students are able to successfully develop skills in scientific inquiry as well as content knowledge. (Apedoe *et al.*, 2006).

2. Having a valid and reliable instrument to measure student conceptual understanding of concepts taught is important. Without good instrumentation, it is impossible to demonstrate changes in student understanding as a result of instruction (Vigeant *et al.*, 2009) be it in any course or with any concepts.

3. Replication of this research to other universities or institutions as suggested by this research validator as shown in Appendix L, would be possible to determine open and short concept conception by other students and justify the depth of the effectiveness of the approach. Samples chosen should come from different universities be it local or private universities, therefore the representative can contribute to general population (Ogunfunmi and Rahman, 2010). This is in line with suggestions by Smaill *et al.* (2011) which states that misconceptions of DC circuits theory is evidence cross institutional and national boundaries.

6.6 Recommendations for Future Work

As a suggestion, it is beneficial for lecturers to change their pedagogical approach from a teacher-centered textbook-driven approach to a student-centered inquiry-based approach. This approach is a powerful mean of teaching and learning for BEC classes. Using simulation in a BEC course, which is the core component of undergraduate curricula in electrical engineering programs, will also help monitor the effectiveness of teaching and learning approach as whether the students are learning the basic concepts in the course. Teaching and learning strategies should shift from lecture and textbook towards student-centered method and incorporate POE tasks where applicable to assist learning.

The application of this simulation-supported with inquiry-based approach provides a more learner-focused approach to assessing a teaching activity, which provides more detail about the relevant cognitive processes used by the student and is a better guide for improving the learning activity. This is inline with the finding by Prince *et al.* (2009b) that suggest inquiry-based activities can be used to help repair persistent engineering misconception held by undergraduate engineering students. The findings of this research suggest that verbalization procedures help students recognizing their own alternative conceptions. Encouragement should be made to allow students verbalize their understanding.

Faculty should place greater emphasis on the role of structured knowledge in their discipline as a powerful framework for designing course curriculum, instruction, and assessment. The faculty should use explicit techniques to emphasize the overall conceptual structure of the discipline being taught throughout the course rather than focusing on topics, concept sequences, or common misconceptions. Lecturers should have proper training of how to go about implementing the inquiry-based teaching and learning activities. Textbooks can be used wisely to enable structured knowledge building. Number of semesters or years student in university was not a good predictor of their academic performance especially on alternative conceptions in electric circuits (Getty, 2009).

6.7 Concluding Remarks

This chapter presents conclusions according to the research objectives. The main objective of this research was to investigate students’ conceptual understanding of BEC. Students were found to have alternative conceptions of open and short circuits concepts. They also hold alternative conceptions of circuits with a switch.

This research concludes that the inquiry-based simulation-supported approach assisted students' learning. The proposed teaching and learning instruction was able to assist students' conceptual learning.

The recommendations for improving students' conceptual understanding and for future research were also elaborated. This chapter also highlights the importance of teaching and learning approaches to assist students' understanding. Merely depending on students' written tests and exam papers or lab reports is inadequate to make them verbalize more about the concepts learned. From the results obtained, lecturers can find better method of teaching and learning that can assist students' conceptual learning.

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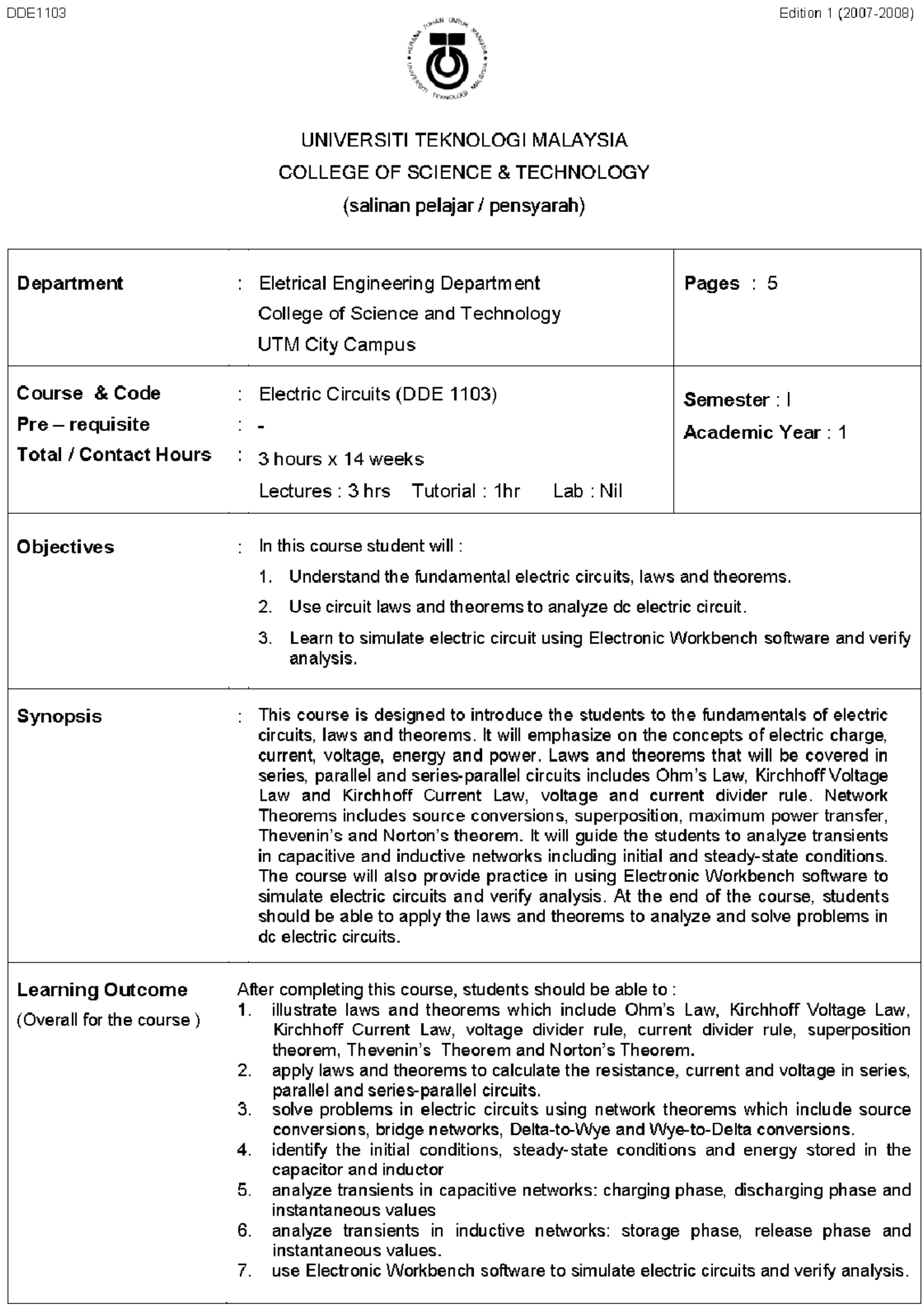
APPENDIX A: Electric Circuits Course Learning Outcome



DDE1103 Edition 1 (2007-2008)

UNIVERSITI TEKNOLOGI MALAYSIA
COLLEGE OF SCIENCE & TECHNOLOGY
(salinan pelajar / pensyarah)

Department	:	Eletrical Engineering Department College of Science and Technology UTM City Campus	**Pages** : 5
Course & Code **Pre – requisite** **Total / Contact Hours**	: : :	Electric Circuits (DDE 1103) - 3 hours x 14 weeks Lectures : 3 hrs Tutorial : 1hr Lab : Nil	**Semester** : I **Academic Year** : 1
Objectives	:	In this course student will : 1. Understand the fundamental electric circuits, laws and theorems. 2. Use circuit laws and theorems to analyze dc electric circuit. 3. Learn to simulate electric circuit using Electronic Workbench software and verify analysis.	
Synopsis	:	This course is designed to introduce the students to the fundamentals of electric circuits, laws and theorems. It will emphasize on the concepts of electric charge, current, voltage, energy and power. Laws and theorems that will be covered in series, parallel and series-parallel circuits includes Ohm's Law, Kirchhoff Voltage Law and Kirchhoff Current Law, voltage and current divider rule. Network Theorems includes source conversions, superposition, maximum power transfer, Thevenin's and Norton's theorem. It will guide the students to analyze transients in capacitive and inductive networks including initial and steady-state conditions. The course will also provide practice in using Electronic Workbench software to simulate electric circuits and verify analysis. At the end of the course, students should be able to apply the laws and theorems to analyze and solve problems in dc electric circuits.	
Learning Outcome (Overall for the course)		After completing this course, students should be able to : 1. illustrate laws and theorems which include Ohm's Law, Kirchhoff Voltage Law, Kirchhoff Current Law, voltage divider rule, current divider rule, superposition theorem, Thevenin's Theorem and Norton's Theorem. 2. apply laws and theorems to calculate the resistance, current and voltage in series, parallel and series-parallel circuits. 3. solve problems in electric circuits using network theorems which include source conversions, bridge networks, Delta-to-Wye and Wye-to-Delta conversions. 4. identify the initial conditions, steady-state conditions and energy stored in the capacitor and inductor 5. analyze transients in capacitive networks: charging phase, discharging phase and instantaneous values 6. analyze transients in inductive networks: storage phase, release phase and instantaneous values. 7. use Electronic Workbench software to simulate electric circuits and verify analysis.	

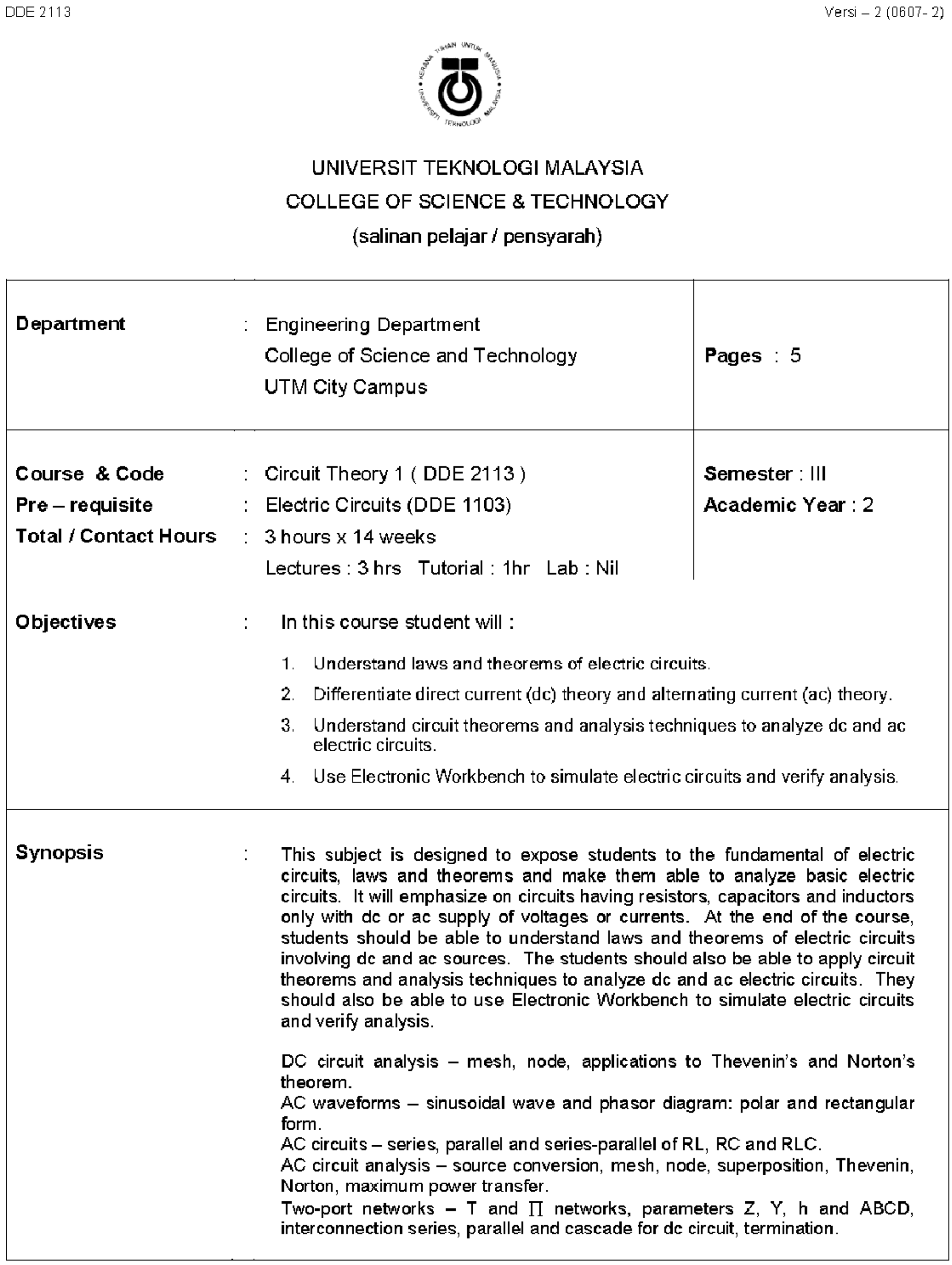
Topic	Learning Outcomes *(For the topics)*
1. INTRODUCTION 1.1 Units of Measurement 1.2 Systems of Units 1.3 Powers of Ten 1.4 Conversion Between Levels of Powers of Ten 1.5 Conversion Between Systems of Units 1.6 Symbols	**Hours : 2** **NOSS-MLVK : - N/A** Student will be able to: i. specify the basic electric quantities and the units for each quantity. ii. identify the SI system of units. iii. perform all the basic algebraic operations with numbers using the power-of-ten notation. iv. convert numbers between levels of powers of ten v. change numbers from one unit of measurement to another. vi. identify symbols used for basic quantities.
2. CURRENT AND VOLTAGE 2.1 Atoms and Their Structure 2.2 Voltage 2.3 Current 2.4 Voltage Sources 2.5 Ampere-Hour Rating 2.6 Conductors and Insulators 2.7 Semiconductors 2.8 Ammeters and Voltmeters	**Hours : 2** **NOSS-MLVK : - N/A** Student will be able to: i. define electric charge, current and voltage ii. identify different types of voltage sources iii. use the ampere-hour rating of a battery to calculate its expected life. iv. differentiate between conductors, insulators and semiconductors. v. use ammeter and a voltmeter correctly to measure a circuit's current and voltage.
3. RESISTANCE 3.1 Resistance 3.2 Wire Tables 3.3 Temperature Effects 3.3.1 Conductors 3.3.2 Semiconductors 3.3.3 Insulators 3.4 Types of Resistors 3.4.1 Fixed Resistors 3.4.2 Variable Resistors 3.5 Color Coding and Standard Resistors Values 3.6 Conductance 3.7 Ohmmeters 3.8 Application	**Hours : 3** **NOSS-MLVK : - N/A** Student will be able to: i. determine resistance of an element and use wire tables ii. identify the effect of temperature on conductors, insulators, and semiconductors. iii. identify the variety of fixed and variable resistors. iv. determine the resistance using the standard color code v. explain the relationship between conductance and resistance. vi. use ohmmeter to measure resistance.

Topic	**Learning Outcomes *(For the topics)***
4. OHM'S LAW, POWER AND ENERGY 4.1 Ohm's Law 4.2 Power 4.3 Energy 4.4 Efficiency 4.5 Plotting Ohm' Law 4.6 Circuit Breakers, GFCIs and Fuses 4.7 Application 4.8 Introduction to Electronic Workbench (EWB) Software	**Hours : 3 NOSS-MLVK : - N/A** Student will be able to: i. define and apply Ohm's Law to a simple electric circuit. ii. differentiate energy, power and efficiency of operation. iii. plot Ohm's Law define factors in the graph. identify the general characteristics of fuses and circuit breakers
5. SERIES DC CIRCUITS 5.1 Series Resistors 5.2 Series Circuits 5.3 Power Distribution in a Series Circuits 5.4 Voltage Sources in Series 5.5 Kirchhoff's Voltage Law 5.6 Voltage Division in a Series Circuit - Voltage Divider Rule (VDR) 5.7 Voltage Regulation and the Internal Resistance of Voltage Sources 5.8 Loading Effects of Instruments 5.9 Application 5.10 Measurement and Troubleshooting using EWB Software	**Hours : 5 NOSS-MLVK : - N/A** Student will be able to: i. identify the characteristics of a series circuit and solve for voltage or current in circuits ii. define the Kirchhoff's voltage law (KVL) and use it in on the analysis of electric circuits. iii. explain how the applied voltage divides in a series circuit and apply voltage divider rule effectively. iv. identify the loading effects of applying meters to a circuit. v. explain how the series configuration can be used effectively in everyday applications vi. use EWB software to solve for the quantities of interest in an electrical circuits.
6. PARALLEL DC CIRCUITS 6.1 Parallel Resistors 6.2 Parallel Circuits 6.3 Power Distribution in a Parallel Circuit 6.4 Kirchhoff's Current Law 6.5 Current Divider Rule 6.6 Voltage Sources in Parallel 6.7 Voltmeter Loading Effects 6.8 Application 6.9 Measurement and Troubleshooting using EWB Software	**Hours : 6 NOSS-MLVK : - N/A** Student will be able to: i. identify the characteristics of a series circuit and solve for voltage or current in circuit. ii. define the Kirchhoff's voltage law (KCL) and use it in on the analysis of electric circuits. iii. apply ohmmeter, voltmeter and ammeter to measure quantities in a parallel circuits. iv. identify the loading effects of voltmeters to a circuit. iv. explain how the parallel configuration can be used effectively in everyday applications. v. use EWB software to solve for the quantities of interest in an electrical circuits.

Topic	**Learning Outcomes *(For the topics)***
7. SERIES-PARALLEL CIRCUITS 7.1 Series-Parallel Networks 7.2 Analysis of Series-Parallel Circuits 7.3 Ladder Networks 7.4 Voltage Divider Supply (Unloaded and Loaded) 7.5 Potentiometer Loading 7.6 Open And Short Circuits 7.7 Application Measurement and Troubleshooting using EWB Software	**Hour : 7 NOSS-MLVK : N/A** Student will be able to: i. dentify the characteristics of a series-parallel circuit and solve for voltage or current in circuits ii. apply the reduce and return approach iii. apply the special notation for voltage sources. iv. use double and single subscript notation. v. use potentiometer to control the voltage across any given load. vi. analyse shorts and open circuits. vii. use EWB software to solve for the quantities of interest in a series-parallel circuits.
8. NETWORK THEOREMS 8.1 Current Sources 8.2 Source Conversions 8.3 Current Sources in Parallel 8.4 Bridge Networks 8.5 Delta-to-Wye and Wye-to-Delta Conversions 8.6 Superposition Theorem 8.7 Thevenin's Theorem 8.8 Maximum Power Transfer Theorem 8.9 Norton's Theorem 8.10 Application 8.11 Electronics Workbench Applications in Circuit Theorems	**Hour : 8 NOSS-MLVK : N/A** Student will be able to: i. identify the characteristic of a current source and analyse circuits with current source. ii. convert from a voltage source to a current source, and vice versa. iii. perform a Delta-to-Wye and Wye-to-Delta Conversions and use conversion effectively in a network analysis. iv. use Superposition Theorem to solve for voltage or current in a circuit. v. apply Thevenin's Theorem to reduce any series-parallel network to a single voltage source and series resistor. vi. apply maximum power transfer theorem to determine the maximum power to a load. vii. apply Norton's Theorem to reduce any series-parallel network to a single current source and parallel resistor. viii. use computer methods to determine the parameters of Thevenin or Norton equivalent circuit.

Topic	**Learning Outcomes *(For the topics)***
9. CAPACITORS 9.1 The Electric Field 9.2 Capacitance 9.3 Capacitors 9.4 Transients In Capacitive Networks. 9.4.1 The Charging Phase 9.4.2 The Discharging Phase 9.5 Initial Conditions 9.6 Instantaneous Values 9.7 Capacitors in Series and in Parallel 9.8 Energy Stored by a Capacitor	**Hour : 3 NOSS-MLVK : N/A** Student will be able to: i. calculate the capacitance of a capacitor and understand the impact of each parameter. ii. identify various types of capacitors and determine their value and rating from the provided labeling. iii. plot the transient response of a capacitor voltage and current. iv. incorporate initial values for the voltage of a capacitor in the transient analysis v. combine capacitors in series and parallel.
10. INDUCTORS 10.1 The Magnetic Field 10.2 Inductance 10.3 R-L Transients: The Storage Phase 10.4 Initial Conditions 10.5 R-L Transients: The Release Phase 10.6 Instantaneous Values 10.7 Inductors in Series and in Parallel 10.8 Steady-State Conditions 10.9 Energy Stored by an Inductor 10.10 Application	**Hour : 3 NOSS-MLVK : N/A** Student will be able to: i. calculate the inductance of an inductor and understand the impact of each parameter. ii. identify various types of inductors and determine their value and rating from the provided labeling. iii. plot the transient response of a inductor current and voltage. iv. incorporate initial values for the current of an inductor in the transient analysis v. combine inductors in series and parallel.
Generic Skills Addressed :	1. Problem Solving 2. Team Working 3. Lifelong Learning 4. Ethics
Text Book :	Robert L **Boylestad**, *Essentials of Circuit Analysis*, 1st Edition, Pearson Prentice Hall, 2004. (TK 7867 B69 2004)
References :	1. Robert L **Boylestad**, *Introductory Circuit Analysis*, 10th Edition, Prentice Hall, 2003. (TK 454 B68 2003) 2. Thomas L **Floyd**, (2003), *Principles of Electric Circuits – Conventional Current Version*, 7th Edition, Prentice Hall. (TK 454 F56 2003) 3. John P **Borris**, (2000), *Electric Circuits Using Electronics Workbench – Hardware and Simulation Exercises*, 2nd Edition, Prentice Hall. (TK 7867 B67 2000)

APPENDIX B: Circuits Theory 1 Course Learning Outcome



DDE 2113 Versi – 2 (0607- 2)

UNIVERSIT TEKNOLOGI MALAYSIA
COLLEGE OF SCIENCE & TECHNOLOGY
(salinan pelajar / pensyarah)

Department	: Engineering Department College of Science and Technology UTM City Campus	**Pages** : 5
Course & Code	: Circuit Theory 1 (DDE 2113)	**Semester** : III
Pre – requisite	: Electric Circuits (DDE 1103)	**Academic Year** : 2
Total / Contact Hours	: 3 hours x 14 weeks Lectures : 3 hrs Tutorial : 1hr Lab : Nil	
Objectives	: In this course student will : 1. Understand laws and theorems of electric circuits. 2. Differentiate direct current (dc) theory and alternating current (ac) theory. 3. Understand circuit theorems and analysis techniques to analyze dc and ac electric circuits. 4. Use Electronic Workbench to simulate electric circuits and verify analysis.	
Synopsis	: This subject is designed to expose students to the fundamental of electric circuits, laws and theorems and make them able to analyze basic electric circuits. It will emphasize on circuits having resistors, capacitors and inductors only with dc or ac supply of voltages or currents. At the end of the course, students should be able to understand laws and theorems of electric circuits involving dc and ac sources. The students should also be able to apply circuit theorems and analysis techniques to analyze dc and ac electric circuits. They should also be able to use Electronic Workbench to simulate electric circuits and verify analysis. DC circuit analysis – mesh, node, applications to Thevenin's and Norton's theorem. AC waveforms – sinusoidal wave and phasor diagram: polar and rectangular form. AC circuits – series, parallel and series-parallel of RL, RC and RLC. AC circuit analysis – source conversion, mesh, node, superposition, Thevenin, Norton, maximum power transfer. Two-port networks – T and Π networks, parameters Z, Y, h and ABCD, interconnection series, parallel and cascade for dc circuit, termination.	

Learning Outcome **(Overall for the course)**	After completing this course, students should be able to : 1. solve circuits with independent and dependent dc and ac sources using mesh analysis, node analysis, superposition theorem, Thevenin's theorem and Norton's theorem. 2. illustrate the characteristics of a sinusoidal waveform and define important parameters and characteristics of a sine wave. 3. represent sinusoidal waveform into phasor and vice versa. 4. identify the characteristics and function of RLC in ac circuits. 5. apply basic laws and analysis methods to solve problems in series, parallel and series-parallel ac circuits. 6. illustrate the frequency response of a series resonant circuit. 7. demonstrate the phase relationship between two or more voltages or currents in a series, parallel or series-parallel circuits. 8. identify common two port networks (T and π 9. identify the parameters (Z, Y, h, ABCD) that can be used to describe two port networks. 10. produce a set of equations for each parameter that relates the variables of the two port network 11. calculate the equivalent parameters for interconnected networks (series, parallel and cascade interconnections). 12. produce current-voltage relationships for the termination circuits and determine variables of the terminated two port networks. 13. use Electronic Workbench software to simulate electric circuits and verify analysis. Subject Mapping LO1-a, LO2-a, LO3-b, LO4-2, LO5-2, LO6-1

Topic	**Learning Outcomes *(For the topics)***
1. DC CIRCUIT ANALYSIS 1.1 Introduction to independent and dependent sources 1.2 Mesh analysis 1.2.1 Circuits with independent sources 1.2.2 Circuits with dependent sources 1.2.3 Supermesh 1.3 Node analysis 1.3.1 Circuits with independent sources 1.3.2 Circuits with dependent sources 1.3.3 Supernode 1.4 Application of mesh and node analysis in solving Thevenin's voltage and Norton's current 1.5 Electronic Workbench applications in DC Circuits Analysis	**Hours : 10 NOSS-MLVK : - N/A** Student will be able to: i. solve circuits with independent dc voltage and current sources using mesh analysis. ii. solve circuits with dependent dc voltage and current sources using mesh analysis. iii. solve circuits with independent dc voltage and current sources using node analysis. iv. solve circuits with dependent dc voltage and current sources using node analysis. v. using various methods in solving simultaneous equations. vi. become familiar with Thevenin's theorem and Norton's theorem. vii. apply mesh analysis and node analysis in solving Thevenin's voltage and Norton's current. viii. use Electronic Workbench software to simulate electric circuits and verify analysis.
2. AC WAVEFORMS 2.1 The Sine Wave 2.2 Sinusoidal Voltage Sources 2.3 Voltage and Current Values of Sine Wave 2.3.1 Characteristics of sinusoidal wave 2.3.2 Phase angle of a sinusoidal wave 2.3.3 Average and RMS value 2.4 Sine Waveform in Phasor Form 2.5 The Complex Number System and Mathematical Operations 2.6 Superimposed DC and AC Voltages 2.7 Basic Nonsinusoidal Waveforms – square, triangular, sawtooth, ramp	**Hour : 6 NOSS-MLVK : N/A** Student will be able to: i. identify a sinusoidal waveform. ii. illustrate the characteristics of a sinusoidal waveform. iii. define important parameters and characteristics of a sine wave. iv. use a phasor to represent sinusoidal waveform and vice versa. v. learn how to apply the phasor format to add and substract sinusoidal waveforms. vi. determine the phase relationship between two or more sinusoidal waveforms of the same frequency. vii. understand how to calculate the average and effective values of a sinusoidal waveform. viii. use complex number to express phasor quantities. ix. become proficient in the use of calculators to support the analysis of ac networks. x. determine the total voltages that have both ac and dc components. xi. identify the characteristics of basic nonsinusoidal waveforms.

Topic	**Learning Outcomes** ***(For the topics)***
3. AC CIRCUITS 3.1 Introduction to R, L, C and Impedance triangle in AC circuits. 3.2 Series Circuits 3.2.1 RL 3.2.2 RC 3.2.3 RLC and Series Resonant Circuit 3.3 Parallel Circuits 3.3.1 RL 3.3.2 RC 3.3.3 RLC and Parallel Resonant Circuit 3.4 Series-Parallel Circuits 3.4.1 RL 3.4.2 RC 3.4.3 RLC 3.5 Electronic Workbench applications in AC Circuits	**Hour : 10** **NOSS-MLVK :N/A** Student will be able to: i. identify the characteristics and function of RLC in ac circuits. ii. identify the response of a resistor, inductor and capacitor to the application of a sinusoidal voltage or current. iii. find the total impedance of any ac network and sketch the impedance diagram. iv. apply basic laws (KVL, KCL, voltage divider rule and current divider rule) to solve problems in series, parallel and series-parallel ac circuits. v. illustrate the frequency response of a series resonant circuit. vi. demonstrate the phase relationship between two or more voltages or currents in a series, parallel or series-parallel circuits. vii. use Electronic Workbench software to simulate electric circuits and verify analysis.
4. AC CIRCUITS ANALYSIS 4.1 Introduction to Source Conversion 4.2 Mesh Analysis - Circuit with independent sources 4.3 Node Analysis - Circuit with independent sources 4.4 The Superposition Theorem 4.5 Thevenin's Theorem – using KCL, KVL and superposition only 4.6 Norton's Theorem – using KCL, KVL and superposition only 4.7. Maximum Power Transfer Theorem 4.8. Electronic Workbench applications in AC circuits	**Hour : 8** **NOSS-MLVK : N/A** Student will be able to: i. convert between voltage and current sources and vice versa in the ac domain. ii. solve circuits with independent ac sources using mesh analysis, node analysis, superposition theorem, Thevenin's theorem and Norton's theorem. iii. identify the conditions that must e met for maximum power transfer to a load in an ac network. iv. use Electronic Workbench software to simulate electric circuits and verify analysis.

Topic	**Learning Outcomes *(For the topics)***
5. TWO PORT NETWORKS 5.1 Introduction to Single-Port and Two-Port Networks 5.2 T and Π networks 5.3 Two port network parameters 5.3.1 Impedance parameters, Z 5.3.2 Admittance parameters, Y 5.3.3 Hybrid parameters, h 5.3.4 Transmission parameters, ABCD 5.4 Termination of two-port network 5.5 Interconnection of two-port network 5.4.1 Series connection 5.4.2 Parallel Connection 5.4.3 Cascade Connection	**Hour : 8** **NOSS-MLVK : N/A** Student will be able to: i. identify common two port networks (T and Π). ii. identify the parameters (Z, Y, h, ABCD) that can be used to describe two port networks. iii. produce a set of equations for each parameter that relates the variables of the two port network. iv. calculate the equivalent parameters for interconnected networks (series, parallel and cascade interconnections). v. produce current-voltage relationships for the termination circuits and determine variables of the terminated two port networks. vi. use Electronic Workbench software to simulate electric circuits and verify analysis.

Generic Skills Addressed :

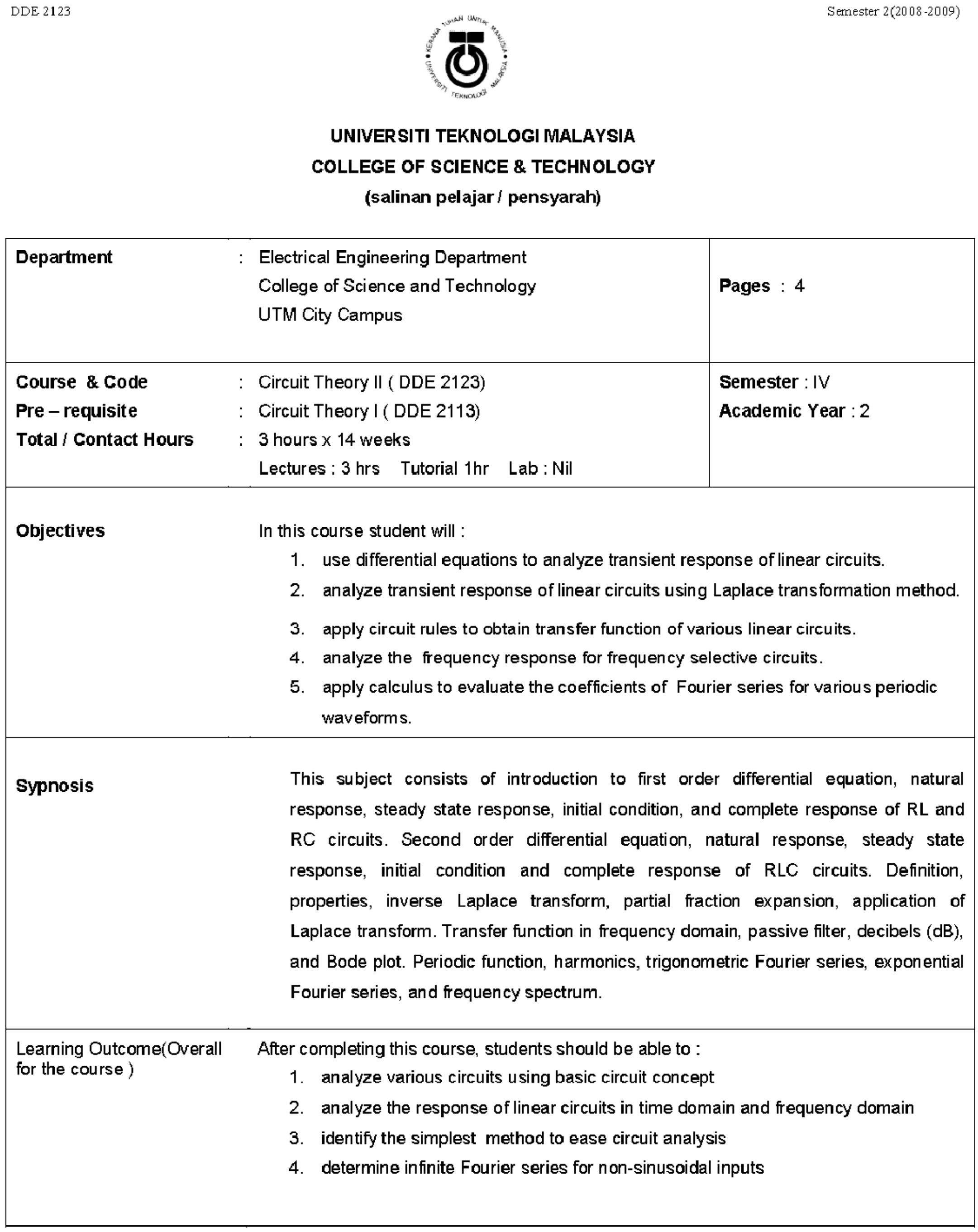
1. Problem Solving
2. Team Working
3. Lifelong Learning
4. Ethics

Text Book : Kamilah Radin Salim, Noor Hamizah Hussain, Norlela Tahir & Putri Zalila Yaacob. (2005), *'Teaching Module : Circuit Theory I'*, Program Pengajian Diploma, UTM.

References :

1. Robert L **Boylestad**, *Essentials of Circuit Analysis*, 1st Edition, Pearson Prentice Hall, 2004. (TK 7867 B69 2004)
2. Robert L **Boylestad**, *Introductory Circuit Analysis*, 10th Edition, Prentice Hall, 2003. (TK 454 B68 2003)
3. Thomas L **Floyd**, (2003), *Principles of Electric Circuits – Conventional Current Version*, 7th Edition, Prentice Hall. (TK 454 F56 2003)
4. David E **Johnson**, John L **Hilburn**, Johnny R **Johnson** & Peter D. **Scott**, *Basic Electric Circuit Analysis*, (1995), 5th Edition, Prentice Hall. (TK 454 J64 1995)
5. Alexander **Sadiku**, (2000), *Fundamentals of Electric Circuits*, McGraw Hill. (TK 454 A43 2000)
6. John P **Borris**, (2000), *Electric Circuits Using Electronics Workbench – Hardware and Simulation Exercises*, 2nd Edition, Prentice Hall. (TK 7867 B67 2000)
7. Johd **Adams**, (2001), *Mastering Electronics Workbench – Version 5 & Multisim - Version 6*, Prentice Hall. (TK 7867 A33 2001)

APPENDIX C: Circuits Theory 2 Course Learning Outcome



DDE 2123 Semester 2(2008-2009)

UNIVERSITI TEKNOLOGI MALAYSIA
COLLEGE OF SCIENCE & TECHNOLOGY
(salinan pelajar / pensyarah)

Department	: Electrical Engineering Department College of Science and Technology UTM City Campus	**Pages** : 4
Course & Code **Pre – requisite** **Total / Contact Hours**	: Circuit Theory II (DDE 2123) : Circuit Theory I (DDE 2113) : 3 hours x 14 weeks Lectures : 3 hrs Tutorial 1hr Lab : Nil	**Semester** : IV **Academic Year** : 2
Objectives	In this course student will : 1. use differential equations to analyze transient response of linear circuits. 2. analyze transient response of linear circuits using Laplace transformation method. 3. apply circuit rules to obtain transfer function of various linear circuits. 4. analyze the frequency response for frequency selective circuits. 5. apply calculus to evaluate the coefficients of Fourier series for various periodic waveforms.	
Sypnosis	This subject consists of introduction to first order differential equation, natural response, steady state response, initial condition, and complete response of RL and RC circuits. Second order differential equation, natural response, steady state response, initial condition and complete response of RLC circuits. Definition, properties, inverse Laplace transform, partial fraction expansion, application of Laplace transform. Transfer function in frequency domain, passive filter, decibels (dB), and Bode plot. Periodic function, harmonics, trigonometric Fourier series, exponential Fourier series, and frequency spectrum.	
Learning Outcome(Overall for the course)	After completing this course, students should be able to : 1. analyze various circuits using basic circuit concept 2. analyze the response of linear circuits in time domain and frequency domain 3. identify the simplest method to ease circuit analysis 4. determine infinite Fourier series for non-sinusoidal inputs	

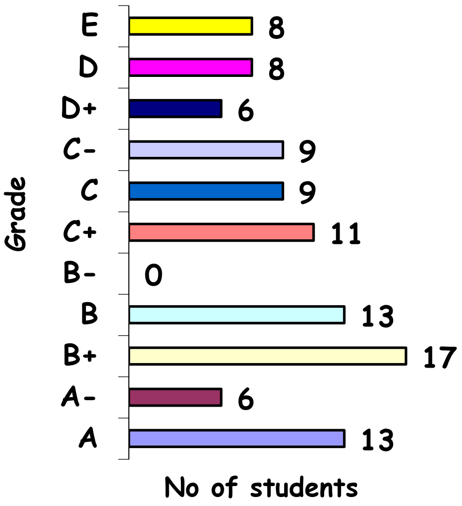
Topic	**Learning Outcomes *(For the topics)***
1. FIRST ORDER TRANSIENT CIRCUITS. 1.1. Circuit with first order differential equation. 1.2. Natural response of first order circuit. 1.3. Forced response of first order circuit to various types of forcing function. 1.4. Initial condition and complete response.	**Hours : 7 NOSS-MLVK : - N/A** Student will be able to: i. Define transient response and steady state response ii. Obtain first order differential equation for RL and RC circuit iii. Determine the transient response of RL and RC circuit iv. Plot the transient response of RL and RC circuit v. Identify the time domain equation for various types of forcing function vi. Identify the steady state assumed solution for various types of forcing function vii. Obtain the steady state response for various types of forcing function viii. Obtain the initial current through inductor and the initial voltage across the capacitor ix. Determine the complete response of the first order RL and RC circuits.
2. SECOND ORDER TRANSIENT CIRCUITS. 2.1. Circuit with second order differential equation. 2.2. Behaviour of second order circuit; overdamped, critically damped, underdamped and undamped 2.3. Natural response of second order circuit. 2.4. Forced response of second order circuit. 2.5. Initial condition and complete response.	**Hour : 10 NOSS-MLVK : N/A** Student will be able to : i. obtain second order differential equation for RLC circuit ii. classify the circuits behaviour either critically damped, overdamped, underdamped or undamped. iii. determine the natural response of RLC circuit iv. determine the transient response of RLC circuit v. obtain the steady state response for various types of forcing function vi. obtain the initial current through inductor and its derivative vii. obtain the initial voltage across the capacitor and its derivative viii. determine the complete response of the second order RLC circuit.

Topic	Learning Outcomes *(For the topics)*
3. LAPLACE TRANSFORM 3.1. Definition and Properties of Laplace transform. 3.2. Inverse Laplace transform using partial fraction expansion. 3.3. Application of Laplace transform in circuit analysis 3.4. Transfer function in s-domain.	**Hour : 10 NOSS-MLVK : N/A** Student will be able to : i. tell Laplace transform properties ii. obtain partial fraction expansion iii. apply the Laplace transform properties and partial fraction expansion in second order circuit analysis iv. obtain the circuit transfer function in s-domain using Laplace transform.
4. FREQUENCY RESPONSE 4.1. The transfer function H(jω) 4.2. Passive filter networks and application; low pass, high pass and band pass filters 4.3. Resonance circuits and applications. 4.4. Bode magnitude and phase plots.	**Hour : 7 NOSS-MLVK : N/A** Student will be able to : i. determine the transfer function in frequency domain H(jω) ii. differentiate the response of low pass, high pass and band pass RC and RL filter. iii. determine the transfer function of a low pass, high pass and band pass RC and RL filter. iv. obtain the cut-off frequency of a low pass, high pass and band pass RC and RL filter. v. sketch the frequency response of a low pass, high pass and band pass RC and RL filter. vi. construct a band pass filter using low pass and high pass filter vii. analyze circuit at resonance. viii. convert the transfer function into decibel (dB) scale sketch the Bode plot of a frequency response on a semilog scale.

Topic	**Learning Outcomes *(For the topics)***
5. **FOURIER SERIES** 5.1. Periodic function and harmonics 5.2. Trigonometric Fourier series; waveform symmetry, Fourier coefficients. 5.3. Exponential Fourier series 5.4. Frequency spectrum; Amplitude and phase	**Hour : 8** **NOSS-MLVK : N/A** Student will be able to : i. examine sinusoid of multiple frequencies (harmonic) ii. produce analytical equation for various non-sinusoid periodic waveform iii. perform evaluation integral for determination of the Fourier coefficients iv. identify waveform symmetry to ease evaluation of the Fourier coefficients v. represent the non-sinusoid periodic waveform as an infinite trigonometric Fourier series vi. represent non-sinusoid periodic waveform as an exponential Fourier series vii. sketch the magnitude and phase spectrum of the Fourier series
Generic Skills Addressed :	1. Team Working *(Mapping : L0 ……)* 2. Problem Solving 3. Life Long Learning 4. Ethics
Text Book : **References** :	1. David Irwin, Basic Engineering Circuit Analysis, 8th Ed., Wiley, 2005, TK 454 I78 2005 C.1 2. Boylestad, Introduction Circuit Analysis 10th Edition, Prentice Hall, 2002, TK 454 B68 2002. 3. R.C Dorf & J.A Svoboda, Introduction to Electric Circuits, 6th Edition, Wiley, 2004, TK 454 D67. 4. David E. Johnson, Electric Circuit Analysis, TK 454 E43. 5. Charles J.Morrier, Electric Circuit Analysis, Prentice Hall, TK 454 M66 2000. 6. William D.Stanley, Network Analysis with Applications, 4th Ed., Prentice Hall, 2001, TK 454.2.S73 2001. 7. Alexander Sadiku, Fundamentals of Electric Circuits, Mc Graw Hill, TK 454 A43 2000.

APPENDIX D: Electric Circuits Grade for 2005/2006-1

Electric Circuits DDE1103
Section 06



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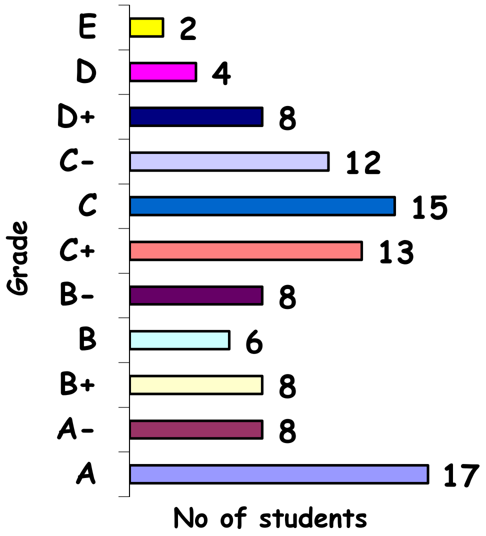

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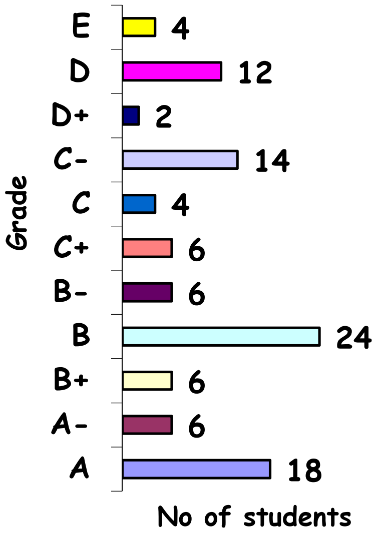
Section 09



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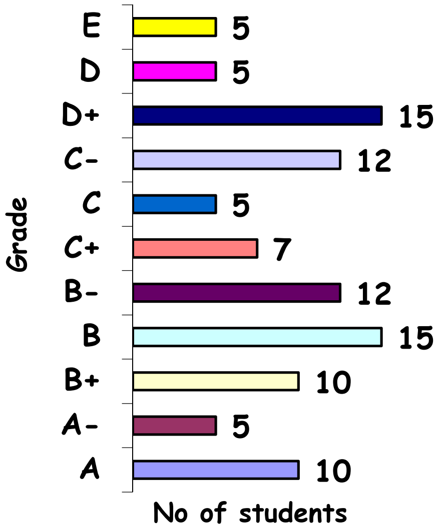
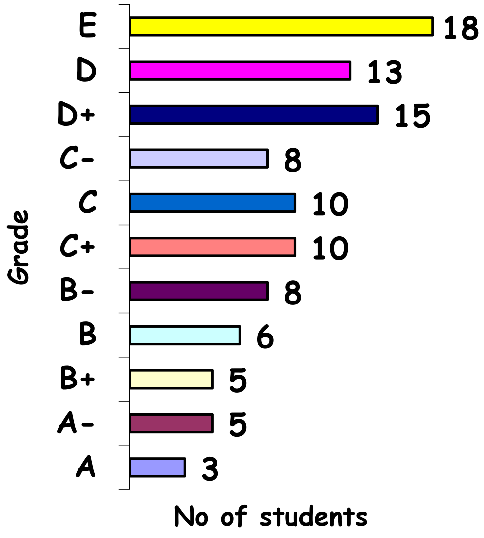
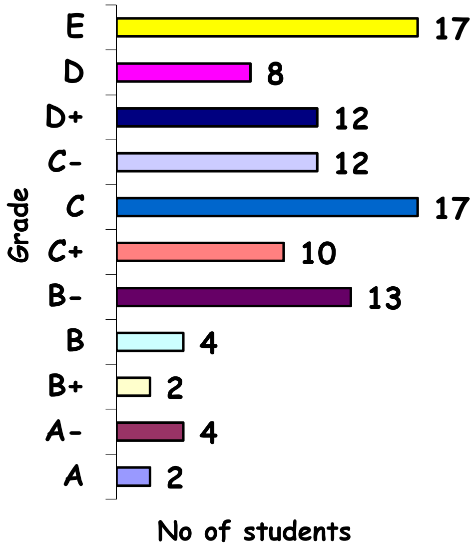
Section 10



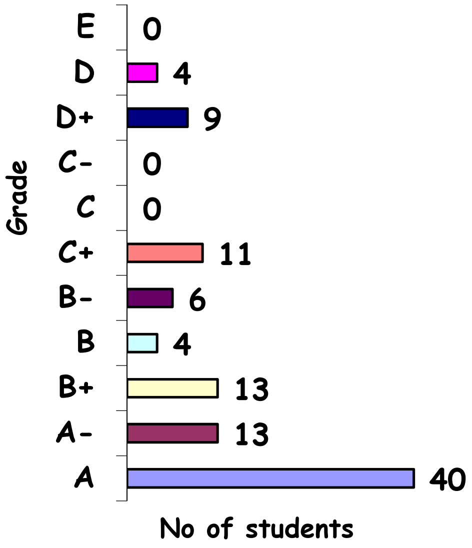
Electric Circuits DDE1103
Section 11



Electric Circuits DDE1103
Section 12



Electric Circuits DDE1103
Section 14



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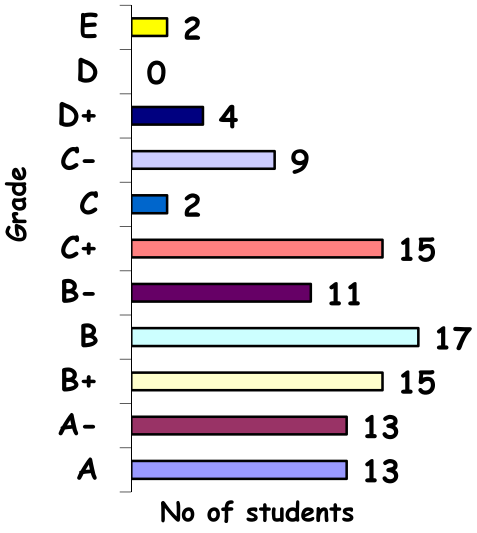
Section 15



APPENDIX E: Thevenin and Norton Theorems

THEVENIN THEOREM

A method of determining the Thevenin Equivalent Circuits: The Thevenin equivalent circuit for any linear network at a given pair of terminals consists of a voltage source V_{TH} in series with a resistor R_{TH}. The voltage V_{TH} and resistance R_{TH} can be obtained as follows:

1. V_{TH} can be found by calculating or measuring the open-circuits voltage at the designated terminal pair on the original network.

2. R_{TH} can be found by calculating or measuring the resistance of the open-circuits network seen from the designated terminal pair whit all independent sources internal to the network set to zero. That is, with independent voltage sources replaced with short circuits, and independent current source replaced with open circuits. (Dependent sources must be left intact)

NORTON THEOREM

A method of determining the Norton Equivalent Circuits: The Norton equivalent circuit for any linear network at a given pair of terminals consists of a current source I_N in parallel with a resistor R_N. The current I_N and resistance R_N can be obtained as follows:

1. I_N can be found by applying a short at terminal pair terminal pair on the original network and calculating or measuring the current through the short circuits.

2. R_N can be found in the same manner as R_{TH} that is by calculating or measuring the resistance of the open-circuits network seen from the designated terminal pair with all independent sources internal to the network set to zero; that is, with independent voltage sources replaced with short circuits, and independent current source replaced with open circuits. (Dependent sources must be left intact)

Adopted from (Agarwal and Lang, 2005; Boylestad, 2004; Dorf and Svoboda, 2004; Irwin, 2002).

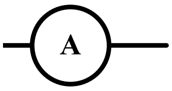
APPENDIX F: Preliminary Test

Basic Electric Circuits Concepts Test

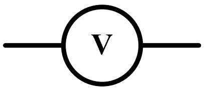
Instructions:

Answer each question as accurately as you can.

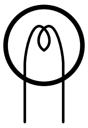
Below are the symbols used / to be used on this test:



Ammeter



Voltmeter



Light Bulb

Switch open

Switch closed

Test Begins:

Q1. A simple DC circuit in Figure 1 is referred.

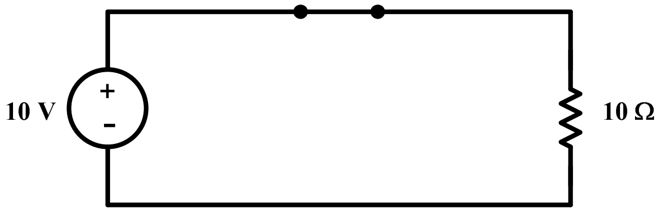


Figure 1

a. Redraw the circuit in Figure 1 to show how to measure the **voltage drop** across 10 Ω resistor.

b. Name laws, rules or theorems that can be used **to calculate the voltage drop** across 10 Ω resistor.

c. Redraw the circuit in Figure 1 to show how to measure the **current flows** through 10 Ω resistor.

d. Name laws, rules or theorems that can be used **to calculate the current through** 10 Ω resistor.

Q2. Referring to Figure 2;

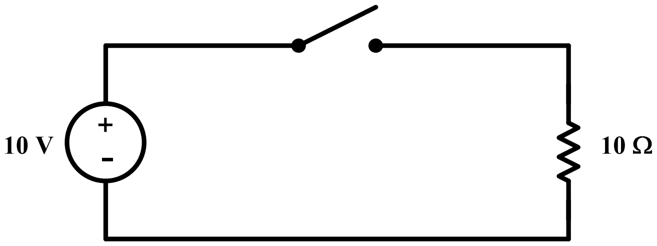


Figure 2

a. Circle the answer for the voltage drop across 10 Ω resistor.

   i. 0 V because of open circuit
   ii. 10 V by using KVL or Ohm’s Law

Explain your answer : ____

____

b. Circle the answer for the current flowing through 10 Ω resistor.
   i. 0 A because of open circuit
   ii. 1 A by using KCL or Ohm’s Law

Explain your answer :____

____

Q3. Referring to Figure 3;

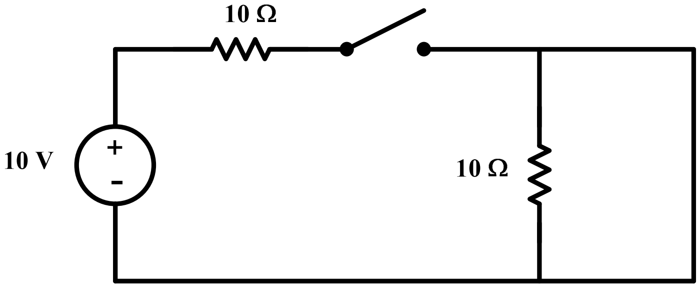


Figure 3

a. Calculate the total resistance of the circuit when the switch is opened.

b. Calculate the total resistance of the circuit when the switch is closed.

APPENDIX G: Concept Test

BASIC ELECTRIC CIRCUIT CONCEPTS TEST

Name : ______________________________

Mobile Number : ______________________________

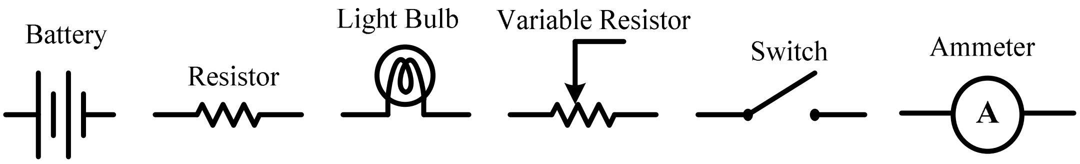
Email Address : ______________________________

INSTRUCTIONS :

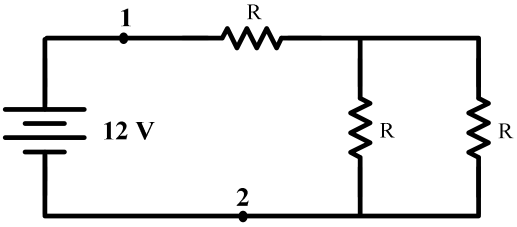
1. This test consists of 12 questions that examine your understanding of electrical circuits.
2. Each questions has multiple choice answers.
3. Please answer the question to your best ability.
4. If you are not sure, try to guess.
5. Do not leave any question unanswered.

REMINDER :

- All resistors, batteries and light bulbs are identical unless you are told otherwise.
- The battery is ideal with a negligible internal resistance.
- In addition, the wires have a negligible resistance too.
- Below is a key to some symbols used in this test:



1. Compare the current at point 1 with the current at point 2. Which point has a larger current?



a. Point 1.

b. Point 2.

c. They are the same

Reason:

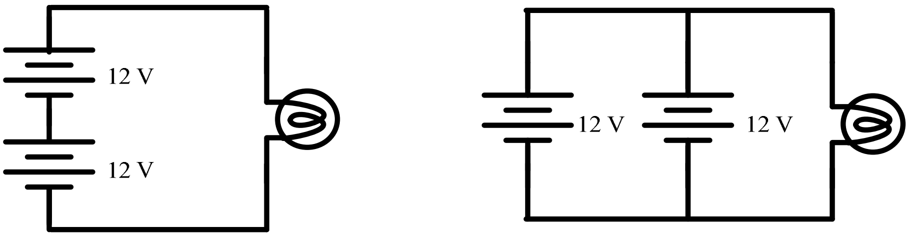
a. Current travels in two directions around the circuit.

b. Current from the battery goes to the circuit and then comes back to the battery.

c. The resistors use up a little of the current.

d. Others (Please specify): ____

2. Compare the brightness of the bulb in Circuit 1 with that in Circuit 2. Which bulb is brighter?



Circuit 1 Circuit 2

a. The bulb in Circuit 1.

b. The bulb in Circuit 2.

c. They are the same

Reason:

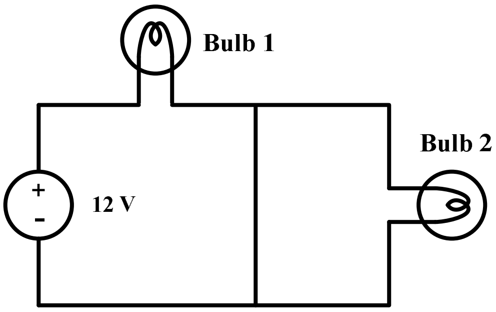
a. Because two batteries in the Circuit 1 provide more voltage.

b. Because two batteries in the Circuit 2 provide more voltage.

c. Because 24 V is applied across the bulb in each circuit.

d. Others (Please specify): ____

3. Compare the brightness of Bulb 1 and Bulb 2 in this circuit, which one is brighter?



a. Bulb 1.

b. Bulb 2.

c. They are the same.

Reason:

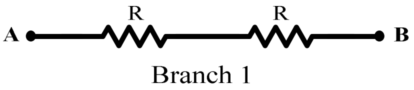
a. Because the bulbs are connected in parallel.

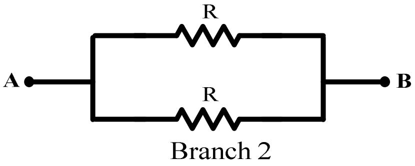
b. Because no current will pass through Bulb 1.

c. Because no current will pass through Bulb 2.

d. Others (Please specify): ____

4. Compare the resistance of Branch 1 with that of Branch 2 where point A and B are open terminals. The resistance of Branch 1 is ____________________ the resistance of Branch 2.





a. Four times

b. Double

c. The same as

d. Half

Reason:

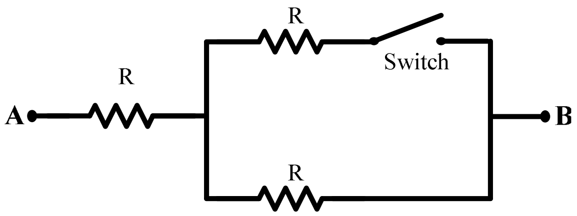
a. The total resistance of each branch equals the sum of the two resistors.

b. Because the total resistance equals zero in open circuits.

c. Adding a resistor to any circuit will increase the overall resistance.

d. Others (Please specify): ____

5. How does the resistance between the terminal A and B change when the switch is closed?



a. Increase by R/2

b. Increase by R

c. Stay the same

d. Decrease by R/2

e. Decrease by R

Reason:

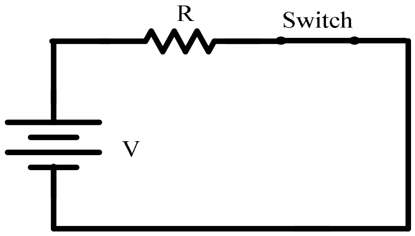
a. Closing the switch will add a resistor in series.

b. The circuit is not affected after closing the switch.

c. Adding a resistance in parallel to any branch decreases its total resistance.

d. Others (Please specify): ____

6. After the switch is opened, what happens to the resistance of resistor R?



a. Increases.

b. Stay the same.

c. Goes to zero.

Reason:

a. The value of resistance depends on the applied voltage.

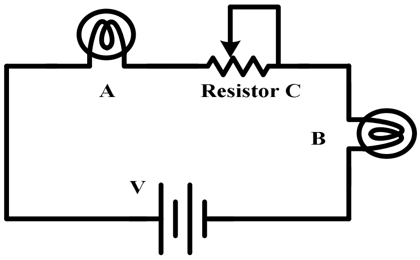
b. Since there is no current, the resistance of the resistor will go to zero.

c. The electrical resistance does not depend on current or voltage.

d. Since there is no current, the resistance of the resistor will increase.

e. Others (Please specify): ____

7. If you increase the resistance of Resistor C, what happens to the brightness of bulbs A and B?

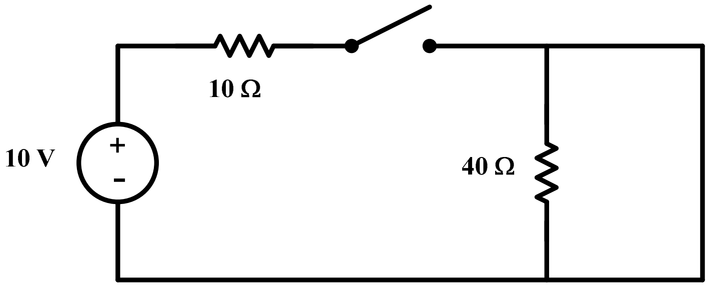


a. A and B increase.
b. A stay the same, but B decrease.
c. A and B decrease.
d. A and B remain the same.

Reason:

a. The battery supplies a constant current to the circuit.
b. Increasing Resistor C will decrease the circuit current.
c. Because Resistor C consumed some current.
d. Others (Please specify): ____

8. What is the total resistance of the circuit when the switch is closed?

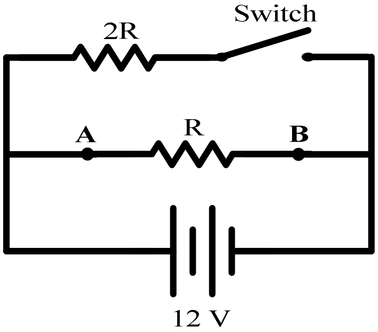


a. 50 Ω
b. 10 Ω
c. 8 Ω
d. 0 Ω

Reason:

a. The total resistance is the sum of the two resistors.
b. Only the 10 Ω resistor operates in the circuit.
c. The two resistors are in parallel.
d. Because the total resistance equals zero in a closed circuit.
e. Others (Please specify): ____

9. What will happen to the voltage between points A and B if the switch is closed?

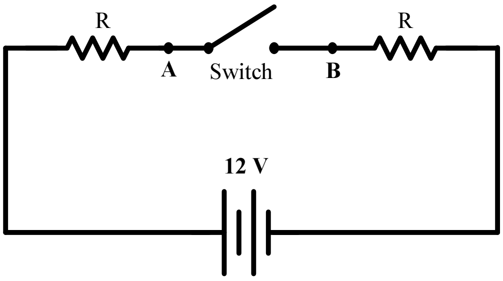


- a. Increase
- b. Decrease
- c. Stay the same

Reason:

- a. The voltage source will be distributed between the resistors based on the value of the resistance.
- b. Closing the switch will increase the total resistance of the circuit.
- c. Adding 2R will decrease both the voltage across R and the current flowing through R.
- d. Adding 2R resistor affects the battery current only.
- e. Others (Please specify): ____

10 What is the voltage between points A and B?

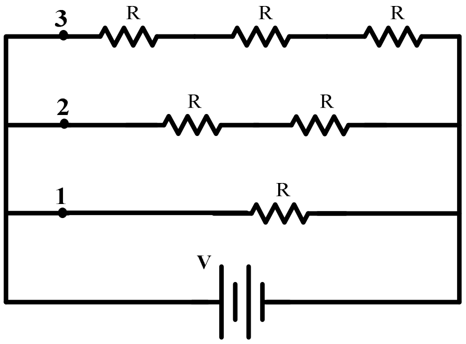


- a. 0 V
- b. 12 V
- c. Less than 12 V

Reason:

- a. There is no voltage since there is no current flowing.
- b. Because some of the voltage of a battery has dropped across the resistors.
- c. If there is no resistance, there will be no voltage dropped.
- d. Others (Please specify): ____

11. At which branch the magnitude of current is the lowest?



a. 1

b. 2

c. 3

d. They are the same

Reason:

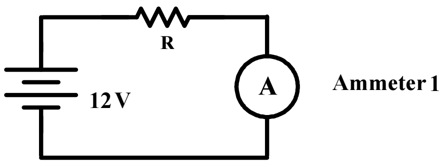
a. Because the farthest away the branch from battery will get the least current.

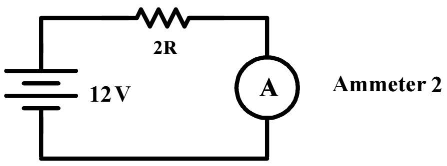
b. Because the current will be divided equally between the branches.

c. Because more current will pass through the low-resistance branch.

d. Others (Please specify): ____

12. Compare the readings of Ammeter 1 and Ammeter 2 in the circuits shown below, which one has higher reading?





a. Ammeter 1.

b. Ammeter 2.

c. They are the same.

Reason:

a. Because the voltage is the same in both circuits.

b. Because the greater the resistance, the lower the current for the same voltage source.

c. Because the resistance does not affect the current.

d. Others (Please specify): ____

APPENDIX H: Lesson Plan

About me

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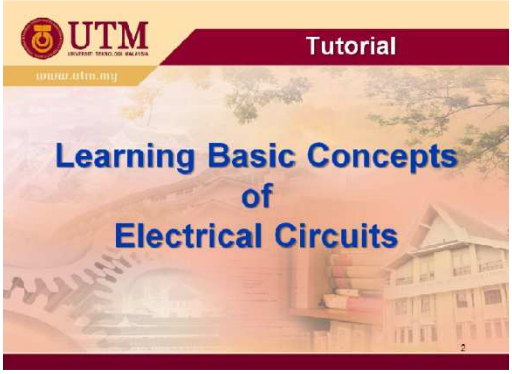
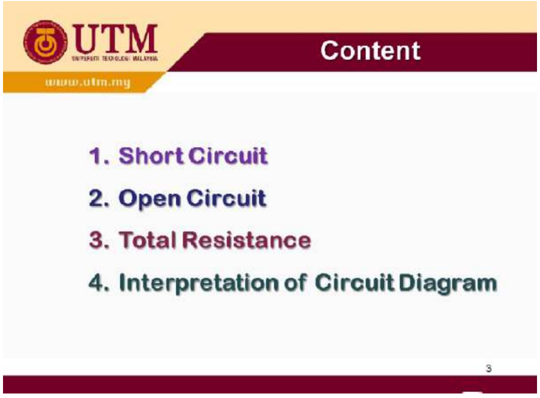
CW 104



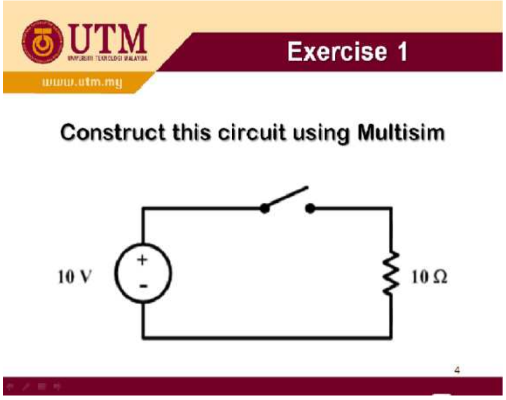
Tutorial

Learning Basic Concepts
of
Electrical Circuits



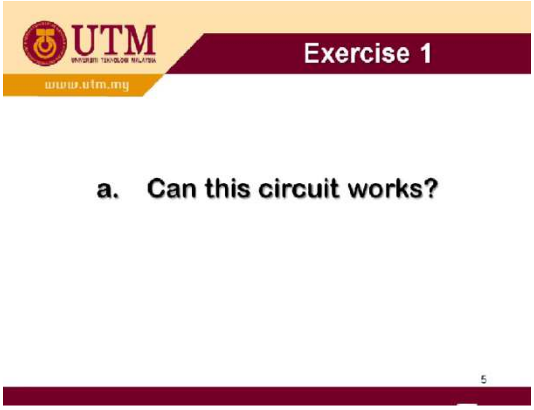
Content

1. Short Circuit
2. Open Circuit
3. Total Resistance
4. Interpretation of Circuit Diagram



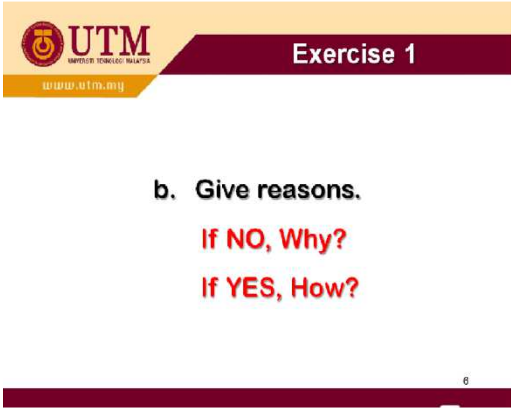
Exercise 1

Construct this circuit using Multisim



Exercise 1

a. Can this circuit works?

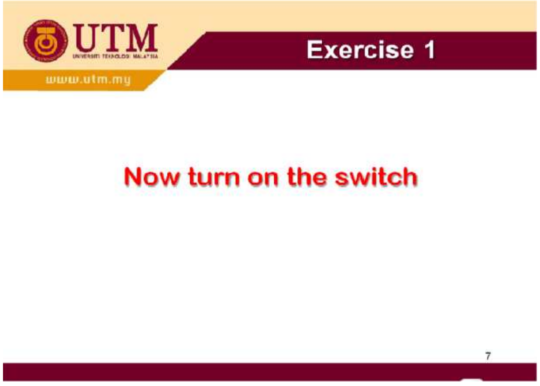


Exercise 1

b. Give reasons.

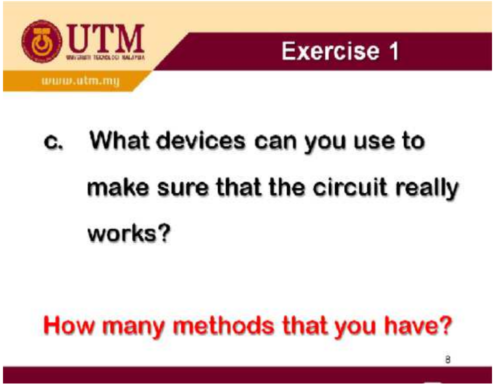
If NO, Why?

If YES, How?



Exercise 1

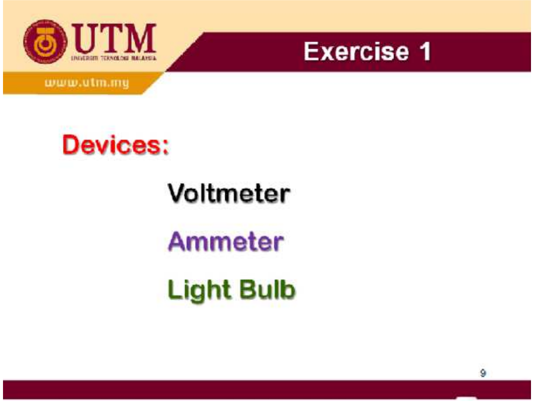
Now turn on the switch



Exercise 1

c. What devices can you use to make sure that the circuit really works?

How many methods that you have?



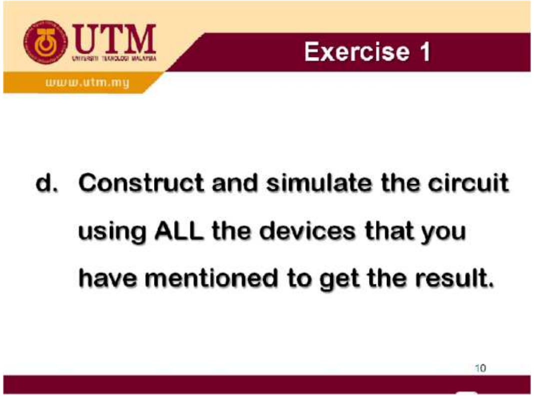
Exercise 1

Devices:

Voltmeter

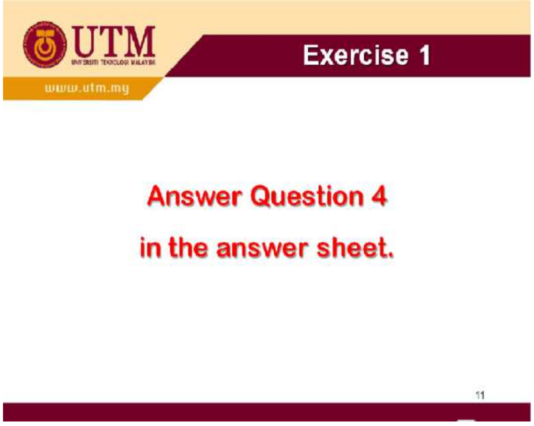
Ammeter

Light Bulb



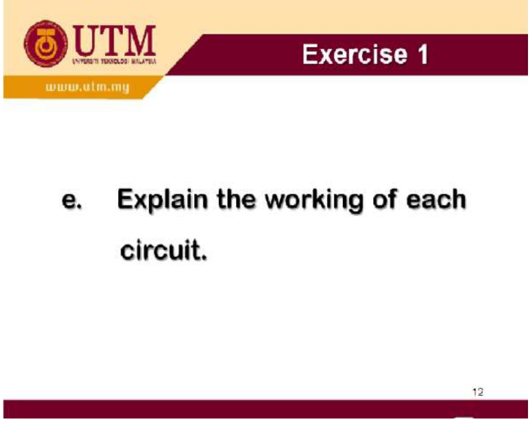
Exercise 1

d. Construct and simulate the circuit using ALL the devices that you have mentioned to get the result.



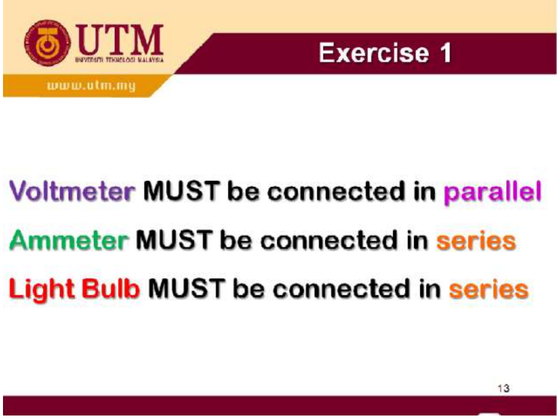
Exercise 1

Answer Question 4
in the answer sheet.



Exercise 1

e. Explain the working of each circuit.

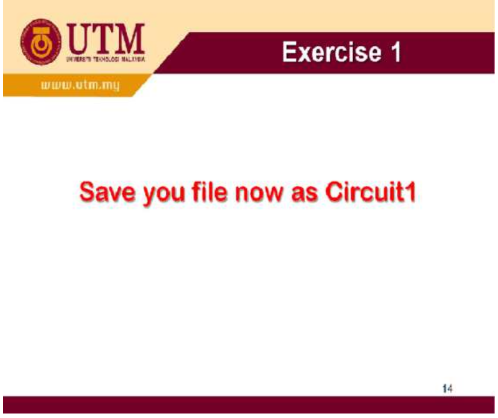


Exercise 1

Voltmeter MUST be connected in parallel

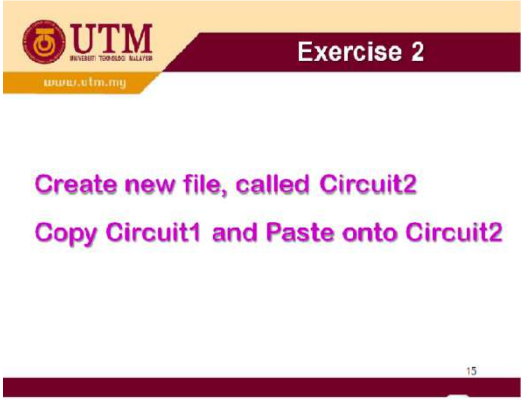
Ammeter MUST be connected in series

Light Bulb MUST be connected in series



Exercise 1

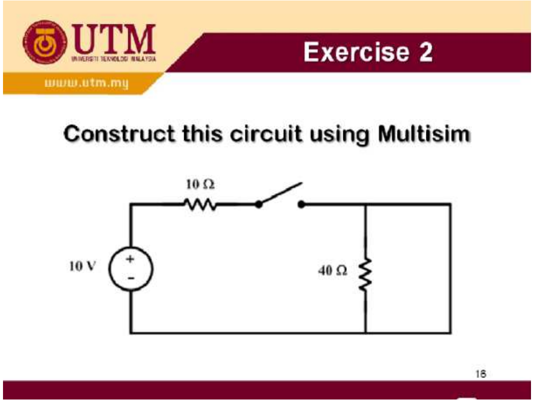
Save you file now as Circuit1



Exercise 2

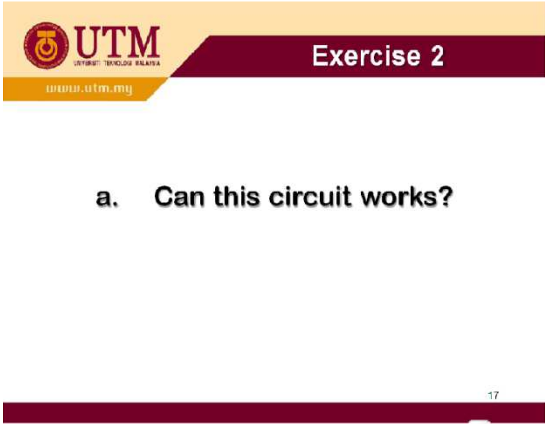
Create new file, called Circuit2

Copy Circuit1 and Paste onto Circuit2



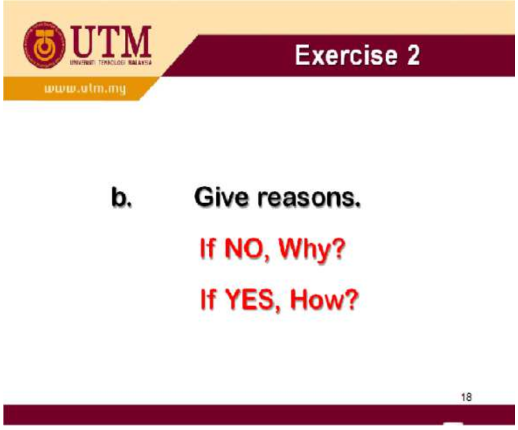
Exercise 2

Construct this circuit using Multisim



Exercise 2

a. Can this circuit works?

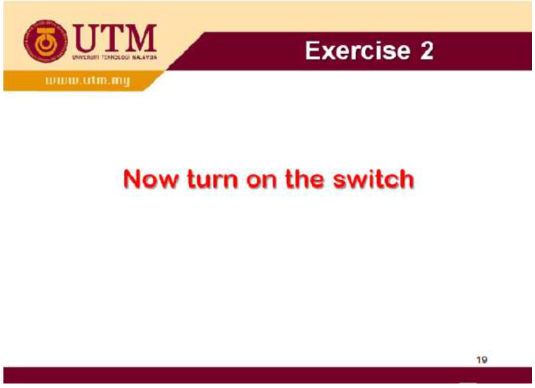


Exercise 2

b. Give reasons.

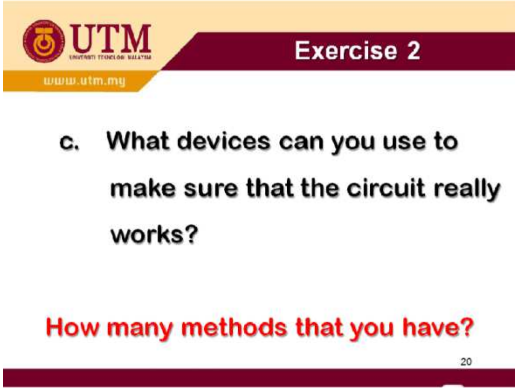
If NO, Why?

If YES, How?



Exercise 2

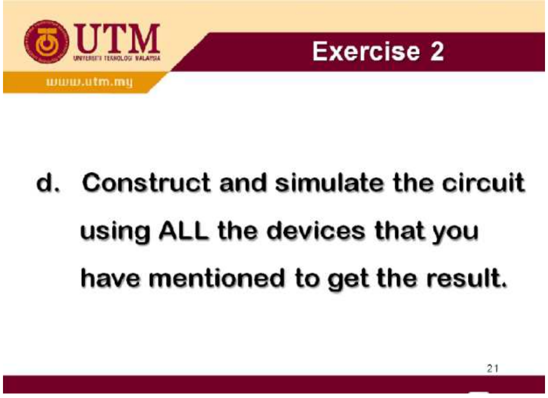
Now turn on the switch



Exercise 2

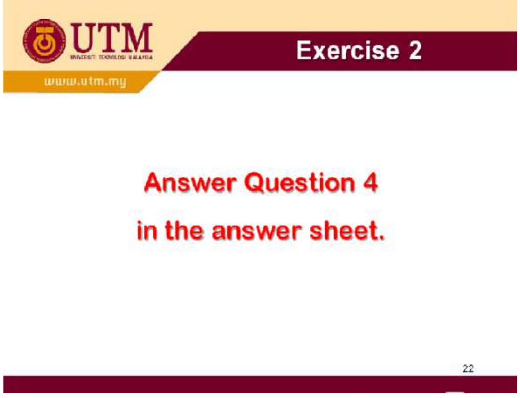
c. What devices can you use to make sure that the circuit really works?

How many methods that you have?



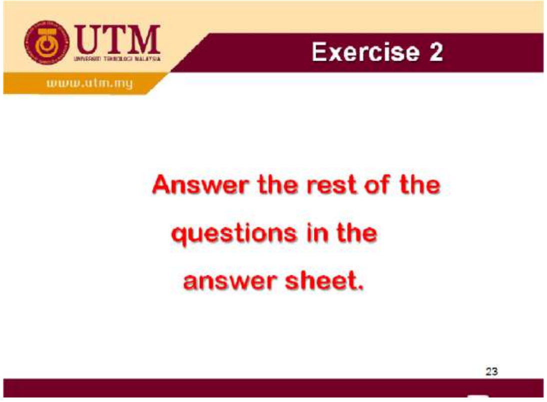
Exercise 2

d. Construct and simulate the circuit using ALL the devices that you have mentioned to get the result.



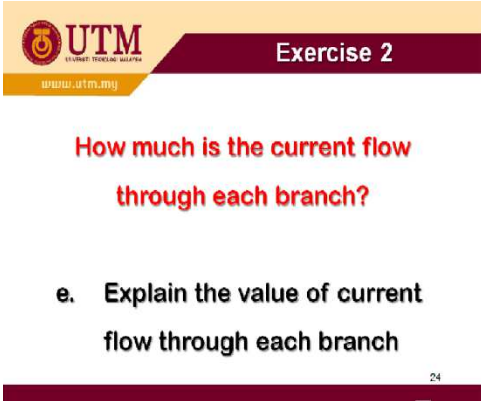
Exercise 2

Answer Question 4
in the answer sheet.



Exercise 2

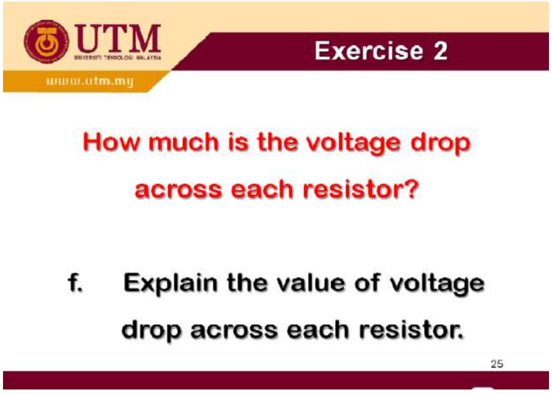
Answer the rest of the
questions in the
answer sheet.



Exercise 2

How much is the current flow through each branch?

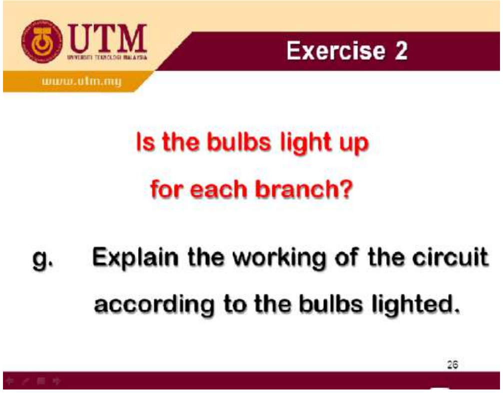
e. Explain the value of current flow through each branch



Exercise 2

How much is the voltage drop
across each resistor?

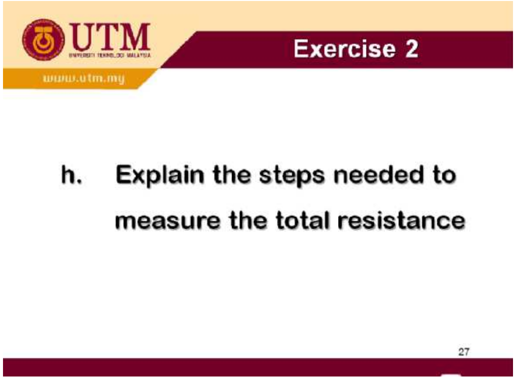
f. Explain the value of voltage drop across each resistor.



Exercise 2

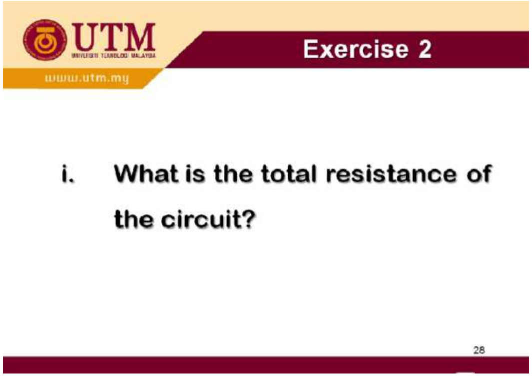
Is the bulbs light up
for each branch?

g. Explain the working of the circuit according to the bulbs lighted.



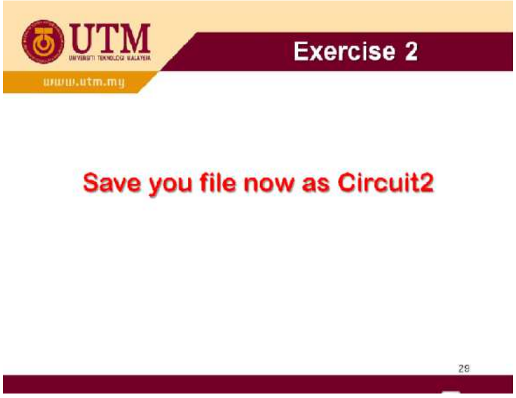
Exercise 2

h. Explain the steps needed to measure the total resistance



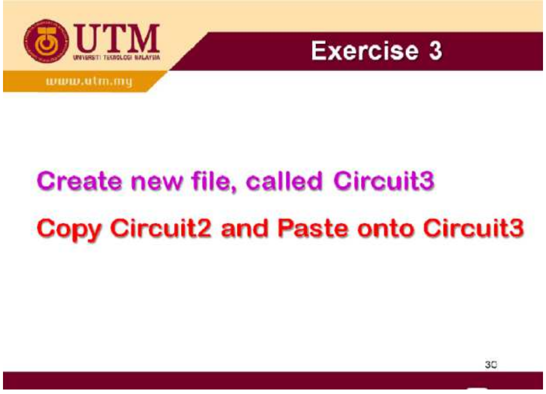
Exercise 2

i. What is the total resistance of the circuit?



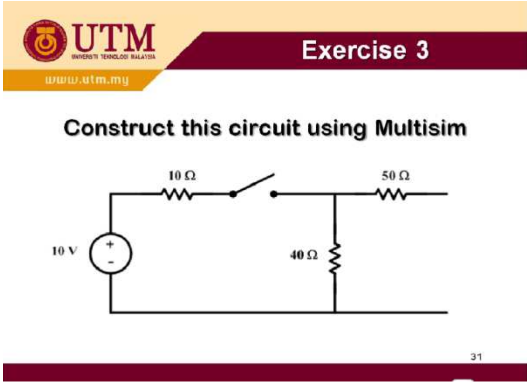
Exercise 2

Save you file now as Circuit2



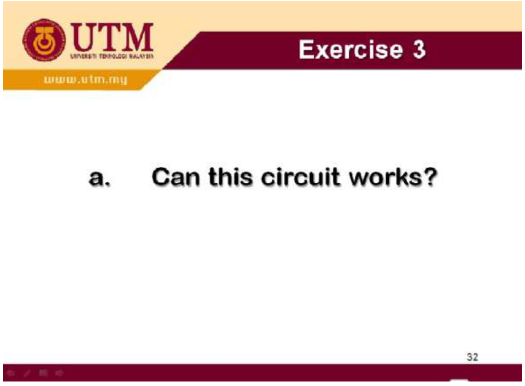
Exercise 3

Create new file, called Circuit3
Copy Circuit2 and Paste onto Circuit3



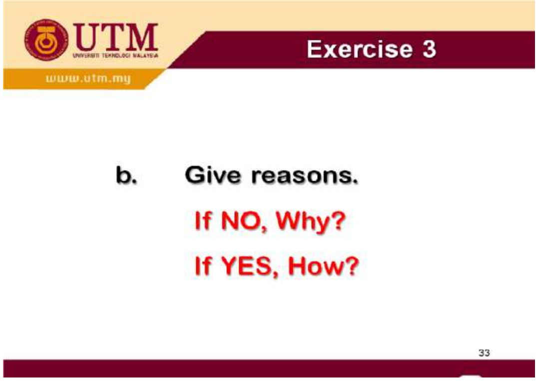
Exercise 3

Construct this circuit using Multisim



Exercise 3

a. Can this circuit works?

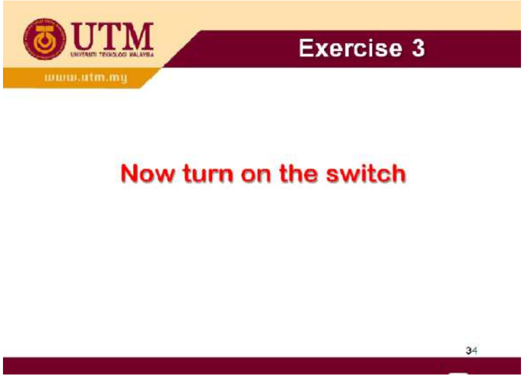


Exercise 3

b. Give reasons.

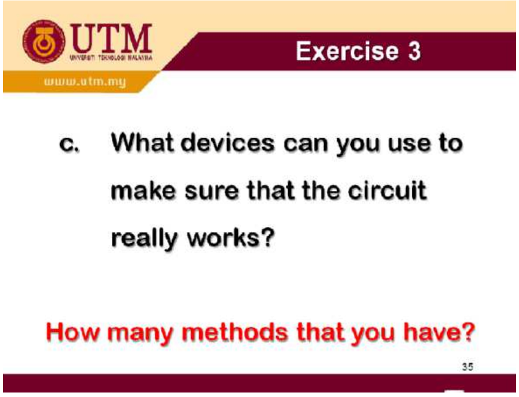
If NO, Why?

If YES, How?



Exercise 3

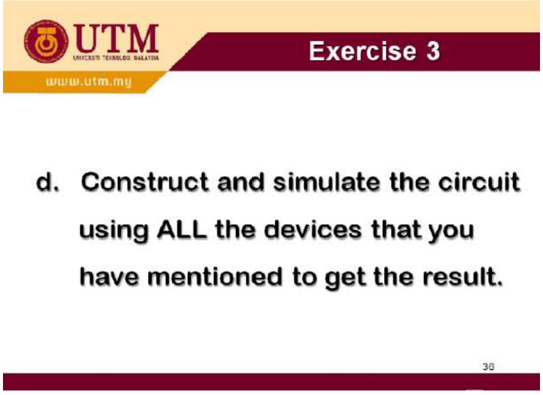
Now turn on the switch



Exercise 3

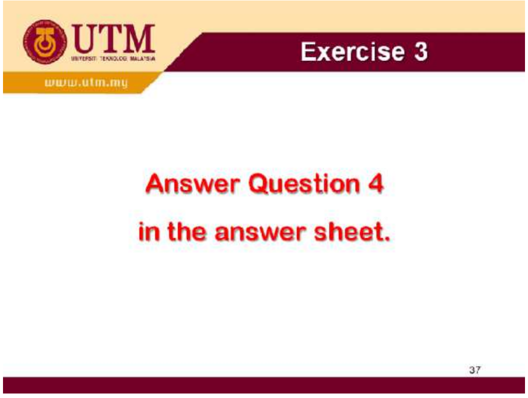
c. What devices can you use to make sure that the circuit really works?

How many methods that you have?



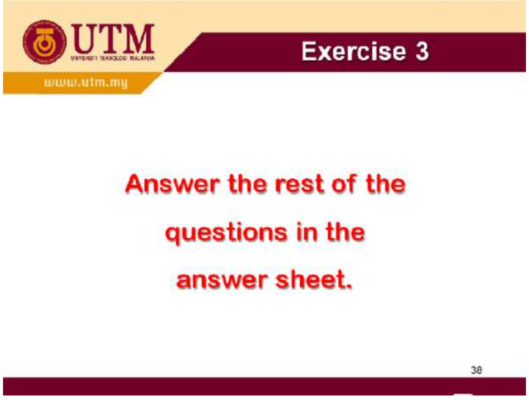
Exercise 3

d. Construct and simulate the circuit using ALL the devices that you have mentioned to get the result.



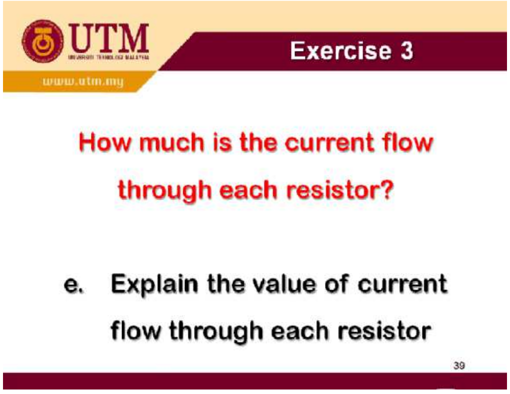
Exercise 3

Answer Question 4 in the answer sheet.



Exercise 3

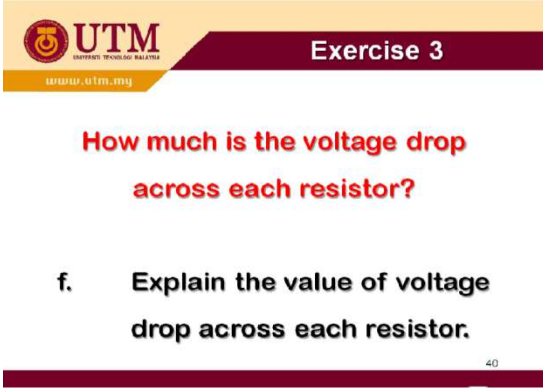
Answer the rest of the questions in the answer sheet.



Exercise 3

How much is the current flow through each resistor?

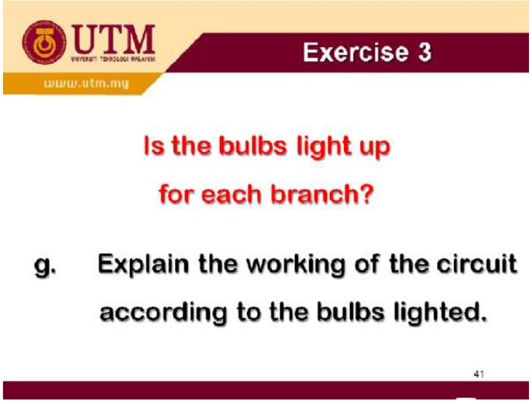
e. Explain the value of current flow through each resistor



Exercise 3

How much is the voltage drop across each resistor?

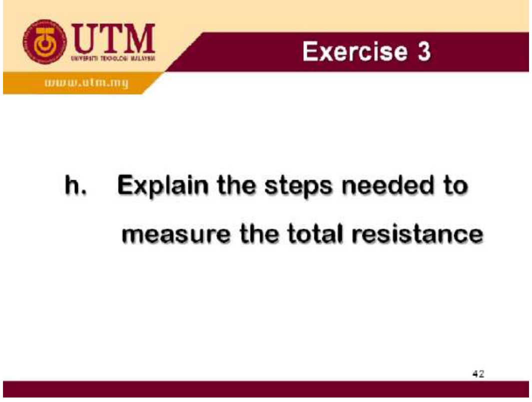
f. Explain the value of voltage drop across each resistor.



Exercise 3

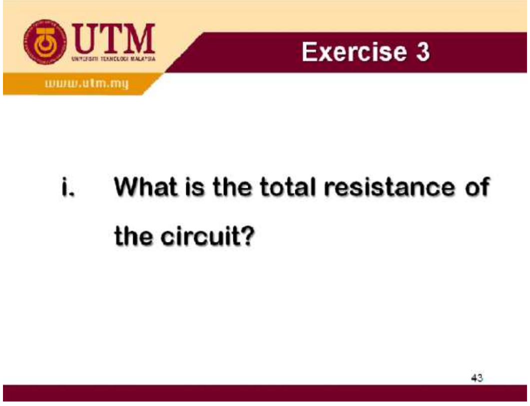
Is the bulbs light up
for each branch?

g. Explain the working of the circuit according to the bulbs lighted.



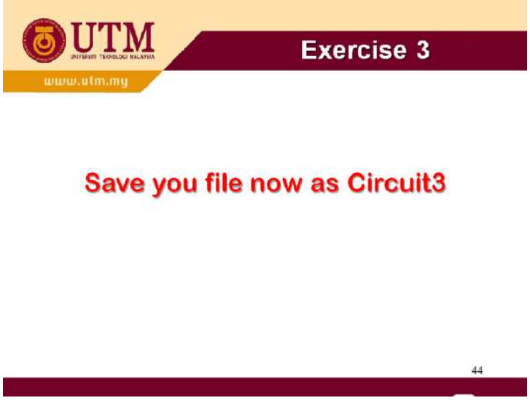
Exercise 3

h. Explain the steps needed to measure the total resistance



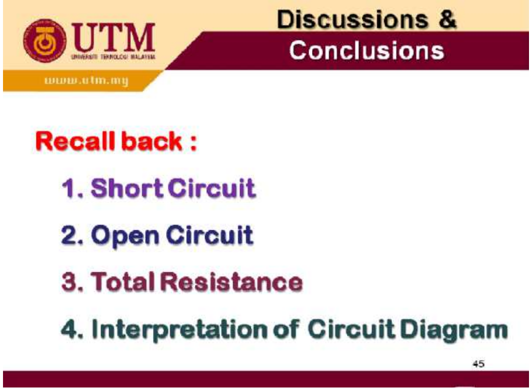
Exercise 3

i. What is the total resistance of the circuit?



Exercise 3

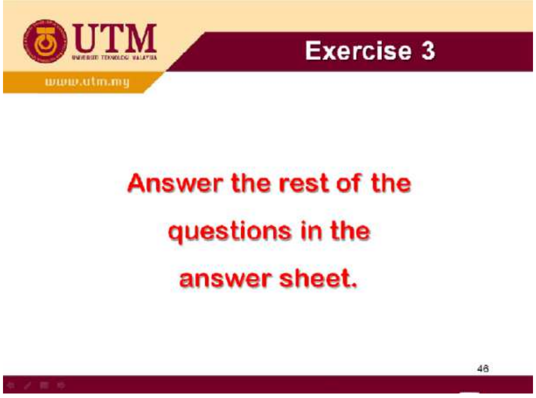
Save you file now as Circuit3



Discussions & Conclusions

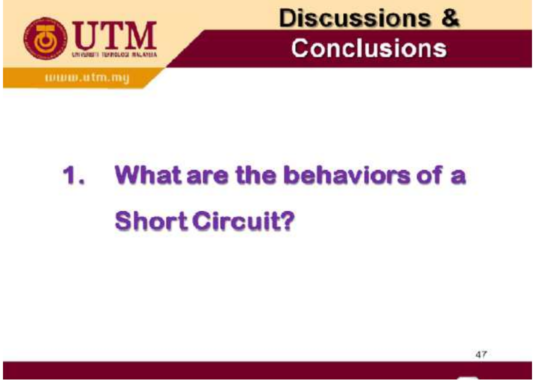
Recall back :

1. Short Circuit
2. Open Circuit
3. Total Resistance
4. Interpretation of Circuit Diagram



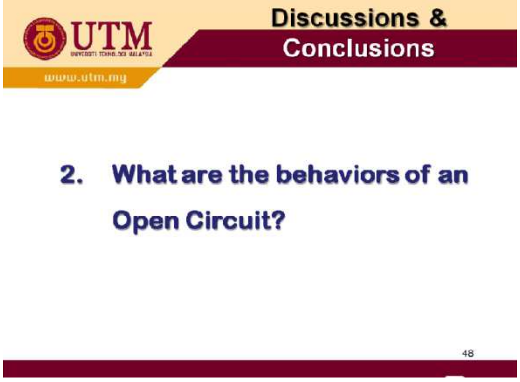
Exercise 3

Answer the rest of the
questions in the
answer sheet.



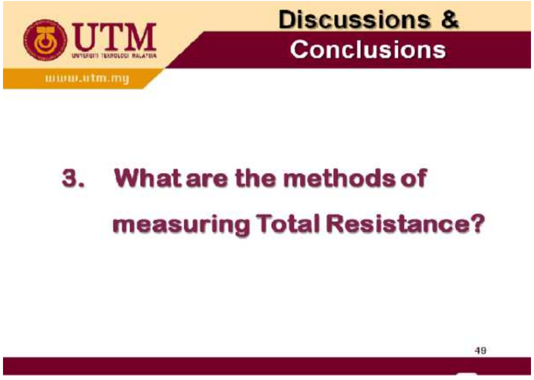
Discussions & Conclusions

1. What are the behaviors of a Short Circuit?



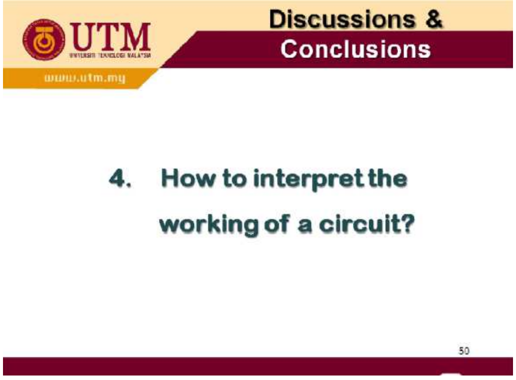
Discussions & Conclusions

2. What are the behaviors of an Open Circuit?



Discussions & Conclusions

3. What are the methods of measuring Total Resistance?



Discussions & Conclusions

4. How to interpret the working of a circuit?

Thank You

APPENDIX I: Answer Sheet

Tutorial Answer Sheet

Learning Basic Concepts of Electrical Circuits

Name : ______________________________

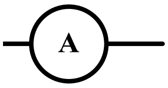
Mobile Number : ______________________________

Email Address : ______________________________

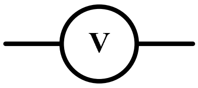
Instructions:

Answer each exercise as elaborately as you can.

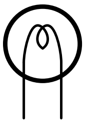
Below are the symbols used / to be used in this exercise:



Ammeter



Voltmeter

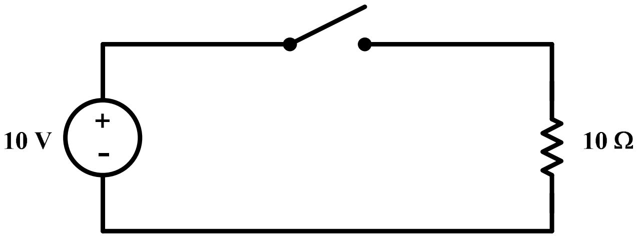


Light Bulb

Switch open

Switch closed

Exercise 1:



1. Can this circuit works?

2. Give reasons to your answer in 1.

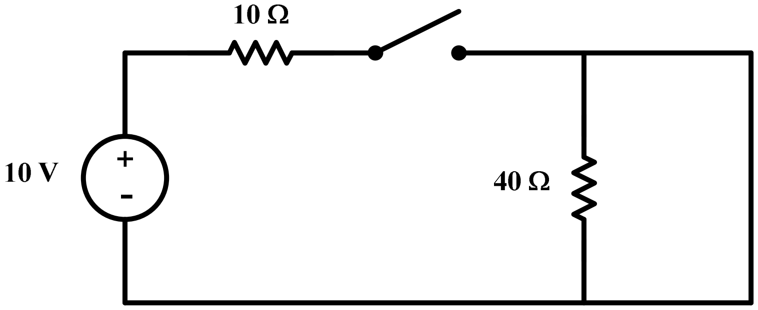
3. Now turn on the switch.

   What devices can you use to make sure that the circuit really works?

4. Draw all circuits containing the devices as mentioned in 3.

5. Explain the working of each circuit as drawn in 4.

Exercise 2:



1. Can this circuit works?

2. Give reasons to your answer in 1.

3. Now turn on the switch.

   What devices can you use to make sure that this circuit really works?

4. Draw all circuits containing the devices as mentioned in 3.

5. Explain the value of current flow through each resistor.

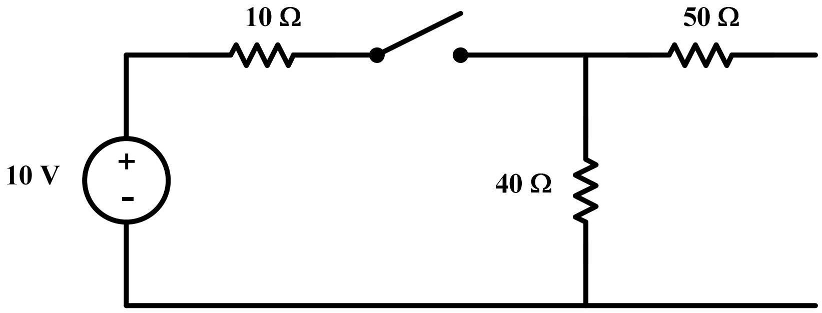
6. Explain the value of voltage drop across each resistor.

7. Explain the working of the circuit according to the bulbs lighted.

8. Explain the steps needed to measure the total resistance.

9. What is the total resistance of the circuit?

Exercise 3:



1. Can this circuit works?

2. Give reasons to your answer in 1.

3. Now turn on the switch.

   What devices can you use to make sure that this circuit really works?

4. Draw all circuits containing the devices as mentioned in 3.

5. Explain the value of current flow through each resistor.

6. Explain the value of voltage drop across each resistor.

7. Explain the working of the circuit according to the bulbs lighted

8. Explain the steps needed to measure the total resistance.

9. What is the total resistance of the circuit?

Discussions and Conclusions:

1. What are the behaviors of a short circuit?

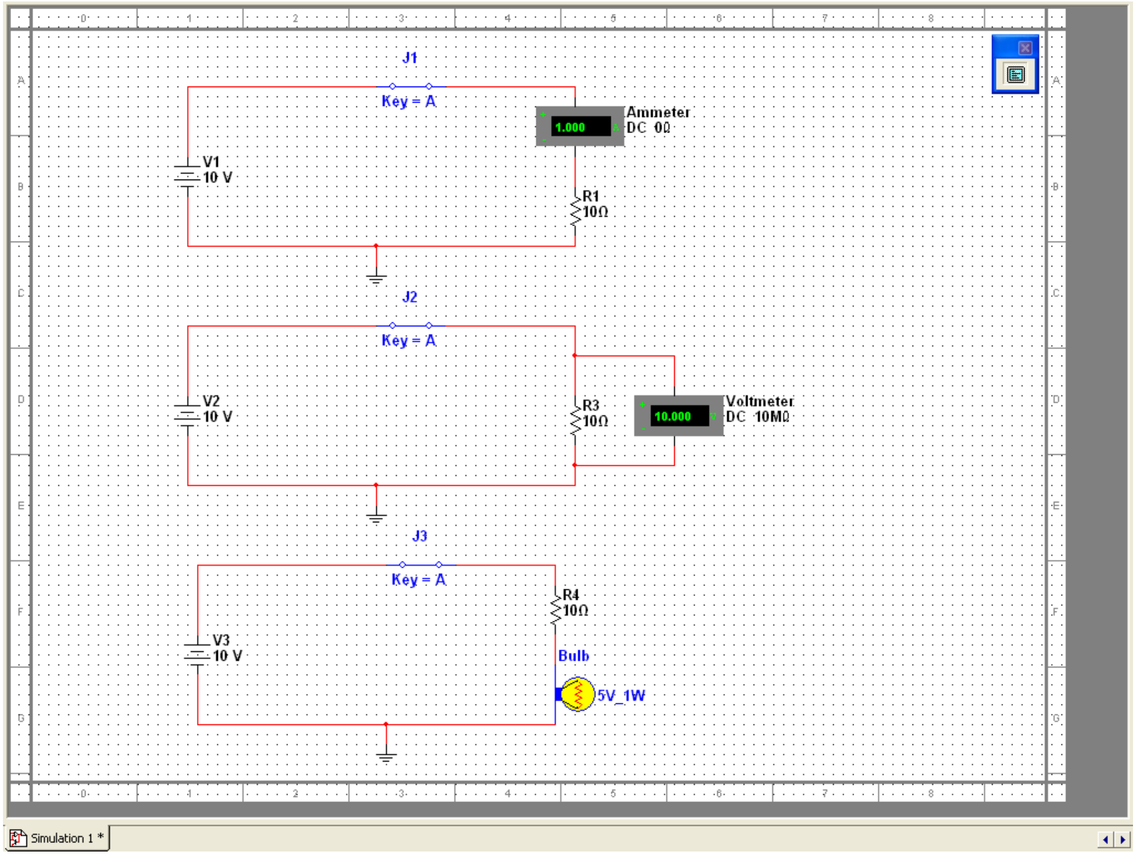
2. What are the behaviors of an open circuit?

3. What are the methods of measuring total resistance?

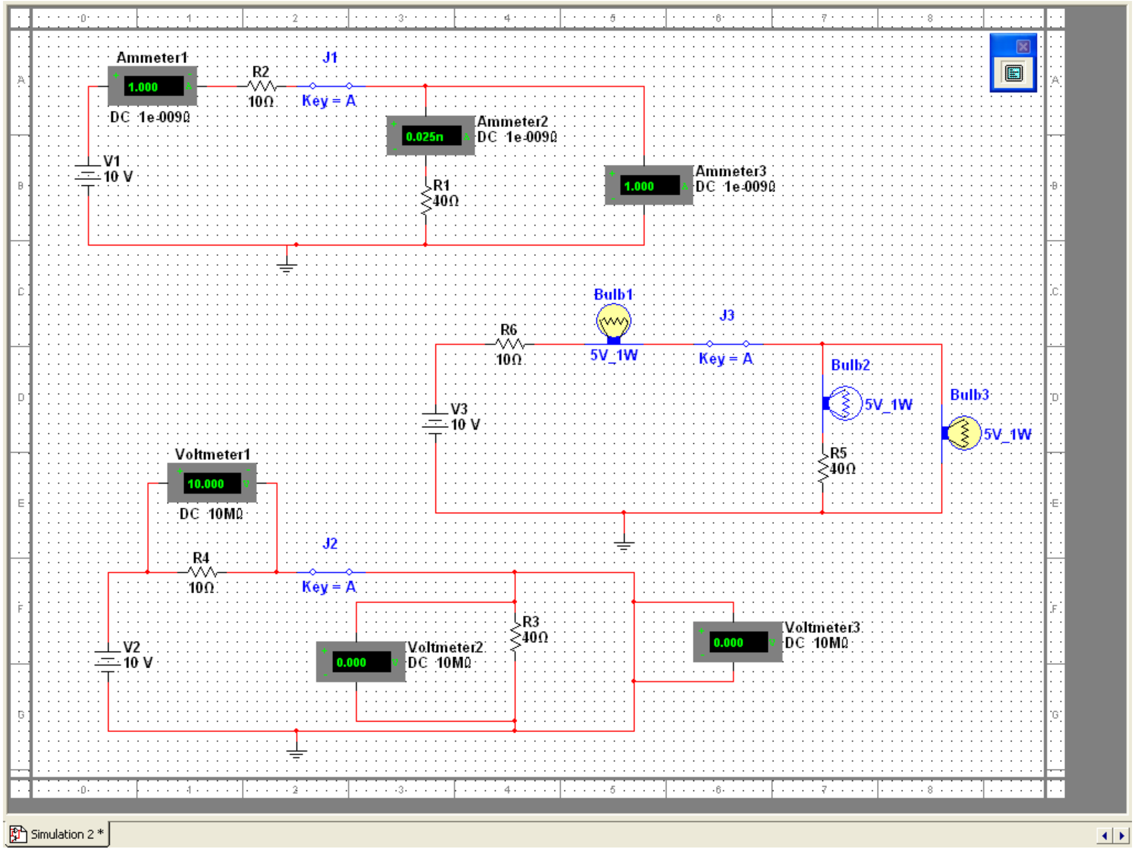
4. How to interpret the working of a circuit?

APPENDIX J: Multisim Simulated Outputs

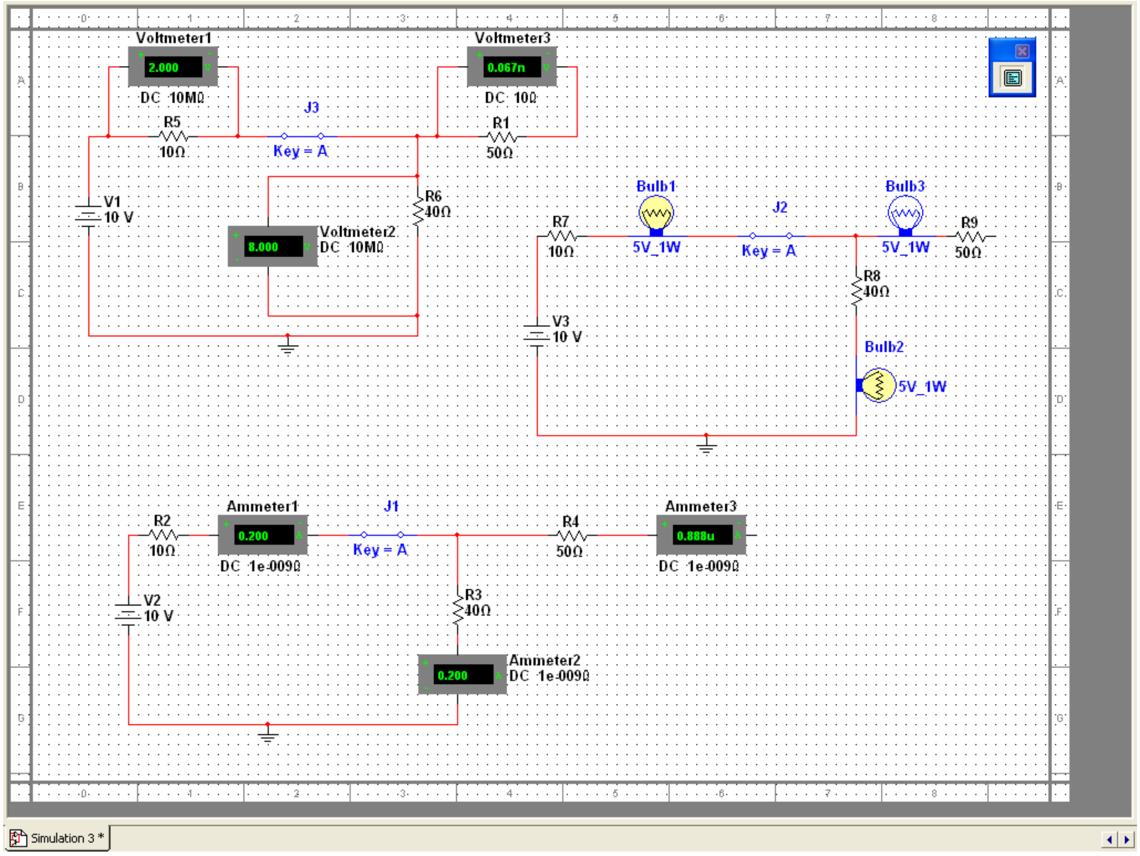
Exercise 1



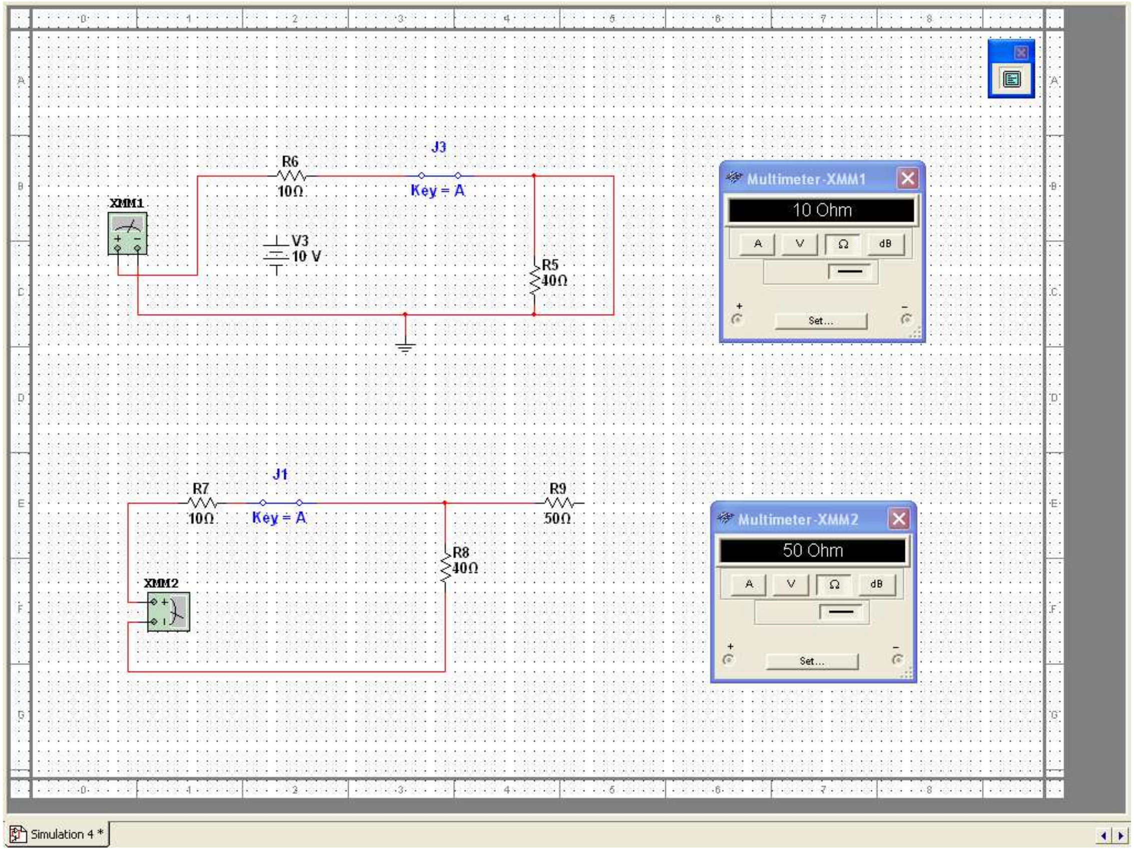
Exercise 2


Ammeter1
1.000
DC 1e-009Ω
R2
10Ω
J1
Key = A
Ammeter2
0.025n
DC 1e-009Ω
V1
10 V
R1
40Ω
Ammeter3
1.000
DC 1e-009Ω
Bulb1
5V_1W
R6
10Ω
J3
Key = A
Bulb2
5V_1W
Bulb3
5V_1W
V3
10 V
R5
40Ω
Voltmeter1
10.000
DC 10MΩ
R4
10Ω
J2
Key = A
V2
10 V
Voltmeter2
0.000
DC 10MΩ
R3
40Ω
Voltmeter3
0.000
DC 10MΩ
Simulation 2 *

Exercise 3


Voltmeter1
2.000
DC 10MΩ
R5
10Ω
J3
Key = A
Voltmeter3
0.067n
DC 10Ω
R1
50Ω
V1
10 V
R6
40Ω
Voltmeter2
8.000
DC 10MΩ
Bulb1
5V_1W
J2
Key = A
Bulb3
5V_1W
R7
10Ω
R9
50Ω
R8
40Ω
V3
10 V
Bulb2
5V_1W
Ammeter1
0.200
DC 1e-009Ω
J1
Key = A
R2
10Ω
R4
50Ω
Ammeter3
0.888u
DC 1e-009Ω
R3
40Ω
V2
10 V
Ammeter2
0.200
DC 1e-009Ω
Simulation 3 *

Resistances for Exercise 2 and 3



APPENDIX K: Explanatory Statement and Consent Form

EXPLANATORY STATEMENT

Learning Basic Concepts of Electric Circuit Using Tutorial Module

The objective of this study is to produce one tutorial module based on inquiry-based learning and using the simulation software with an aim for students to master difficult concepts in basic electric circuit.

CONSENT FORM

I agree to take part in the above Universiti Teknologi Malaysia research project. I have had the research explained to me, and I have read this Explanatory Statement. I understand that agreeing to take part means that: (*Please tick the appropriate box*)

- ☐ I am willing to participate in the researcher's activities.
- ☐ I allow the activities to be taped using voice recorder and video camera.
- ☐ I am willing to be interviewed by the researcher.
- ☐ I allow the interview to be voice recorded.
- ☐ I will make myself available for a further activities, if it is required.
- ☐ I also understand that my participation is voluntary, which means I can choose not to participate in part or all of the research and that I can withdraw at any stage of the research.

Name : ____

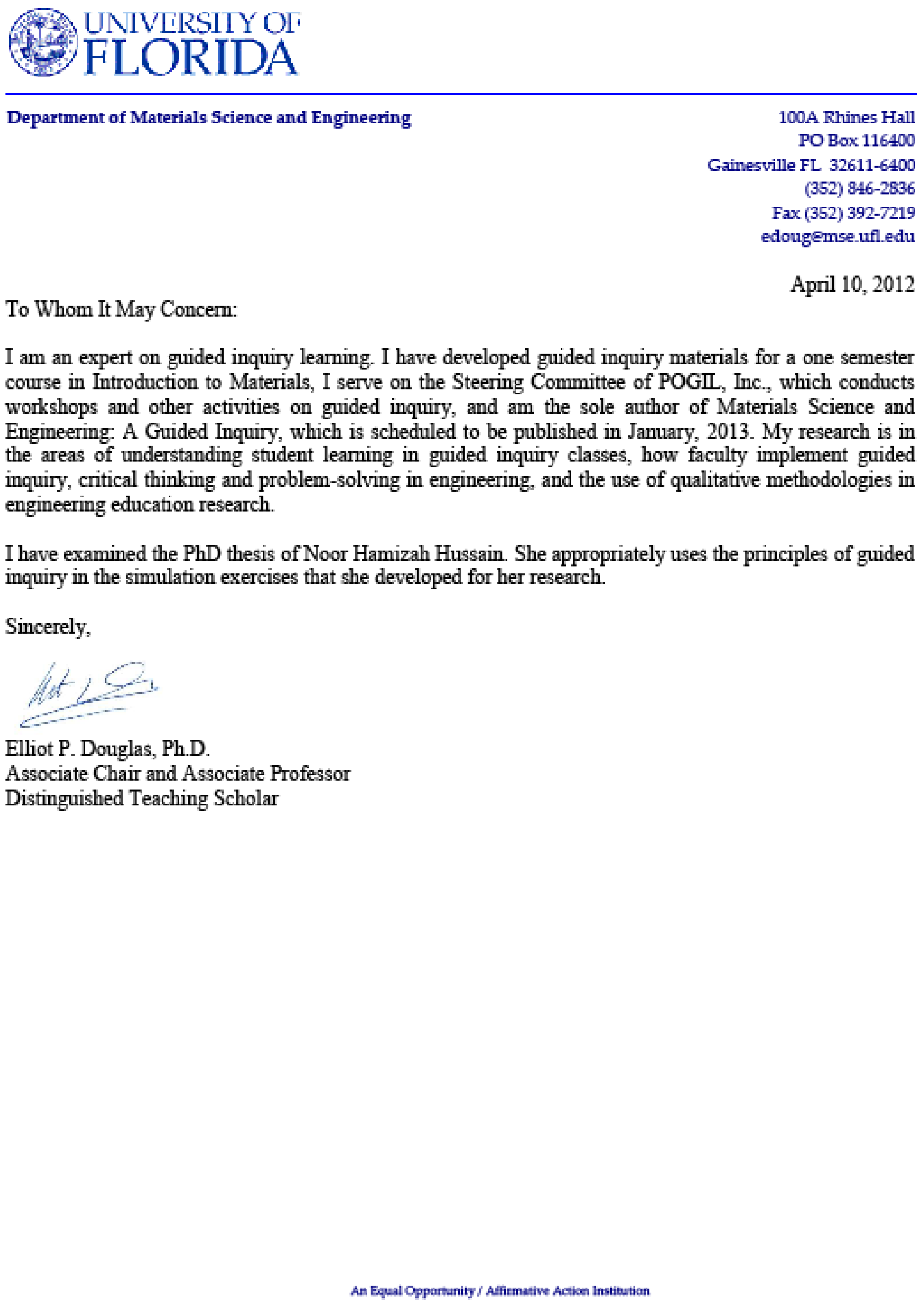
Email address : ____

Mobile number : ____

This consent form is a totally confidential document. It will be stored in UTM International Campus, Jalan Semarak, Kuala Lumpur and used for no other purposes except as part of UTM's internal requirements which are designed to protect the confidentiality and interests of the persons assisting with this research.

Name of researcher: **NOOR HAMIZAH HUSSAIN**

APPENDIX L: Content Validation by Expert



UNIVERSITY OF FLORIDA

Department of Materials Science and Engineering

100A Rhines Hall
PO Box 116400
Gainesville FL 32611-6400
(352) 846-2836
Fax (352) 392-7219
edoug@mse.ufl.edu

April 10, 2012

To Whom It May Concern:

I am an expert on guided inquiry learning. I have developed guided inquiry materials for a one semester course in Introduction to Materials, I serve on the Steering Committee of POGIL, Inc., which conducts workshops and other activities on guided inquiry, and am the sole author of Materials Science and Engineering: A Guided Inquiry, which is scheduled to be published in January, 2013. My research is in the areas of understanding student learning in guided inquiry classes, how faculty implement guided inquiry, critical thinking and problem-solving in engineering, and the use of qualitative methodologies in engineering education research.

I have examined the PhD thesis of Noor Hamizah Hussain. She appropriately uses the principles of guided inquiry in the simulation exercises that she developed for her research.

Sincerely,

Elliot P. Douglas, Ph.D.
Associate Chair and Associate Professor
Distinguished Teaching Scholar

Instrument Validation by Expert

Title of Research:

Overcoming Learning Difficulties about Short-Circuit and Open-Circuit : Technology-Supported Inquiry-Based Approach

---

I hereby acknowledge that the instrument adapted by Noor Hamizah Hussain from Universiti Teknologi Malaysia International campus has been checked. The outcome is as follows: (Please tick)

1.	The objective of the instrument is understood	[✓ Yes]	No	Need modification
2.	The instrument format is appropriate.	[✓ Yes]	No	Need modification
3.	The instructions are within the scope of the research questions.	[✓ Yes]	No	Need modification
4.	The instructions are relevant to the concepts that are difficult for students to grasp.	[✓ Yes]	No	Need modification
5.	The instructions are relevant to the content of basic electric circuit subjects.	[✓ Yes]	No	Need modification
6.	The instructions are direct and clear. Students can understand the instructions easily.	[✓ Yes]	No	Need modification
7.	The content of concept-test is relevant to the concepts asked.	[✓ Yes]	No	Need modification
8.	The inquiry-based teaching and learning has been implemented thoroughly.	[✓ Yes]	No	Need modification

Other comments related to the content and instructions:

The instrument provides a way to gauge the understanding of student in an important focus area of electric circuit study. I recommend it to be used on students at UNITEN to ~~see whether the~~ gauge the understanding of student.

Instrument Validation by Expert

I hereby acknowledge that the instruments designed and adapted by **Noor Hamizah Hussain** from Universiti Teknologi Malaysia International campus has been checked and ready for validation. Thank you.

Signature :

Full Name : Norashidah Md Din

Designation : Head of Dept.

Years of Experience in Teaching : 18 years

Name and Address of Employer : Universiti Tenaga Nasional
Jalan IKRAM - UNITEN, 43000 Kajang

Stamp of Employer : Assoc.Prof.Ir.Dr.Norashidah Md.Din
Head
Dept.of Electronics & Communication
College of Engineering
Universiti Tenaga Nasional

Instrument Validation by Expert

Title of Research:

Overcoming Learning Difficulties about Short-Circuit and Open-Circuit : Technology-Supported Inquiry-Based Approach

---

I hereby acknowledge that the instrument adapted by Noor Hamizah Hussain from Universiti Teknologi Malaysia International campus has been checked. The outcome is as follows: (Please tick)

1.	The objective of the instrument is understood	[✓ Yes]	No	Need modification
2.	The instrument format is appropriate.	[✓ Yes]	No	Need modification
3.	The instructions are within the scope of the research questions.	[✓ Yes]	No	Need modification
4.	The instructions are relevant to the concepts that are difficult for students to grasp.	[✓ Yes]	No	Need modification
5.	The instructions are relevant to the content of basic electric circuit subjects.	[✓ Yes]	No	Need modification
6.	The instructions are direct and clear. Students can understand the instructions easily.	[✓ Yes]	No	Need modification
7.	The content of concept-test is relevant to the concepts asked.	[✓ Yes]	No	Need modification
8.	The inquiry-based teaching and learning has been implemented thoroughly.	[✓ Yes]	No	Need modification

Other comments related to the content and instructions:

1. Title of research is suggested to be revised such as :
   "Overcoming Learning Difficulties About Basic Electrical Circuits : Technology . - - - - - -

2. One of the main focus of the work is to improve the students capability of interpreting basic electrical circuits

3. The questions on Concepts Test are highly appropriate to address the Research Questions

Instrument Validation by Expert

I hereby acknowledge that the instruments designed and adapted by **Noor Hamizah Hussain** from Universiti Teknologi Malaysia International campus has been checked and ready for validation. Thank you.

Signature :

Full Name : DR. YASMIN HANUM MD THAYOOB

Designation : SENIOR LECTURER

Years of Experience in Teaching : 19 YEARS

Name and Address of Employer :
COLLEGE OF ENGINEERING,
UNIVERSITI TENAGA NASIONAL,
JALAN IKRAM- UNITEN,
43009 KAJANG,
SELANGOR

Stamp of Employer :
Dr. Yasmin Hanum Md Thayoob
Senior Lecturer
Department of Electrical Power Engineering
College of Engineering
Universiti Tenaga Nasional

Instrument Validation by Expert

Title of Research:

Overcoming Learning Difficulties about Short-Circuit and Open-Circuit : Technology-Supported Inquiry-Based Approach

---

I hereby acknowledge that the instrument adapted by Noor Hamizah Hussain from Universiti Teknologi Malaysia International campus has been checked. The outcome is as follows: (Please tick)

1.	The objective of the instrument is understood	[✓ Yes]	No	Need modification
2.	The instrument format is appropriate.	[✓ Yes]	No	Need modification
3.	The instructions are within the scope of the research questions.	[✓ Yes]	No	Need modification
4.	The instructions are relevant to the concepts that are difficult for students to grasp.	[✓ Yes]	No	Need modification
5.	The instructions are relevant to the content of basic electric circuit subjects.	[✓ Yes]	No	Need modification
6.	The instructions are direct and clear. Students can understand the instructions easily.	[✓ Yes]	No	Need modification
7.	The content of concept-test is relevant to the concepts asked.	[✓ Yes]	No	Need modification
8.	The inquiry-based teaching and learning has been implemented thoroughly.	[✓ Yes]	No	Need modification

Other comments related to the content and instructions:

There is no comment of the content only a suggestion to put numbering in the figure. The research objectives and methodology of the work are very clear and graspable.

From the perspective of education expert on basic concepts of electrical circuit, I strongly believed that these instruments are suitable for diploma level. Moreover, I am very much supportive on the contents and instruction of the research to be done by Noor Hamizah Hussain.

Instrument Validation by Expert

I hereby acknowledge that the instruments designed and adapted by **Noor Hamizah Hussain** from Universiti Teknologi Malaysia International campus has been checked and ready for validation. Thank you.

Signature :

Full Name : ROSILAH HASSAN

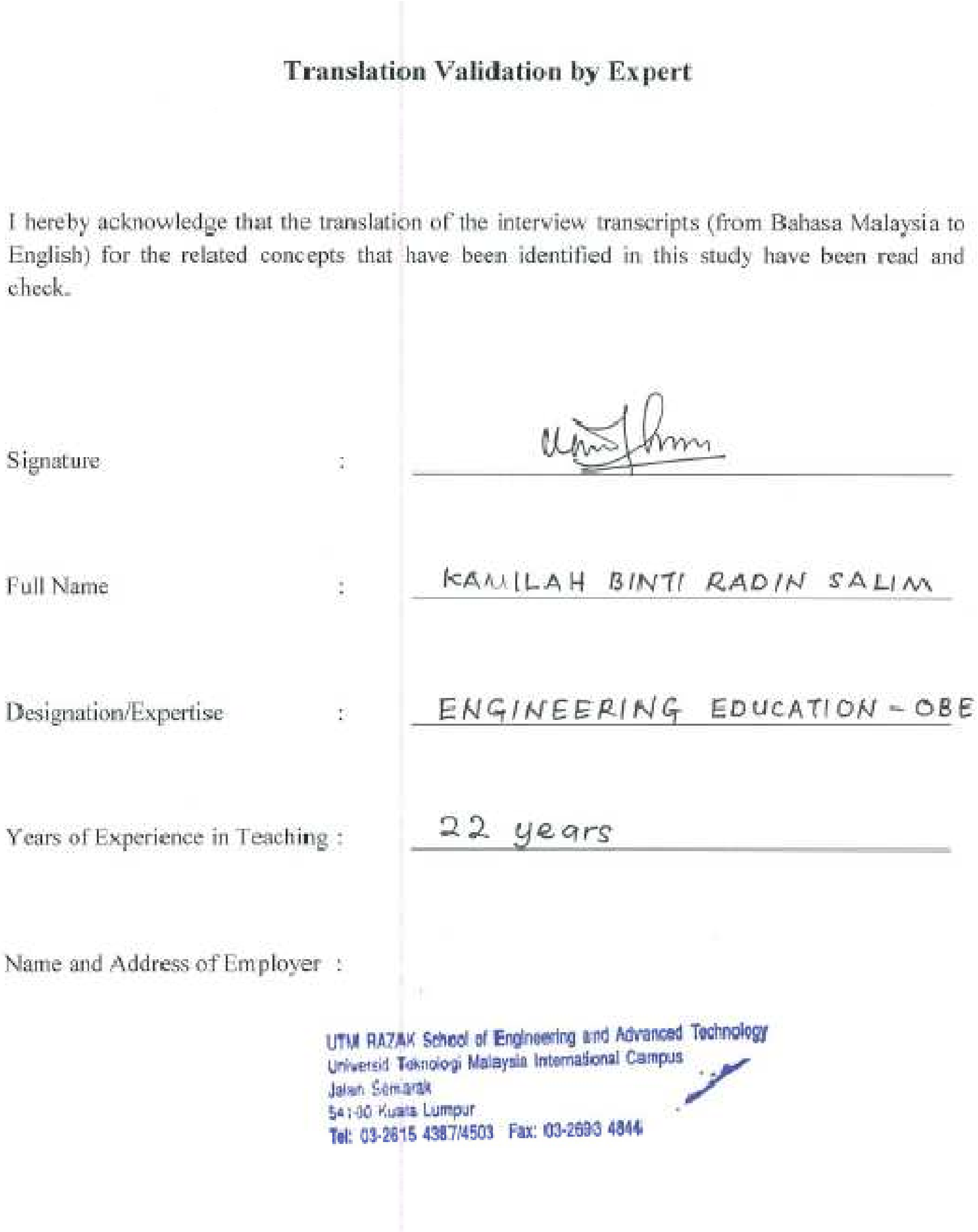
Designation : PENSYARAH UNIVERSITI DS54

Years of Experience in Teaching : 13 YEARS

Name and Address of Employer :
PUSAT PENGAJIAN SAINS KOMPUTER
FAKULTI TEKNOLOGI & SAINS MAKLUMAT
UNIVERSITI KEBANGSAAN MALAYSIA
43600 UKM BANGI
SELANGOR

Stamp of Employer :
PROF. MADYA DR. ROSILAH HASSAN
PUSAT PENGAJIAN SAINS KOMPUTER
Fakulti Teknologi dan Sains Maklumat
Universiti Kebangsaan Malaysia
43600 UKM Bangi
Selangor

APPENDIX M: Translation Validation by Expert



Translation Validation by Expert

I hereby acknowledge that the translation of the interview transcripts (from Bahasa Malaysia to English) for the related concepts that have been identified in this study have been read and check.

Signature :

Full Name : KAMILAH BINTI RADIN SALIM

Designation/Expertise : ENGINEERING EDUCATION – OBE

Years of Experience in Teaching : 22 years

Name and Address of Employer :

UTM RAZAK School of Engineering and Advanced Technology
Universiti Teknologi Malaysia International Campus
Jalan Semarak
54100 Kuala Lumpur
Tel: 03-2615 4387/4503 Fax: 03-2693 4844

Translation Validation by Expert

I hereby acknowledge that the translation of the interview transcripts (from Bahasa Malaysia to English) for the related concepts that have been identified in this study have been read and check.

Signature :

Full Name : ARBA'IAH INN

Designation/Expertise : ENGINEERING COMUNICATION.

Years of Experience in Teaching : 14 YEARS.

Name and Address of Employer :

ARBA'IAH BINTI INN
Head Department of Joint Programme
Centre for Diploma Studies *UTMSPACE*
UTM International Campus
Jalan Semarak
54100 Kuala Lumpur

APPENDIX N: Flow of Research Activities

FLOW OF RESEARCH ACTIVITIES

Pre-test session: To brief on the flow of activities, conduct Pre-Test and to solicit volunteers for the tutorial session.

Time : First week of semester

Venue : Classroom

1 Ice-breaking session
2 Assign volunteers to the tutorial session according to laboratory time slot
3 Conduct pre-test
4 Distribute souvenirs
5 Exit speech

Interview after pre-test: To gain information on the students cognitive level of concepts understanding

Time : After the pre-test and before the tutorial session

Venue : Instructors' room

1 Welcome wishes and built rappo
2 Have students sign the consent form
3 Conduct interview
4 Distribute souvenirs
5 Closing remarks

Tutorial session: To implement the simulation tutorial module with inquiry-based approach.

Time : During semester

Venue : Computer laboratory

1 Have the checklist ready.
2 Get the attendance of the students according to the assigned time slot
3 Guide students to their workstation.
4 Students fill up the consent form.
5 Instructor starts the tutorial
6 Students fill up the tutorial answer sheet
7 Students fill up the exit survey.
8 Distribute souvenirs

Post-test session To conduct Post-Test.

Time : Final week of the semester

Venue : Classroom

1 Welcome wishes and build rappo
2 Post-test
3 Give souvenirs
4 Exit wishes

Interview after post-test: To conduct interview to determine students' cognitive conflict and enhancement.

Time : After the post-test

Venue : Instructors' room

1 Welcome wishes and built rappo
2 Have students sign the consent form
3 Conduct interview
4 Distribute souvenirs
5 Closing remarks

APPENDIX O: Checklist during Intervention

Checklist during tutorial session

BEFORE STUDENTS ARRIVE

	Ensure computer laboratory is properly set up
	Turn on all computers
	Turn on all voice recorder and video camera
	Ready with name list of students assigned for the slot
	Ensure tutorial answer sheets are ready at the workstation
	Ensure consent form ready at the workstation
	Ensure souvenirs are ready on the registration table

AT THE BEGINNING OF TUTORIAL SESSION

	Welcome all participants
	Ensure participants are sitting at the allocated workstation
	Request participants to think-aloud
	Request participants to complete tutorial answer sheet
	Solicit for questions

AT THE END OF TUTORIAL SESSION

	Thank participants for their support
	Distribute souvenirs to participants
	Show their way out

AFTER STUDENTS LEAVE

	Save and turn off the voice recorder and video camera
	Turn off all computers
	Close and lock the computer laboratory

APPENDIX P: Assessing Reliability and Normality

Cronbach Alpha coefficient for Concept Test

Case Processing Summary

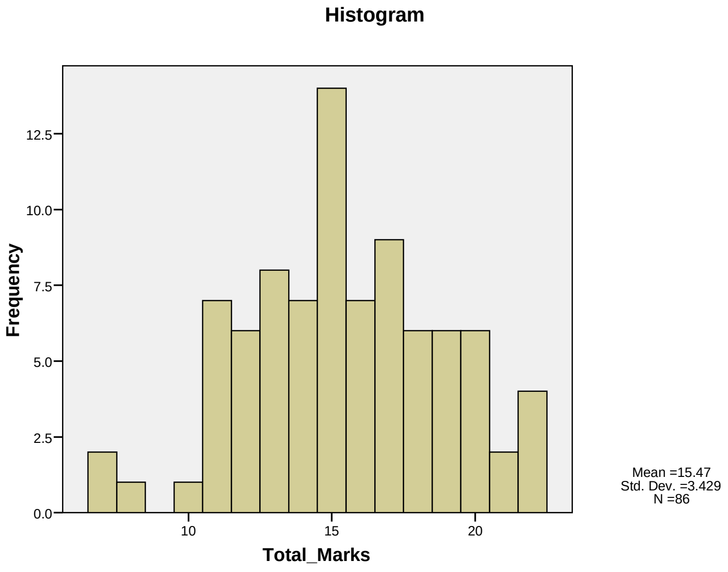
		N	%
Cases	Valid	86	100.0
	Excluded[a]	0	.0
	Total	86	100.0

a. Listwise deletion based on all variables in the procedure.

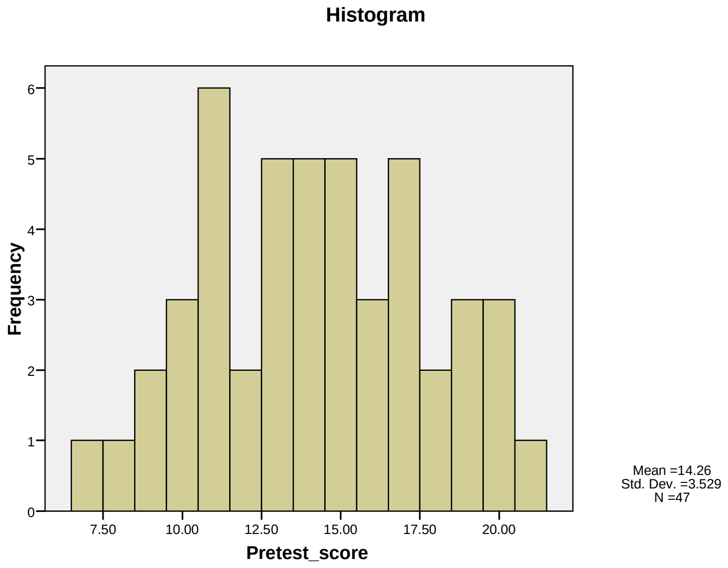
Reliability Statistics

Cronbach's Alpha	N of Items
.721	24

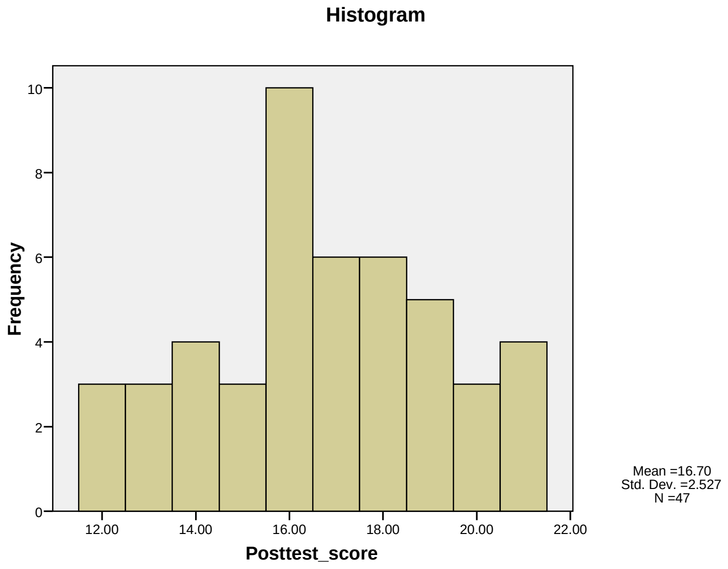
1. Pilot Test Normality



2. Pretest Normality



3. Posttest Normality



APPENDIX Q: Paired-Sample T-Test

1. Posttest and Pretest

Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	Posttest_score	16.7021	47	2.52737	.36865
	Pretest_score	14.2553	47	3.52918	.51478

Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	Posttest_score - Pretest_score	2.44681	3.05606	.44577	1.54952	3.34410	5.489	46	.000

2. Complete Circuits

Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	Post_Complete_circuit	8.4681	47	2.09400	.30544
	Pre_Complete_Circuit	7.1702	47	1.88032	.27427

Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	Post_Complete_circuit - Pre_Complete_Circuit	1.29787	2.97025	.43326	.42577	2.16997	2.996	46	.004

3. Open Circuits

Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	Post_Open_Circuit	3.6170	47	.87360	.12743
	Pre_Open_circuit	1.0851	47	.92853	.13544

Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	Post_Open_Circuit - Pre_Open_circuit	2.53191	1.31630	.19200	2.14543	2.91840	13.187	46	.000

4. Short Circuits

Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	Post_Short_circuit	2.8723	47	1.45389	.21207
	Pre_Short_Circuit	2.4681	47	1.03946	.15162

Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	Post_Short_circuit - Pre_Short_Circuit	.40426	1.72777	.25202	-.10304	.91155	1.604	46	.116

5. Resistance

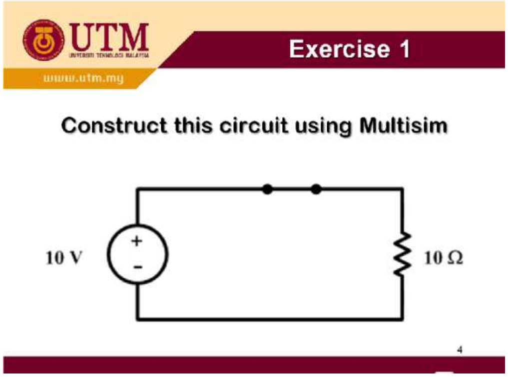
Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	Post_Resistance	3.2553	47	.82008	.11962
	Pre_Resistance	1.8936	47	1.14653	.16724

Paired Samples Test

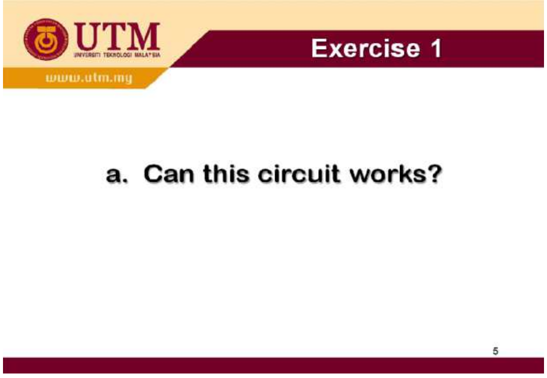
		Paired Differences					t	df	Sig. (2-tailed)
					95% Confidence Interval of the Difference				
		Mean	Std. Deviation	Std. Error Mean	Lower	Upper			
Pair 1	Post_Resistance - Pre_Resistance	1.36170	1.16890	.17050	1.01850	1.70490	7.986	46	.000

APPENDIX R: Deleted Question



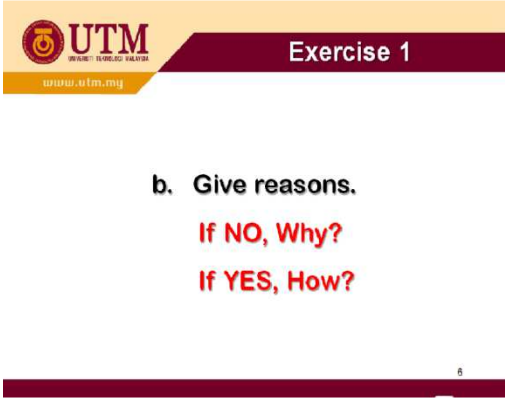
Exercise 1

Construct this circuit using Multisim



Exercise 1

a. Can this circuit works?

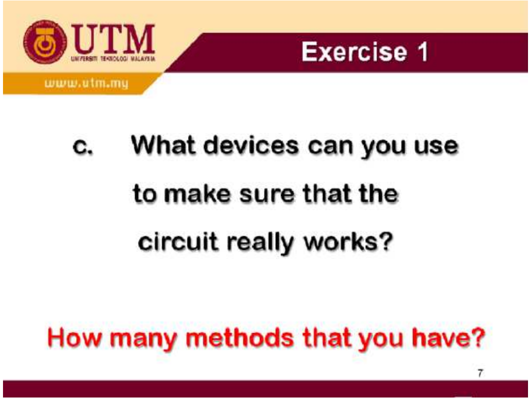


Exercise 1

b. Give reasons.

If NO, Why?

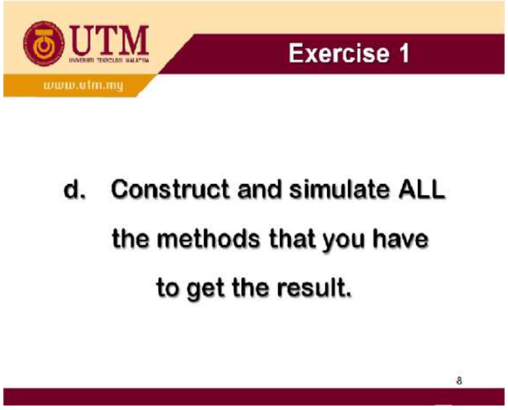
If YES, How?



Exercise 1

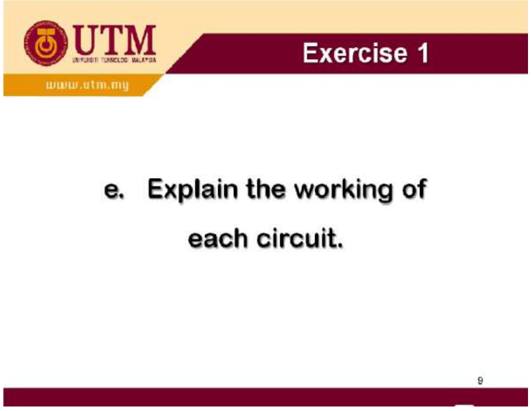
c. What devices can you use to make sure that the circuit really works?

How many methods that you have?



Exercise 1

d. Construct and simulate ALL the methods that you have to get the result.



Exercise 1

e. Explain the working of each circuit.

APPENDIX S

Published Papers

1. Sakdiah Basiron, Rosmah Ali, Kamilah Radin Salim, **Noor Hamizah Hussain** and Habibah @ Norehan Haron (2008), "History, Philosophy and Trends in Engineering Education (EE): The Malaysian Context". *International Conference on Engineering Education: New Challenges in Engineering Education and Research in the 21st Century*, July 27-31, Pécs-Budapest, HUNGARY.

2. Normah Mulop, Morina Abdullah, Dinar Nurdin, **Noor Hamizah Hussain** and Noraini Rajab (2008). "Enhancement First-Year Engineering Curriculum". *7th ASEE Global Colloquium on Engineering Education*, October 19-23, Cape Town, SOUTH AFRICA.

3. Noraini Rajab, Kamsiah Mohd Ismail, Norhayati Mohamed Nor and **Noor Hamizah Hussain** (2009), "How Students Learn Engineering". *International Conference on Engineering and Education in the 21st Century*, March 23-25, Kuching, Sarawak, MALAYSIA.

4. **Noor Hamizah Hussain**, Liza Abdul Latiff and Nazli Yahaya (2009). "Learning Difficulties among Electrical Engineering Students". *The International Journal of Science in Society*, Volume 1, Issue 4, Champaign, Illinois, USA. By Common Ground Publishing LLC.

5. **Noor Hamizah Hussain**, Liza Abdul Latiff and Nazli Yahaya (2012). "Alternative Conception about Open and Short Circuits Concepts". *Regional Conference on Engineering Education & Research in Higher Education 2012 (RCEERHEd2012)*, April 10-12, Seremban, Negeri Sembilan, MALAYSIA. By Elsevier Ltd.