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The Effect Of Different Written Task Instructions On Students' Scores In A Physical And Virtual Environment

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THE EFFECT OF DIFFERENT WRITTEN TASK INSTRUCTIONS ON STUDENTS' SCORES IN A PHYSICAL AND VIRTUAL ENVIRONMENT

by

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This thesis, submitted by Ademola Abdul-Rahman Amida in partial fulfillment of the requirements for the Degree of Master of Science from the University of North Dakota, has been read by the Faculty Advisory Committee under whom the work has been done and is hereby approved.

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ABSTRACT

Electronic laboratory activities offer opportunities to help students learn about concepts and develop practical competencies in electronic circuit systems. Evidence in the literature suggests that the effectiveness of laboratory activities might be affected by the type of instructions provided (explicit or implicit), and the lab environment (physical or virtual) in which the activities were performed.

This study investigated the effect of different written task instructions (explicit versus implicit) and lab environment (physical versus virtual) on students' scores in an electronic circuit task. This study was a quantitative experiment that used a repeated measure factorial design to determine how the written instructions used in different environments affected students' scores.

Study results showed that there was no statistical significant difference in scores when students were presented with implicitly or explicitly written instructions. Similarly, results indicated no significant difference in scores when students used either physical or virtual environments. However, the computed effect size revealed that virtual environments might have a slightly higher effect on students' scores. These results suggest that the type of written instructions presented and the lab environment used may not have significantly affected students' scores.

CHAPTER I

INTRODUCTION

Overview

Teaching and learning in engineering and technology involve both theoretical concepts and practical applications in order to fully develop students' learning experiences (Welch, 2007). Teaching and learning some of these theoretical concepts such as electronic circuit concepts, are said to be pedagogically challenging (Reiner, Slotta, Chi, & Resnick, 2000). This is because electronic concepts, like voltage, resistance, and current are abstract in nature, and students may find it difficult to understand these concepts (Jaakkola, Nurmi, & Veermans, 2011). Hence, the challenge for instructors is to figure out how best to present the materials and assess the effectiveness of these instructions in aiding students' understanding.

While a content knowledge component is important, applying this knowledge in tangible ways may require the completion of a laboratory exercise. Laboratory activities have long been considered an important element in engineering and technology education. Singer, Nielsen and Schweingruber (2012) stated that students can develop vital competencies with engineering and technological practices during laboratory activities. Additionally, not only do laboratory activities help students develop their abilities to conduct experiments, analyze data, and interpret data, but also laboratory

activities help students to develop their abilities to use modern engineering tools (Nickerson, Corter, Esche, & Chassapis, 2007). Furthermore, Cochrane, Eversole and Graham (2010) claimed that a well-designed laboratory exercise can improve student retention and employability. Due to the aforementioned, it is evident that laboratories are essential in engineering and technology education.

To an extent, laboratory environments have been presented mostly with physical equipment and guided instructions (mostly teacher-centered). However, this is changing with the introduction of technology into the laboratory. Generally, the format of delivery of laboratory instructions can be either physical or computer-mediated labs (Corter, Esche, Chassapis, Ma, & Nickerson, 2011). Computer-mediated labs may include virtual (simulations) or remote laboratories. However, this paper only examined a virtual form of a computer-mediated lab.

Instructional formats (such as implicit and explicit) are the techniques used by faculty to achieve desired learning objectives (Richa, 2014). Written lab instructions are a form of instructional format used in presenting information or guidelines to students in a lab. There are two main types of written instructions: explicit instruction and implicit instruction. Explicit instructions are highly instructor-directed, and involve a step-by-step guide through the task to be performed. Whereas implicit instructions are instructions with less instructor guidance and are more student-oriented (Richa, 2014). Numerous researchers (e.g., Kollöffel & Jong, 2013; Veermans, de Jong, & Joolingen, 2006) have examined how different instructions affect student learning in the classroom. However, existing research on this topic still appears to be inconclusive about how different

instructions (implicit versus explicit) affects students in understanding series-parallel circuits.

In summary, it is not only important to decide on the content of laboratory activities, but also on how the type of written instructions and lab environments affect students' scores. This study will investigate the effect of different written task instructions (implicit versus explicit) and lab environment (physical versus virtual) on students' scores in an electronic circuit task.

Research Problem

Laboratory activities are important in fostering theoretical concept understanding and developing students' practical competence in engineering and technology education. Evidence from previous studies suggests that the effectiveness of laboratory activities may be affected by the type of written task instructions (Klahr & Nigam, 2004; Mayer, 2004), and the lab environment in which the activity was performed (Jaakkola et al., 2011; Ma & Nickerson, 2006). However, as important as laboratory activities are in education, limited research has been conducted to determine the effect of both written task instructions and lab environment on students' learning in the laboratory (Feisel & Rosa, 2005; Rashid, Tasadduq, Zia, Al-Turkistany, & Rashid, 2012). Additionally, Brinston (2015) argued that the results of research on the effect of written task instructions and lab environment might differ from one discipline to another. Therefore, there is a need to investigate the effects of written instructions and lab environments in an electronic circuit course.

There is growing criticism of the effectiveness of explicitly written task instructions (presented mainly in conventional lab manuals) in students' learning theoretical concepts (Hofstein & Lunetta, 1982). Domin (1999) argued that this criticism may be due to the fact that students performing explicitly written instructions may not pay attention to the interpretation of their lab results, thereby not drawing necessary inferences (conclusions) from their tasks that could aid their conceptual understanding. Thus, there are growing calls to investigate the effect of other forms of written instructions (such as implicit) in the lab (Herrington & Nakhlek, 2003; Singer et al., 2012).

Virtual environments (simulations) are increasingly being used in education in place of or to complement physical environment. However, there have been different debates on the effectiveness of virtual environments in education (Ma & Nickerson, 2006) and many questions still remain as to whether virtual environments should or can replace physical environments (Harder, 2010; Kelly, Bradley, & Gratch, 2008). Therefore, there is a need for controlled studies to compare the effect of virtual environments with physical environments in education (Clark, Nelson, Sengupta, & D'Angelo, 2009; Ma & Nickerson, 2006).

Research Purpose

The purpose of this study was to investigate the effect of different written task instructions (implicit versus explicit) and lab environment (physical versus virtual) on students' scores in completing electronic circuit tasks. Specifically, the study looked at

how using written task instructions in different lab environments affected students' scores in performing a series-parallel circuit exercise.

Research Questions

The following research questions were investigated in this study.

1. How do the written task instructions provided to students significantly affect their scores on the assigned activities?
2. How do the lab environments used by students significantly affect their scores on the assigned activities?
3. What significant interaction (if any) exists between written task instruction and the lab environment used by students to complete the activities?

Justification and Contribution

It is the responsibility of educators to provide the most appropriate kind of training and education to students. However, as indicated above, there are still ongoing debates among researchers about which written task instruction and lab environment should be used to best provide students with an effective laboratory experience. Therefore, the present study should assist instructors and curriculum developers in determining the most appropriate form of written task instructions and lab environments needed to better help students develop an understanding of electronic circuit concepts.

Moreover, Farrokhnia and Esmailpour (2010) maintain that there is no framework that describes the most appropriate methods for implementing physical and virtual lab environments to achieve desired goals. Thus, this study intends to provide preliminary data that could help in developing a framework in the future for types of written

instructions and lab environments that would provide students with a "best" learning experience.

The contributions of this study therefore, could be summarized as follows:

- It will contribute to the discussion about how best to present laboratory instructions to students to improve students' understanding in an electronic circuit course.
- It will help stakeholders in higher education to make important decisions about whether they wish to implement a different type of laboratory approach in an attempt to reduce laboratory equipment cost while ensuring a great laboratory experience for students.

Limitations

One of the limitations of this study is the small sample size. In order to make up for the small sample size, a repeated-measure factorial was used in the experimental design of the study (Creswell, 2002). Another limitation is the fact that the simulator software (Multisim) that was used may not represent all other forms of virtual environments. Additionally, the study was conducted with industrial technology students; therefore, the findings may be different in other fields of study.

Delimitation

Participants in this study were primarily sophomore industrial technology students that were mostly taking electronics classes for the first time.

Definition of Terms

Computer Mediated Lab: These are labs facilitated via a computer. They allow easy accessibility to lab resources.

Environment: This means the type of lab environment or setup where laboratory experimentation can be conducted. Two examples would be a physical and a virtual environment.

Explicit Instructions: These are instructions that are highly instructor directed, and are structured to provide step-by-step guidance throughout the instruction. The instructor presents students with specific meanings and understandings of the instruction.

Implicit Instructions: These are discovery kind of instructions with less instructor guidance, and are more student-centered. Students are allowed to explore and develop their own meaning and understanding of the instruction.

Instructions: These are guidelines or directions on how a task can be performed or on how an item should be used.

Instructional Formats: These are the methods used by instructors to support learning in a classroom or laboratory.

Laboratory: This is a place or an environment where practical works, scientific experiments, and investigations can be conducted.

Laboratory Activity: A lab activity involves purposeful actions performed by learners in a laboratory setting in order to achieve the desired course goals. Laboratory activities are more general in nature when compared with lab exercises.

Laboratory Exercises: These are guided or unguided laboratory actions or practices that are intended to achieve specific lab objectives.

Laboratory Tasks: These are the things learners do or perform in the laboratory, using their existing abilities. A completed laboratory task should have an outcome or result.

Physical Environment: This term is synonymous with a hands-on laboratory. This is a kind of laboratory where tangible or touchable equipment are used to conduct experiments. It requires a physical space and the use of real equipment.

Virtual Environment: This term is synonymous with the word simulation. This is a kind of virtual laboratory where computer software is used to mimic a real system or operation of a device.

CHAPTER II

LITERATURE REVIEW

The purpose of this study was to investigate the effect of different written task instructions (explicit versus implicit) and lab environment (physical versus virtual) on students' scores in completing an electronic circuit task. Specifically, the study looked at how using written task instructions in different lab environment affected students' scores in performing a series-parallel circuit exercise. Students' scores were evaluated by assessing their understanding of series-parallel circuit using two different written task instructions and lab environments in completing an electronic circuit task. Students' understanding of series-parallel circuit was measured as determined by students' individual scores and time taken to complete task. Table 2.1 outlines the different areas that this chapter focuses on.

Table 2.1 Chapter 2 Outline

1. The Evolution of Engineering and Technology Education
2. The Role of Laboratory Experience in Education
3. Laboratory Environment
4. Written Instruction
5. Previous Related Studies.
6. What is missing?
7. Study's Conceptual Framework
8. Chapter Summary

Engineering and Technology Education

Engineering education teaches application of scientific and practical knowledge and principles related to engineering practices (Tan, 2014). Historically, engineering education has been taught through apprenticeship (Seely, 2005). Hence, engineering knowledge was gained only in workshops and construction sites (Tryggvason & Apelian, 2006). However, teaching and learning in engineering shifted from workshops to classrooms at the end of the nineteenth century (Reynolds, 1992). Researchers believed that there were many reasons that necessitated the shift, but one main factor appeared to be the need for engineers to become more grounded in basic science (Seely, 2005). For instance, electrical engineers needed more knowledge of mathematics to design or improve existing devices. Therefore, engineering education should not only teach theoretical principles, but also practical applications (Goodhew, 2010).

Wright et al. (1993) defined technology education as an educational program that assists individuals in developing an understanding and proficiency in designing and using technology products. McCormick (1996) argued that technology education was mainly seen as a form of activity than a content knowledge. It has mainly been centered on doing and making things (Williams, 2000). This implies that technology education involves practical knowledge content. In other words, engineering and technology education involve the teaching of practical applications. Thus, engineering and technology education go beyond classroom learning, it also requires the teaching and learning of how to apply content knowledge in some tangible ways. This may require exposing students to laboratory activities.

The Role of Laboratory Activity in Education

Hofstein and Lunetta (1982) presented a brief history about the role of laboratory experience in science in their work, and identified a series of events in the history of laboratory experience as described below:

- In the 19th century, laboratory works were used to create concrete experience for students about concepts and are seen as an important part of science schools.
- In 1910, laboratory works began to adopt more investigative approach.
- At the end of the First World War, laboratory works were largely used to demonstrate and confirm facts in school laboratories.
- With the introduction of the new curriculum by the 1960s, laboratory works began to lay more emphasis on developing cognitive skills, which involved the process of inquiry and investigation.

It is clear from this brief history that the role of laboratory has evolved over time. It has developed from creating concrete experience to developing cognitive skills in learners.

According to Schweingruber, Hilton, and Singer (2005), the U.S. National Research Council described the role of laboratory as follows: enhancing mastery of subject matter; developing scientific reasoning skills; understanding the complexity of empirical work; developing practical skills; understanding the nature of science, cultivating interest in science; and developing teamwork abilities. Despite the proposition made by The National Research Council regarding the roles of laboratory, Singer et al. (2012) argued that the role of laboratory session is not very clear. Thus, they

recommended that researchers and educators should identify important laboratory outcomes and how those outcomes can be achieved. Laboratory instructions should then be developed to target the identified outcomes.

Laboratory Environment

The physical lab is probably the most common form of lab used in education. However, this may be changing with the increase use of computer technologies in the lab. These changes could be attributed to the increasing number of student enrolment in institutions, economic issues, and limited resources like time and space (Balakrishnan & wood, 2013; Nickerson et al. 2007). Corter et al. (2011) stated that laboratory activities can be conducted in physical or computer-mediated labs. An example of computer-mediated lab is the virtual environment. This literature review will focus on the physical and virtual lab environment (simulation).

Physical Environment

Physical lab environment involves the use of physical resources, and apparatus for real experimentation by physically present students in a lab setting (Ma & Nickerson, 2006). Advocates of the physical labs are of the opinion that engineers and technologists may learn better interacting with actual equipment, which generates real data in real-time (Elawady & Tolba, 2009; Nickerson et al., 2007). For instance, physical lab allows the direct contact with actual equipment providing the opportunity to experience equipment malfunction or other real-world, uncontrolled variables (Nickerson et al., 2007). Conversely, physical lab equipment may be expensive to implement, consumes a lot of space and time, and could sometimes pose safety concerns (Ma & Nickerson, 2006).

Additionally, physical labs are not easily maneuvered when operated; therefore, they are restrictive since experiments cannot be easily repeated or re-run (Nickerson et al., 2007).

As for electronic circuit building, Kollöffel and Jong (2013) argued that during lab exercises, students can develop skills about how to use actual electronic lab equipment. These exercises also allow students to learn how to deal with unexpected occurrence when working with real circuits and equipment (Finkelstein et al., 2005). However, during experimentation with physical lab, students mostly do not relate their lab exercises with theoretical concepts learnt in classroom (Kollöffel & Jong, 2013); thus, this presents an interesting challenge to instructors. Therefore, instructors may need to change labs (as appropriate) to help student relate concepts to practice.

Virtual Environment (Simulated lab)

Virtual lab environments are simulated labs (simulators) where computer software are used to mimic or imitate a real system (Elawady & Tolba, 2009; Shyr, 2010). Examples of hardware simulators are the mannequins used in the nursing school and flight simulators. Examples of virtual environments include multisim (electronic circuit simulator) and RSLogix (a Programmable Logic Controller simulator).

Simulations were first used in the military. One of the earliest examples was in the sixth century, which involves the simulation of chess as a war game (Rosen, 2008). Other early usage of simulation includes the use of jousting for training knights off the battlefield, and the Kriegspeil (invented in 18th century) warfare simulation (Bradley, 2006). In 1929, Edwin Link invented the blue box, which was the first flight simulator trainer (Rosen, 2008). The flight simulator was invented mainly because of safety and

cost concerns during flight training and the blue box flight trainer was used extensively by the military (Rosen, 2008). Today, simulators are increasingly being introduced into education largely because of their unique educational value (Olympiou & Zacharia, 2012). An example of educational value offered by simulation may include allowing students to visualize concepts such as current flow.

Advocates of simulators believe that it may be less expensive (Ma, & Nickerson, 2006), and is effective in teaching conceptual understanding (Balakrishnan & wood, 2013). Simulators also provide a unique function to users allowing pause and play operation of working world scenario, which enables the student to stop and observe (in order to draw inference) the simulated process (Parush, Hamm & Shitab, 2002, Tiwari, Nafees & Krishnan, 2014). Intelligent simulators (such as intelligent tutoring systems) can be used to offer personalized learning experience for students that may not be possible in the classroom environment (Bell & Kozlowski, 2007). In addition, simulators enable students to learn both in classrooms and at home to develop fundamental skills essential for their professional career (Shyr, 2010). Furthermore, physical phenomenon (such as electromagnetic field and electron flow) that are not readily visible to students can be illustrated using simulation to enable a better understanding (Kadlowec et al., 2002). However, for a simulator to be considered effective, it has to be designed such that it adequately imitates the characteristics of the real system in order to enrich the experience of the user (Russell, Lucas, & McRobbie, 2004). Some critics of simulated labs believe that simulations do not generate real data, no interaction with actual equipment and no real operational challenges (such as equipment malfunction difficulty);

therefore, students may not learn how to handle real world equipment (Balakrishnan & wood, 2013; Sauter, Uttal, Rapp, Downing & Jona, 2013). It is possible that critics of simulation did not consider that it is a safer environment for students to experiment and learn through multiple practices. Thus, simulation cannot be considered useless as a pedagogical tool.

In the case of electronic circuit, Kollöffel and Jong (2013) claimed that electronics circuit simulators (such as Multisim) can allow students to change variables (like resistance, voltage), observe, and then draw inferences on the relationships between the variables. Additionally, simulators may enable students validate or refute their mental map of theoretical concepts (Papadouris & Constantinou, 2009). Therefore, it appears that simulators like Multisim may be a viable tool to provide students with an immersive experience needed to better improve their understanding of concepts.

Comparison between Physical and Virtual Environment (or Simulated Lab)

Table 2.2 shows comparisons between physical and virtual environments adapted from Elawady and Tolba (2009).

Table 2.2 Comparisons between Physical and Virtual Lab Environments

Feature	Physical	Virtual
Accessed	Access is physical real data.	Access is simulated data.
Setup	Real physical equipment.	Virtual equipment (sim. software).
	Real-world experience for students.	Simulated world experience for students.
	Need regular maintenance.	May require software update.
	Equipment may develop fault.	Virtual equipment faults are rare but may develop software glitches.
	Raises safety concerns.	Limited safety concern.
Educational	Collaborative learning (teamwork skills).	Individualized learning (Student can personalize their learning).
	Develop real-life equipment handling skills.	Can help develop concept understanding.
	Supervision is required.	Limited supervision required.
	May not be easily manipulated and rerun.	May be easily manipulated and experimented with.
	Cannot be used in dangerous scenarios.	Can be used to simulate dangerous scenarios.
	Cannot be used to create a virtual experience for students.	Can be used to create a virtual experience for phenomenon.
Total Cost	Relatively more expensive (maintenance, logistics, space & instructor time).	Relatively less expensive.

Written Instructions Format (Instructional Format)

Instructional formats are the methods used by instructors to support learning in the classroom or laboratory (King, Sattler-Weber, & King, 2002). These methods drive the instructor's instructional plan, materials and the manner of delivery. Corconan and Silander (2009) argue that an effective instructional format must lead to a measureable improvement in students' performance. That is, all effective instructional format must promote learning. Additionally, Meador (2015) suggested that instructional format should be directed towards achieving the instructor's learning objectives.

There are several instructional formats that instructors and educators can use when designing an instruction in classroom or lab. This literature review will only focuses on the explicit and implicit written instructions. The reason is largely because this study considered the type of instruction as a means of presenting information or guidelines either in the classroom or in the lab. Therefore, the written task instruction in this study was either explicit or implicit written instructions. According to Jaakkola et al. (2011) these instructions could be applied in laboratory activities.

Explicit Instruction

Explicit instructions are also known as direct or expository instructions. Explicit instructions are instructions that are highly instructor guided, with step-by-step guide through instruction (Richa, 2014). These instructions are thought to be teacher-centered and could be said to be the common method of instruction in the classroom and laboratory. Manitoba Education (2015) and Richa (2014) identified the purpose of explicit instructions as: to present content knowledge information, to clearly state

learning objectives, to provide content awareness and importance, to train lower level skills and facts, to promote procedural skills (step-by-step) and to construct knowledge. Explicit instruction can also be used to introduce other instructions.

Explicit instructions, however, have some drawbacks. Explicit instructions are highly structured and cannot be used in high level learning such as creativity skills and problem solving (Richa, 2014). In the lab, explicitly written instructions (mostly traditional lab) require that instructors (or lab manual) provide students with lab procedures (step-by-step), and the lab outcomes are predetermined by the instructor (Domin, 1999). The students follow the lab procedure step-by-step to build the circuit, carry out measurements and complete the lab activity. Although, these practical exercises may help develop equipment-handling skills, very little attention is given to lab planning, investigation, and measurements interpretation (Tobin, Tippins & Gallard, 1994). Critics of explicit lab instruction argued that very little thinking and learning take place during the process of completing explicitly developed laboratory activities (Hofstein & Lunetta, 1982).

Implicit Instruction

Implicit instructions are instructions with less instructor guidance and are more student-oriented (Richa, 2014). This instructional format encourages students to be more active in the learning process and the instructor acts as a facilitator by monitoring the process. Manitoba Education (2015) and Richa (2014) identified the purpose of implicit instructions as: present opportunity to apply knowledge; to train higher level skills such as problem solving; to promote creativity; and to develop conceptual understanding.

However, implicit instructions have been criticized for being time-consuming and ineffective for lower level learners. Implicit instructions have also been disparaged because it may be difficult to coordinate (Richa, 2014).

Implicitly written instructions demand that students generate the procedures required to complete the lab activity on their own (Domin, 1999). Proponents of the implicit written instructions believe that it is an alternative to the traditional explicit instruction (Domin, 1999), because students can develop a higher thinking process with the implicit instruction. Implicit instructions can also be attributed to promoting students' positive attitudes toward sciences (through active learning and student engagement) and critical thinking (Raths, Wassermann, Jonas & Rothstein, 1987).

Comparison between Explicit and Implicit Written Instructions

Table 2.3 below shows some comparison between explicit and implicit instructions (Manitoba Education, 2016; Richa, 2014; Sun, Mathews & Lane, 2007).

Table 2.3 Comparisons between Explicit and Implicit Instructions

Features	Explicit	Implicit
Knowledge	Gained by following directions.	Gained by doing or experiencing.
Approach	Teacher-centered approach (classroom lectures).	Student-centered approach (more interactive, active learning).
Skills Training	Lower level skills, promote procedural skills.	Higher level skills (problem solving).
Delivery Mode	Direct instructional delivery from instructor to student.	Indirect delivery, instructor acts as a facilitator.
Educational	Factual knowledge.	Application, analytical knowledge
Lab	Little thinking about lab interpretation.	Higher thinking process about interpretation of data.

Previous Related Studies

Several studies compared students' scores in a virtual lab environment with that in a physical lab environment, and concluded that students in the virtual environment showed higher knowledge of content (Frederick, 2014; Gibbons, Evans, Payne, Shah, & Griffin, 2004; Gopal et al., 2010; Gorghiu, Alexandrescu & Borcea, 2009). For instance, Finkelstein et al. (2005) conducted a study to examine the effect of replacing a physical environment with a virtual environment in a direct current (DC) circuit lab. The study compared students' conceptual learning and practical skills in both lab environments. In Finkelstein et al.'s study, students' conceptual understanding on simple circuit construction (including voltage, current, series and parallel circuit) and their ability to connect light bulbs, resistors and to take measurements were assessed. At the end of the lab session, students completed lab reports, worksheets, and recorded time taken to complete the task. Finkelstein et al.'s study revealed that despite the fact that the traditional group took a longer time to complete their task, virtual environment group performed better in conceptual understanding than their traditional counterparts. Other studies, however, revealed that physical environment may be more effective in students' content gain (Engum, 2003; Zacharia, 2012). However, Tatli and Ayas (2013) conducted a study that investigated the effect of virtual environment on student achievement among 90 students and concluded that both the physical and virtual environment groups showed an equal level of achievement. It is possible that the differences in opinion among researchers on the effectiveness physical and virtual environment maybe due to the fact that learning objectives were measure against dissimilar outcomes (Ma & Nickerson,

2006). Thus, more standardized measures need to be implemented in order to effectively study the effect of physical and virtual lab on students' achievements.

The different studies discussed above did not specifically mention the kind of lab instructions (or written task instructions) that were used in their studies. The studies only focused on comparing the effect of physical and virtual environments on students' achievements. So the question worth asking is, what effect does the format of written instructions has on lab effectiveness?

Research that investigated the effect of lab instructions revealed that explicit instruction can have a considerable effect on student learning (Klahr & Nigam, 2004; Palinscar & Brown, 1984). Ardac and Sezen (2002) conducted a study to investigate the effectiveness of explicit and implicit computer-based instruction on improving students' content knowledge and process skills. They concluded that the explicit instruction in the lab had higher impact on students than the implicit instructions. Similarly, other studies (De Jong & Van Joolingen, 1998; Veermans, Joolingen, & de Jong, 2006) revealed that instructional guidance appeared to have substantial effect, particularly in the case of virtual environment. This maybe because the explicit instruction, which is structured instruction, constricts the task's workspace thereby allowing students to easily identify the important components in the task rather than exploring the entire space (Jaakkola et al., 2011). In contrast, advocates of implicit instructions suggested otherwise. For instance, studies show students that were presented with implicit instructions may demonstrate a higher conceptual knowledge than their explicit instructions counterparts (Chen, 2010; Vreman-de Olde, de Jong, & Gijlers, 2013). This may be because implicit

instructions allow students to think deeper and develop higher-level skills when performing the task.

Kollöffel and Jong (2013) conducted a study to investigate ways of facilitating conceptual understanding in electronic circuit. The study compared two groups: physical lab environment with explicit instruction and virtual lab environment with implicit instruction. They evaluated students' conceptual understanding and procedural skills, and found that students in the virtual lab with implicit instruction scored significantly higher in both conceptual understanding and procedural skills (practical skills). This result was also supported by the study conducted by Jaakkola et al. (2011). Kollöffel and Jong's findings could be due to the fact that the virtual environment enables students to develop procedural skills (or practical skills) and improve their understanding of concepts.

What is Missing?

Past research examined the different combinations of lab environments with written instruction (Ardac & Sezen, 2002; Finkelstein et al., 2005; Jaakkola et al., 2011; Kollöffel & Jong, 2013; Olde et al., 2013). However, very few studies have examined the effect of the four different combinations of lab instructions in a single study. This is important because it could allow researchers to compare the lab instructions with the same experimental conditions (that is within the same study). Moreover, Ma and Nickerson (2006) argued that researchers are confounding many dissimilar factors in their studies. Hence, it is imperative for this study to investigate the influence of different written instructions (implicit versus explicit) on students' scores in both physical and virtual environments.

The current study adopted a different methodology in evaluating the students' performance in a physical and virtual lab environments based on Brinson (2015) and Chignell et al. (2014) recommendations. Brinson (2015) conducted a literature review on traditional and non-traditional lab environments studies and reported that about 71% of those studies he reviewed used exam or quiz as their evaluation instrument. He noted further that the evaluation instrument used assessed only students' content knowledge. Furthermore, most past studies only looked at scores to estimate students' performance and did not take into account the time taken to complete the task as suggested by Chignell et al. (2014). The current study is designed to investigate the influence of written task instructions and lab environments on students' scores in completing a practical lab task. Additionally, the current study will consider the total time taken to complete the task and scores to estimate students' performance.

Conceptual framework

The study examined the effect of different written task instructions (explicit versus implicit) and lab environments (physical versus virtual) on students' scores in completing an electronic circuit task. Three effects were investigated: the main effect of written task instructions on students' scores; the main effect of the lab environment on students' scores; and the interaction effect between the written task instructions and the lab environment used by the students in completing the exercise. Students' ability to demonstrate an understanding of series-parallel circuit was measured as determined by students' individual scores and time. Figure 2.1 displays the conceptual framework for

this study with the independent variables (each with two level) — written task instruction and lab environment; and dependent variables— students' scores and time taken.

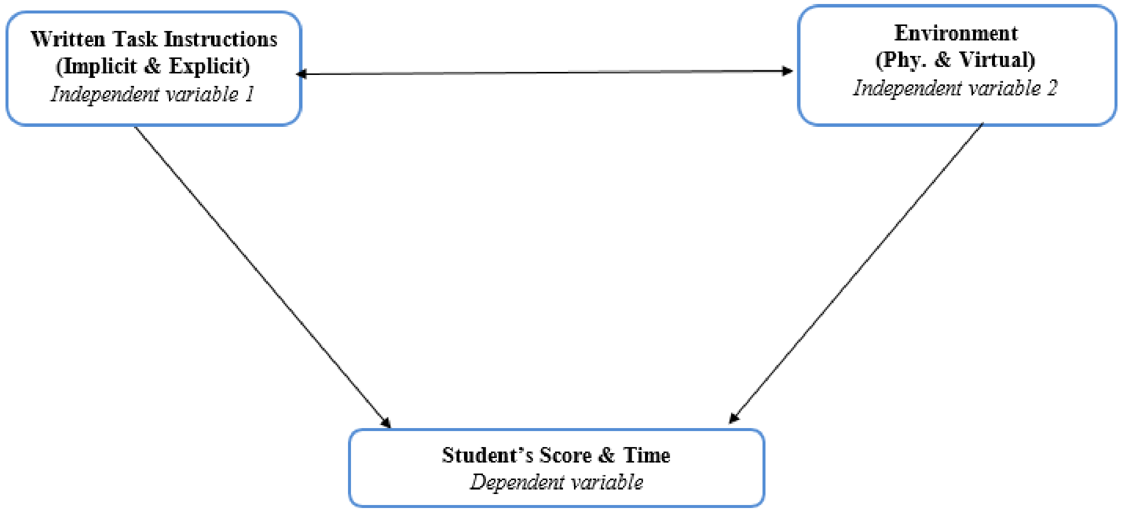


Figure 2.1. Conceptual Framework

Summary

Ma and Nickerson (2006) conducted an extensive literature review and revealed that researchers measure efficacy of lab technologies against dissimilar learning objectives and standards. Ma and Nickerson reported that this may be responsible for the differences in research results on the effectiveness of virtual labs. Hence, they recommended that studies should further isolate and study the effect of virtual labs.

The debate about the effectiveness of physical and virtual lab environments rages on. Research appears to show that the two different formats have their benefits. For instance, one important benefit of virtual lab is in investigating unobservable phenomena such as current flowing in a circuit (de Jong, Linn, & Zacharia, 2013). Likewise, one benefit of physical lab is in developing practical abilities such as equipment handling techniques (de Jong, Linn, & Zacharia, 2013). Similarly, the discussion about which

written instruction is more effective appears to be inconclusive. However, some researchers agree that implicit instruction can better help students develop higher thinking abilities (Domin, 1999), and others believe that explicit instruction promote procedural skills (Richa, 2014). Therefore, it could be said that different written instruction (explicit and implicit) may have specific pedagogical values. Hence, there is the need to study the effect of these specific pedagogical values in different lab environments in order to ascertain their effectiveness.

Research is not clear about the effect of combining the different lab environments with different written instructions. Hence, the current study investigated the influence of different written task instructions and lab environments on students' scores and time taken in completing an electronic circuit task. This was done by assessing their understanding of series-parallel circuit using two different written task instructions and lab environments in completing a series-parallel circuit exercise.

CHAPTER III

METHODOLOGY

The purpose of this study was to investigate the effect of different written task instructions (implicit versus explicit) and lab environment (physical versus virtual) on students' scores in completing an electronic circuit task. Specifically, the study looked at how using written task instructions in different lab environment affected students' scores in performing a series-parallel circuit exercise. Students' scores were evaluated by assessing their understanding of series-parallel circuit using two different written task instruction and lab environment. Students' understanding of series-parallel circuit were measured as determined by students' individual scores and time taken to complete task. The order in which the study methodology was conducted is depicted in Table 3.1. This chapter discusses each stage of the methodology in detail.

Table 3.1 Chapter 3 Outline

1. Instrument Design
2. Pilot Study
3. Experimental Design
4. Task Performed
5. Experimental Procedure
6. Participants
7. Variables

Instruments Design

The instruments (see appendix B) were designed based on course lab materials (Buchla, 2002). The instrument assessed students' understanding on series-parallel circuit. The series-parallel circuit concept was used in developing the instrument because it is a fundamental concept in the electronic circuit course. The lab activity required students to build series-parallel circuit, and measure voltage and current, in order to assess their understanding of series-parallel circuit concept. After completion of the activities, students' tasks were graded based on their recorded readings (voltage and current).

In addition, students were asked to record the time taken (planning and execution time) to complete their tasks. The scores and time recorded enabled a holistic measure of students' performance in completing the series-parallel circuit task. Evidence of this evaluation method could be found in research conducted by Finkelstein et al. (2006) and Farrokhnia and Esmailpour (2010).

Pilot Study

A pilot study was conducted prior to the commencement of the main study. The lab activity was administered not only to test the instruments but also to assess the clarity of the instructions. The preliminary test of instrument also allowed the researcher to examine the feasibility of the study's methodology, to identify errors and ambiguity in the instrument. For instance, it was identified during the pilot study that the lab activity instruction did not specify the exact sources voltage value that was required in the exercise. Additionally, it was also discovered that some parts of the activity instructions

were not clear and could be misinterpreted. Participants for the pilot study were recruited through purposive sampling. The pilot study was conducted with a group of four students that was considered representative of the study population. The pilot sample was selected based on the fact that participants were all former students of the electronic circuit course. Participants were invited to participate in the pilot study through emails. Comments and feedbacks from participants were used to revise the instruments.

Experimental Design

This study was a quantitative experiment that used a repeated-measure factorial (within-subject) design. The repeated-measure factorial design employed a single group which participated in all conditions. This experimental design was chosen because it allows measurement of the dependent variable (students' scores and time) across different treatment conditions, hence enabling several studies to be combined into one (Field, 2009).

In addition, Creswell (2002) suggested that repeated-measure factorial design is an appropriate technique to use when there is limited number of participants (small sample size). Moreover, this experimental design was not affected by internal validity since the same participants were measured across the different conditions; thus, the problems arising from history was minimized by making the activities as different as possible— by altering the sequence of arrangement and layout of the circuit component for each condition (Creswell, 2002). Furthermore, because the experimental design employed only one sample group across treatment conditions, there is likely to be a reduction in the influence of outside variables (such as participants' motivation level) that

may distort the data (Gravetter, & Wallnau, 2016). The use of experimental design enabled the researcher to test the main effects of the two independent variables (written task instruction and lab environment) and the interaction effect between the two independent variables.

Task Performed

Table 3.2 below shows the differences and similarities between the tasks performed of the four treatment conditions. The virtual environment used was Multisim. Multisim (version 14.0) software is a circuit design software which allows students to build and stimulate circuit in a virtual environment.

Table 3.2 The Tasks Performed of Each Treatment

Treatments	Treatment A Phy+Imp	Treatment B Vir+Imp	Treatment C Phy+Exp	Treatment D Vir+Exp
Lab Environment Used	Physical environment used physical equipment such as breadboard, resistors, power supply unit and multimeter.	Virtual environment (Multisim) used virtual devices such as virtual resistors, virtual DC power & multimeter.	Physical environment used physical equipment such as breadboard, resistors, power supply unit & multimeter.	Virtual environment (Multisim) used virtual devices such as virtual resistors, virtual DC power & multimeter.
Written Task Instruction Presented	Implicitly written instruction—no step-by-step guide.	Implicitly written instruction— no step-by-step guide.	Explicitly written instruction—step-by-step guide.	Explicitly written instruction—step-by-step guide.
Activities Performed	Students determined how to build circuit on physical breadboard, connect devices and measure voltage & current values.	Students determined how to build circuit in virtual workspace (Multisim), connect virtual devices & measure voltage current values.	Students used step-by-step guide to build circuit on physical breadboard, connect devices and measure voltage & current values.	Students used step-by-step guide to build the circuits in Multisim, connect virtual devices and measure voltage & current values.

Experimental Procedures

The Institutional Review Board approval was obtained prior to the commencement of this study. Students from the Electric Circuits and Devices class were asked to volunteer for the study through e-mail and consent was given via a signed consent form (see appendix A). The study consisted of 14 participants who were enrolled in the Electronics Circuits and Devices Course. The electronic course covered series-parallel circuit concepts.

All participants experienced the four treatment conditions in the electronics lab at four different times in a span of two weeks. The experiment consists of four treatment conditions involving four different activities of the same content (series-parallel concept). Figure 3.1 displays the study's experimental procedures. The experiments were conducted as follows:

a. In the first session, participants used the physical environment with implicit written instructions to perform activity 1 (Phy+Imp).
b. The second session, participants used virtual environment with implicit written instructions to perform activity 2 (Vir+Imp).
c. The third session, participants used physical environment with explicit written instructions to perform activity 3 (Phy+Exp).
d. In the final session, participants used virtual environment with explicit written instructions to perform activity 4 (Vir+Exp).

The above order of treatment conditions was used because the pilot study results revealed that students scored lower when presented with implicit compared to explicit

written instructions. Lower scores were also recorded when physical compared to virtual environment was used. These results were also supported by previous studies (Ardac & Sezen, 2002; Finkelstein et al., 2005; Jaakkola, Nurmi, & Veermans, 2011; Kollöffel, & Jong, 2013; Olde et al., 2013). Thus, the treatment order was designed based on the level of difficulty of the activity in a descending order.

In each activity, participants took as much time as they required in completing the task. They were asked to record the time taken to plan and execute the task, and also record voltage and current measurement as related to the activity performed (see appendix B). Figure 3.1 depicts the study experimental procedures.

Activities	**Activity 1**	**Activity 2**	**Activity 3**	**Activity 4**
Treatments	Treatment A	Treatment B	Treatment C	Treatment D
Format of Environment + Type of Written Instruction	Physical + Implicit instruction Phy+Imp	Virtual + Implicit instruction Vir+Imp	Physical + Explicit instruction Phy+Exp	Virtual + Explicit instruction Vir+Exp

Time →

Figure 3.1. Study Experimental Procedure

Participants

The study was conducted at an upper mid-western university. Participants were undergraduate Industrial Technology students enrolled in an Electronic Circuits and Devices Course. Students in the said course were expected to have completed Trigonometry and basic Physics courses as prerequisites before enrolling in the

Electronic Circuits and Devices Course. While 17 students were enrolled in the Course, only 14 students completed the study.

Variables

Independent Variables

Two independent variables (each has two levels) were manipulated to test their effect on the dependent variable. The independent variables were: the written task instruction, which includes explicit and implicit written instructions; and format of the lab environment, which encompasses the physical and virtual environments.

Dependent Variable

The dependent variable is the variable that was influenced by the independent variables. The dependent variable for this study is the students' score and the time taken to complete the task.

Chapter four reported the data analysis process and the findings of the study. The chapter discussed data analysis as it addressed each of the research questions and presented details of study findings.

CHAPTER IV

DATA ANALYSIS

The purpose of this study was to investigate the effect of different written task instructions (implicit versus explicit) and lab environment (physical versus virtual) on students' scores in completing an electronic circuit task. Specifically, the study looked at how using written task instructions in different lab environments affected students' scores in performing a series-parallel circuit exercise. Students' scores were evaluated by assessing the extent to which they were able to demonstrate their understanding of series-parallel circuit using two different written task instructions and lab environment. Students' understanding of series-parallel circuit were measured as determined by students' individual scores and time.

This chapter reports the data analysis and the findings of the study. The data analysis addresses each of the research questions to determine the effect of task instructional and laboratory environment on students' scores. Table 4.1 shows the chapter outline.

Table 4.1 Chapter 4 Outline

1. Research Questions
2. Overview of the Study
3. Data Description
4. Data Analysis
5. Summary of the finding

Research Questions

1. How do the written task instructions provided to students significantly affect their scores on the assigned activities?

2. How do the lab environment used by students significantly affect their scores on the assigned activities?

3. What significant interaction (if any) exists between written task instruction and the lab environment used by students to complete the activities?

Overview of the Study

As earlier explained in chapter 3 (Experimental Design Section), this study was a quantitative experiment that used a repeated-measure factorial design. This experimental design was chosen because of the following reasons:

- It allows measurement of the dependent variable (students' scores and time) across each treatment condition, hence enabling several studies to be combined into one (Field, 2009).
- The design is an appropriate technique to use when there is a limited number of participants (Creswell, 2002).
- It is not affected by internal validity since the same participants are measured across the different conditions.
- The problems arising from history can be minimized by making the activities distinct— by altering the sequence of arrangement and layout of the circuit for each condition (Creswell, 2002).

Pilot Study

A pilot study was conducted prior to the commencement of the main study. The pilot was administered not only to test the instruments but also to assess the clarity of the instructions. In addition, the preliminary test of instrument also allowed the researcher to examine the feasibility of study methodology, to identify errors and ambiguity in the research instruments. Chapter 3 provides more details on some of the findings of the pilot studies.

Task Score Measurement

In order to measure students' task score, four series-parallel circuit exercises (see appendix B) were designed and assigned to students. Students' graded scores on the exercise were recorded. In addition, students were asked to record the time taken to complete their tasks. The scores and time recorded were meant to enable a holistic measure of students' performance in completing the series-parallel circuit task. However, during the data analysis, the time recorded by students was not utilized because of reliability issues arising from the fact that the time recorded by some students were inconsistent. This will be discussed more later in this session.

Data Description

The data description section includes the raw data and the descriptive statistics. The raw data consist of 14 participants' scores and the time taken to complete the task (planning and execution time).

Raw Data

Table 4.2 shows the scores (raw data) of 14 participants in the four different treatments. The table also shows the mean scores and standard deviation for each treatment.

Table 4.2 Raw Data for Students' Scores

Participants	**Phy+Imp**	**Vir+Imp**	**Phy+Exp**	**Vir+Exp**
Participants 1	7	10	8	7
Participants 2	8	6	8	10
Participants 3	10	10	6	10
Participants 4	10	10	1	3
Participants 5	2	5	1	5
Participants 6	8	6	8	5
Participants 7	10	10	5	3
Participants 8	3	0	6	8
Participants 9	0	0	9	3
Participants 10	1	5	9	10
Participants 11	10	4	5	10
Participants 12	0	10	2	10
Participants 13	5	10	6	8
Participants 14	7	10	10	8
Average	5.79	6.86	6.00	7.14
Standard Deviation	3.89	3.72	2.96	2.82

Table 4.3 shows the raw data for total time taken including planning and execution time for each participant to complete the task. However, during the data analysis, the time recorded by students was not utilized because of reliability issues arising from the fact that the time recorded by some might not be accurate. For instance, it can be seen from table 4.3 that participants 5, 7 and 14 reported zero mins for the planning time which is possible. In addition, participants 3, 4, and 10 reported one minute for planning time, but this appeared to be inaccurate.

Table 4.3. Show the Raw Data for Planning Time, Execution Time and Time Taken

	Phy+Imp Time			Sim+Imp Time			Phy+Exp Time			Sim+Exp Time		
Participants	**Plan.**	**Exec.**	**Total**	**Plan**	**Exec**	**Total**	**Plan**	**Exec**	**Total**	**Plan**	**Exec**	**Total**
Participants 1	10	15	25	2	14	16	4	15	19	2	8	10
Participants 2	10	35	45	3	13	16	5	9	14	2	8	10
Participants 3	5	5	10	1	5	6	2	18	20	2	5	7
Participants 4	4	20	24	1	8	9	2	12	14	1	9	10
Participants 5	20	40	60	5	15	20	0	10	10	0	10	10
Participants 6	15	50	65	3	10	13	5	10	15	2	7	9
Participants 7	0	41	41	3	28	31	3	29	32	2	15	17
Participants 8	5	25	30	4	6	10	6	23	29	5	10	15
Participants 9	5	40	45	4	7	11	5	10	15	2	5	7
Participants 10	10	20	30	2	6	8	5	15	20	1	12	13
Participants 11	10	26	36	5	7	12	4	15	19	2	7	9
Participants 12	5	25	30	3	7	10	5	15	20	5	10	15
Participants 13	5	10	15	2	6	8	2	8	10	5	10	15
Participants 14	0	20	20	5	15	20	5	15	20	2	8	10
Average Time	7.43	26.57	34.00	3.07	10.50	13.57	3.79	14.57	18.36	2.36	8.86	11.21

Descriptive Statistic

Table 4.4 shows the descriptive statistic for the four different treatment scores. As seen from the table, the Phy+Imp mean score was the lowest recorded score at 5.79, and Vir+Exp has the highest at 7.14 out of a total possible score of 10. The table also shows that the Vir+Exp group had the smallest standard deviation, which indicates that the data points are closer to mean, whereas Phy+Imp had a higher standard deviation. Another important measure is skewness and kurtosis which tell if the distribution is normal. The skewness of all four variables are negative values and this suggests a negatively skewed distribution (e.g., data structure have an upper bound). The kurtosis of all four variables are negative values which indicates that the distributions are probably flat and light tailed (there are no outliers).

Table 4.4. Descriptive Statistic for Scores

		Phy+Imp	**Vir+Imp**	**Phy+Exp**	**Vir+Exp**
N	Valid	14	14	14	14
Mean		5.79	6.86	6.00	7.14
Median		7.00	8.00	6.00	8.00
Mode		10	10	6	10
Std. Deviation		3.886	3.718	2.961	2.825
Variance		15.104	13.824	8.769	7.978
Skewness		-.380	-.812	-.601	-.456
Kurtosis		-1.510	-.513	-.699	-1.417
Range		10	10	9	7

Analysis of Data

The analysis of the data was done using repeated measures two-way ANOVA. The within-subject ANOVA was used because it measures the dependent variable (students' scores) repetitively for all participants within a single treatment condition. The underlining goal of the data analysis was to determine if the task instructions (explicit versus implicit) and lab environment (physical versus virtual) had any effect on the students' scores. There are two within-subject factor: task instructions and lab environments. These factors were used to creates a matrix 2x2 to form four different combinations of the variables — Phy+Imp, Vir+Imp, Phy+Exp and Vir+Exp. This session reported the main effects, interaction effect and contrasts.

Main Effect of Written Task Instruction and Lab Environment

The main effect of a factor is the mean difference between the levels of that factor. For instance, table 4.5 shows the factor A (Task Instr.) and its two levels—implicit and explicit, where the differences in the mean score among these levels is the main effect of factor A. The main effect was computed individually for each factor. Table 4.5 also shows the students' mean scores for each treatment, marginal mean (overall mean) for each row (each task instruction), and marginal mean for each column (each lab environment).

Table 4.5. Students' Means Scores and Marginal Means

		Factor B (Lab Environment)		
		Physical Environment	Virtual Environment	*Marginal Mean*
Factor A (Task Instr.)	Implicit	**5.76**	**6.86**	6.31
	Explicit	**6**	**7.14**	6.57
	Marginal Mean	5.88	7	

Research Question 1: How do the written task instructions provided to students significantly affect their scores on the assigned activities?

In order to determine how written task instructions affected students' scores, that is the main effect of written instruction, three analyses were conducted: Analysis of the main effect graph; statistical analysis ANOVA; and effect size.

Table 4.5 shows the marginal mean of task instruction, which was plotted in figure 4.1. It is clear from figure 4.1 that explicit instruction has slightly higher marginal mean than implicit instruction. To determine whether this difference is statistical significant, statistical test was conducted in SPSS (data analysis software).

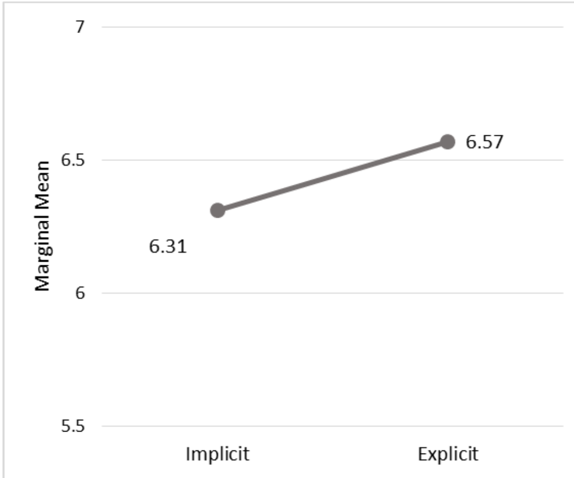


Figure 4.1. The Main Effect of Task Instruction

A two-way ANOVA, with task instructions as the main effect, was used to determine whether the main effect for task instruction was statistically significant or not. Table 4.6 shows the output of two-way ANOVA with the sum of square values, degree of freedom df, mean square values, F-ratio and significant values. The sum of square represents the amount of the difference that was as a result of experimental manipulation and the sum square error tells the amount that is not (Field, 2009). The sum of square for the effect of task instructions is 0.88 and its error value is 218.88. This implies that only 0.88 unit of the difference can be explained by the experimental manipulation and 218.88 unit cannot. The table also shows the degree of freedom df of the effect of task instruction as 1, and df error as 13. The mean square is the average amount of the difference that was as a result of the experimental manipulation, and the mean square error tells the average amount that is not (Field, 2009). The mean square is 0.88 and its error value is 16.84. The F-ratio is the ratio of the amount of difference explained by experimental manipulations and the amount that is not. The F-ratio is 0.05. The

significance value p from the table is 0.823. Therefore, there is no statistically significant effect on the type of written task instruction used to complete the task on students' scores at $p < 0.05$, p value =0.823. The main effect of written task instructions on students' scores was not significant at $p < 0.05$, $F(1, 13) = 0.052$.

Table 4.6. Test of Within-Subjects Effects

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
TaskInst	Sphericity Assumed	.875	1	.875	.052	.823
	Greenhouse-Geisser	.875	1.000	.875	.052	.823
	Huynh-Feldt	.875	1.000	.875	.052	.823
	Lower-bound	.875	1.000	.875	.052	.823
Error(TaskInst)	Sphericity Assumed	218.875	13	16.837		
	Greenhouse-Geisser	218.875	13.000	16.837		
	Huynh-Feldt	218.875	13.000	16.837		
	Lower-bound	218.875	13.000	16.837		
LabEnvi	Sphericity Assumed	17.161	1	17.161	1.897	.192
	Greenhouse-Geisser	17.161	1.000	17.161	1.897	.192
	Huynh-Feldt	17.161	1.000	17.161	1.897	.192
	Lower-bound	17.161	1.000	17.161	1.897	.192
Error(LabEnvi)	Sphericity Assumed	117.589	13	9.045		
	Greenhouse-Geisser	117.589	13.000	9.045		
	Huynh-Feldt	117.589	13.000	9.045		
	Lower-bound	117.589	13.000	9.045		
TaskInst * LabEnvi	Sphericity Assumed	.018	1	.018	.003	.955
	Greenhouse-Geisser	.018	1.000	.018	.003	.955
	Huynh-Feldt	.018	1.000	.018	.003	.955
	Lower-bound	.018	1.000	.018	.003	.955
Error(TaskInst*LabEnvi)	Sphericity Assumed	71.732	13	5.518		
	Greenhouse-Geisser	71.732	13.000	5.518		
	Huynh-Feldt	71.732	13.000	5.518		
	Lower-bound	71.732	13.000	5.518		

Note: p <.05,
TaskInst means Written Task Instructions
LabEnvi means Lab Environment

Even though the main effect for task instruction on student's score may not be significant, it is important to determine the effect size of the effect (Field, 2009; Oser, 2013). The effect size allows the magnitude of the influence of an experimental treatment to be quantified (Coe, 2002). Therefore, it may be necessary to report the effect size.

Contrast (see table 4.7) between implicit and explicit revealed that F (0.05, 13), r (effect size) = 0.06. This yields a small effect size, which can only accounts for 1% of the total variance. Hence, the effect may not be practically significant.

Research Question 2: How do the lab environment used by students significantly affected their score in the assigned task?

Similarly, to determine how the type of lab environment (physical versus virtual) affected students' scores, three analyses were conducted: the main effect graph; statistical test (ANOVA) and effect size.

The effect of lab. environment plotted in figure 4.2 shows a higher marginal mean score for virtual compared to the physical environment. To determine whether this main effect is statistical significant, a statistical test (ANOVA) was conducted in SPSS.

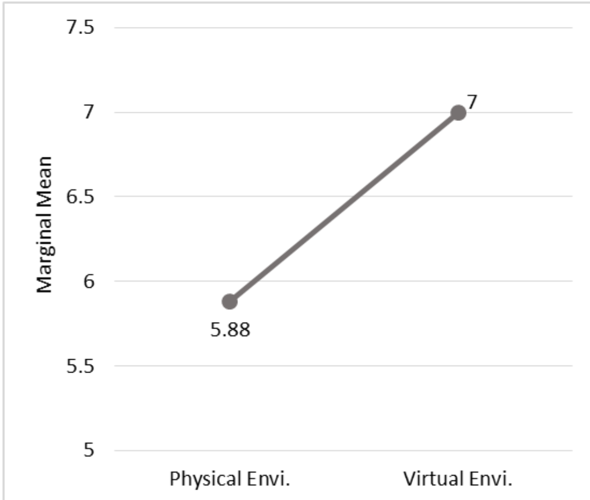


Figure 4.2. The Main Effect of Lab environment

A two-way ANOVA was used to determine whether the main effect for lab environment was statistically significant or not. Table 4.6 shows the sum of squares values, degree of freedom (df), mean square, F-ratio (F) and significant values. The sum of square for the effect of lab environment (LabEnvi) is 17.16 and its error value is 117.59. This means that only 17.16 unit of the difference can be explained by the experimental manipulation, and 117.59 unit cannot. The mean square is 17.16, and its error value is 9.05. The F-ratio is 1.90. The significance value p from the table is 0.19. Thus, there is no statistically significant effect on the type of lab environment used to complete the task on students' scores at $p < .05$, p value =.19 (table 4.6). The main effect of lab environment on students' score was not significant at $p < .05$, $F(1, 13) = 1.90$.

The experimental strength of the effect for environment on students' score was computed as the effect size. Lakens (2013) argued that effect size could allow researchers to quantify the experiment's manipulation effects and suggest practical significance. The

computed effect size was (r) = 0.36. From the effect size template suggested by Field (2009), the computed effect size produced medium sized effect. Therefore, the effect explains 9% of the total variance. However, the effect size revealed that there may be practically significant difference between the types of lab environment used. It is worth noting that effect size for environment main effect (0.36) is larger than that of task instruction (0.06).

Interaction Effect between Written Task Instructions and Lab environment

The interaction effect helps determine whether the mean difference on factor A depends on the levels of factor B. It can be said to be the effect of two factors influencing one another (Gravetter & Wallnau, 2016). In a graph, interaction can be explained considering the graph pattern (see figure 4.3). For instance, if the two-plotted lines are parallel, then there may be no interaction between the two factors. However, if the two lines cross each other it implies that there is some interaction between the variables.

Research Question 3: What significant interaction (if any) exists between written task instructions and lab environment used?

In order to determine whether an interaction exist between written task instructions and the lab environment used (interaction effect), three analyses were conducted: Analysis of graphical representation of interaction effect; ANOVA; and effect size.

Figure 4.3 visually represents the interaction effects for task instructions and lab environment in a line graph. The line graph displays data patterns with the dependent variable (students' mean scores) on the vertical axis. The graph shows two separate

graph: task instructions (implicit versus explicit) and lab environment (physical versus virtual). Note that the two lines are not parallel and distance between them are unequal. This shows that there may be an interaction between the two independent variables.

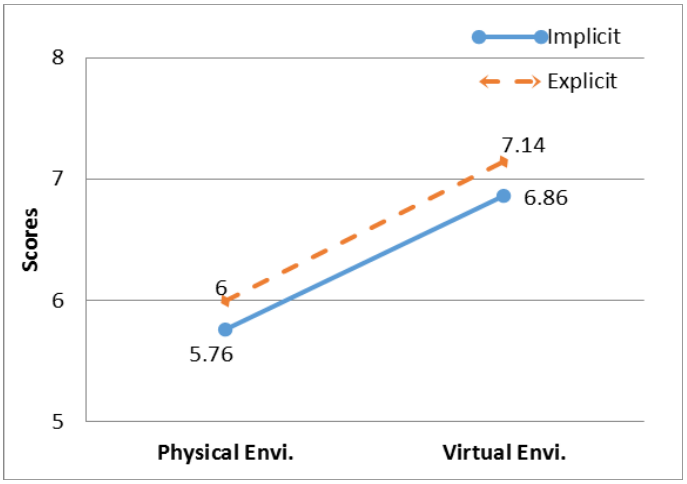


Figure 4.3. Line Graph of Interaction Effect

Table 4.6 shows the result of the ANOVA test to determine whether there is a statistically significant interaction between task instruction and lab environment.

Table 4.6 shows 0.018 as the sum of square for the interaction effects, and its error value to be 71.732. This implies that only 0.018 unit of the difference was as a result of the experimental manipulation, and 71.732 unit was not. The mean square is 0.018, and its error value is 5.518. The F-ratio is 0.003. The significance value p from the table is 0.955.

The result indicates that there is no significant interaction at $p < .05$, p value =.955 (see table 4.6). The interaction effect between task instructions and lab environment used was not significant at $p < .05$, $F(1, 13) = 0.003$. Contrast between task instructions and

lab environment used revealed that F (0.003, 13), r = 0.048. This yields a small effect size which can only account for 1% of the total variance. Hence, the effect may not be practically significant.

Contrasts for Repeated-Measure Variables

In order to validate the interpretation of the main and interaction effects, within-subject contrasts were computed. Contrasts also allow levels of the independent variables to be compared to see whether they differ. Table 4.7 shows contrasts of the main effects and interaction effects. The first contrast compares level 1 (implicit) with level 2 (explicit) and revealed that F (1, 13) = 0.052, p value =.955. The sum of square value (0.875) and mean square values (0.052) are similar to the values reported in the task instruction main effect reported earlier. This is because there are only two levels of contrasts. The second contrast compares level 1 (physical) with level 2 (virtual), F (1, 13) = 1.897, p value =0.192. The interaction effect contrast compares level 1 (task instructions) with level 2 (lab environment), F (1, 13) = 0.003, p value =0.955. The main and interaction effect contrasts are not statistically significant at $p < .05$.

Table 4.7 Test of Within-Subject Contrasts

Source	TaskInst.	LabEnv	Type III Sum of Squares	df	Mean Square	F	Sig.
TaskInst.	Level 1 vs Level 2		.875	1	.875	.052	.823
Error (TaskInst.)	Level 1 vs Level 2		218.875	13	16.837		
LabEnvi.		Level 1vs. Level 2	17.161	1	17.161	1.897	.192
Error (LabEnvi.)		Level 1vs. Level 2	117.589	13	9.045		
TaskInst.* LabEnvi.	Level 1 vs.Level 2	Level 1 vs. Level 2	.071	1	.071	.003	.955
Error (TaskInst.* LabEnvi.)	Level 1 vs Level 2	Level 1 vs. Level 2	286.929	13	22.071		

Note: $^*p < .05$,
TaskInst level 1 means implicit task instruction, level 2 means explicit task instruction
LabEnvi level 1 means physical environment, level 2 means virtual environment

Summary of Findings

This chapter described the analysis of data and the results obtained from statistical tests based on the research questions. The main goal of the study was to determine how using different written task instructions (explicit versus implicit) and lab environment (physical versus virtual) affected students' scores in completing a series-parallel circuit exercise.

Higher scores were recorded when tasks were completed in virtual environment irrespective of the type of instructions used. Similarly, slightly higher scores were reported when explicit instructions were used regardless of the type of lab environment in which the task was performed.

To determine whether the mean difference of task instructions (Factor A) is influenced by the levels of lab environment (factor B) an interaction effect was reported. The line graph showed that there is an interaction between the two factors, but the interaction appeared not to be statistically significant. This result suggested that the type of lab environment used appeared not to have a different effect on students' score when combined with either implicit or explicit task instructions. This may imply that the different combinations of written task instructions and lab environment may not significantly affect students' scores in a series-parallel circuit task.

The effect size revealed a higher value for both lab environment ($r = 0.36$) indicating that the effect size is medium compared with task instruction ($r = 0.063$) small effect size. Although statistical analysis showed that the effect may not be significant, there appears to be a clear difference between the two main effects. Consequently, it can be said that there appears to be an effect for lab environment on students' scores. When students used the virtual environment to complete the task, they appeared to demonstrate (on the average) a slightly higher understanding of series-parallel circuit (based on higher scores) than when they used physical environment. However, the effects of task instructions appear to only have minimal effect on students' scores. This means that when students were presented with explicitly written instructions (ignoring the type of environment used), the difference in their scores compared with the implicit was very small (see effect size above).

It can be seen from table 4.5 that when students were using implicitly written instructions in a virtual environment (Vir+Imp), higher scores were recorded compared to

when explicit instructions were used in a physical environment (Phy+Exp). This result is consistent with previous studies (Kollöffel, & Jong, 2013; Olde et al., 2013). The other findings included: Vir+Exp recorded higher scores than Vir+Imp conditions (Ardac, & Sezen, 2002); Vir+Exp treatment scored higher compared with Phy+Exp (Finkelstein et al., 2005); Vir+Imp recorded higher scores than Phy+Imp; and Phy+Exp reported higher mean score than Phy+Imp. Overall, students' scores tend to be highest when they used explicitly written instructions to complete task in a virtual environment. Likewise, students had lowest scores when they used implicitly written instructions in a physical environment.

The next chapter discusses the significance of these results. It will also discuss the limitations of this study; the implications of results for both research, and educators; and also suggests possible future research area.

CHAPTER V

DISCUSSION AND CONCLUSIONS

The purpose of this study was to investigate the effect of different written task instructions (implicit versus explicit) and lab environment (physical versus virtual) on students' scores in completing an electronic circuit task. Specifically, the study looked at how using written task instructions in different lab environments affected students' scores in completing a series-parallel circuit exercise. Students' scores were evaluated by assessing their understanding of series-parallel circuit using two different written task instructions and lab environment. Students' understanding of series-parallel circuit were measured as determined by students' individual scores and time. Table 5.1 outlines the areas discussed in this chapter.

Table 5.1. Chapter 5 Outline

1. Overview of Study
2. Restate Research Questions
3. Discussion on Study Findings
4. Implication of Findings
5. Suggestion for Future Research
6. Limitation of this Study
7. Conclusion

Overview of Study

This study originated from the researcher's interest to determine students' knowledge, understanding including their application skills in a series-parallel circuit task. More importantly, the researcher was interested in examining the effect of using written task instructions with different lab environments on students' scores in completing a series-parallel circuit exercise. This was based on the rationale that only few studies have investigated the combination of these variables (task instructions and lab environment) to examine their effect in a single study. Moreover, Farrokhnia and Esmailpour (2010) suggested that there is no framework that describes the most appropriate methods for implementing physical and virtual environment to achieve desired goals. Thus, this study was directed at providing data that could help in developing a future framework for written task instructions and lab environments.

This study was a quantitative experiment that used a repeated-measure design to determine if the task instructions and lab environment had any effect on students' scores. The experiment consists of four treatment conditions involving four different tasks of similar difficulty levels (see figure 3.1). Each activity was graded, and scores were recorded. Students' task scores were compared across all four treatments. The purpose of these tasks was to investigate how students demonstrated an understanding of series-parallel circuits using written instructions in both physical and virtual environments to complete an electronic circuit activity.

Research Questions

1. How do the written task instructions provided to students significantly affect their scores on the assigned activities?

2. How do the lab environment used by students significantly affect their scores on the assigned activities?

3. What significant interaction (if any) exists between written task instruction and the lab environment used by students to complete the activities?

Discussion of Study Findings

Research Question 1: How do the written task instructions provided to students significantly affect their scores on the assigned activities?

The data suggested that the written task instructions used did not significantly affect students' scores at $p < .05$. The computed effect size ($r= 0.06$) was very small and only accounted for 1% of the total difference. This result means that there was no significant difference in scores when students were presented with either implicit or explicit instructions (ignoring the type of lab environment used). This implied that students did equally well using both the implicit and explicit instructions. The similarity between the effects of the two written instructions may be due to several factors.

In the implicit task (see Task Performed section in chapter 3 page36), students were not specifically required to reflect deeper about the task they performed. So, it could be that students may not have taken necessary time to think while they were completing the task. Hence, students may have interacted with the implicit and explicit task instructions in a similar manner, thereby minimizing the distinct influence of the task

instructions. This could be the reason why students performed well in both task instructions. Previous studies have identified similar occurrence. For instance, Swaak, De Jong and Van Joolingen (2004) conducted a study comparing the effect of implicit and explicit instructions on students' knowledge. They concluded that there was no difference in explanation knowledge between the implicit and explicit groups. Hence, Swaak et al. (2004) suggested that students may have performed task without contemplating on their actions in completing the activity, thereby erasing the distinct effect of implicit and explicit written instructions.

Additionally, the fact that this study found no significant difference between the task instructions may also be because the instrument was only measuring the lower level of the Blooms' taxonomy (knowledge, understanding and application). A similar result was reported by previous research. For instance, Veermans, Joolingen and De Jong (2006) compared the use of two learning environment in learning physics —collision. They measured the domain knowledge of 46 students in two different groups (explicit versus implicit). The Veermans et al.'s study concluded that both explicit and implicit equally supported domain knowledge acquisition. Veermans et al.'s study also measured the lower level of Blooms' taxonomy. Riche, (2014) suggested that implicit works better for developing higher-level thinking.

Research Question 2: How do the lab environments used by students significantly affect their score on the assigned activities?

The results of the data analysis suggested that the type of lab environment used did not statistically significantly affected students' scores at $p < .05$. However, the effect

size (r = 0.36, medium effect size) revealed that there may be practical significance differences between the type of environment used. The effect size accounted for 9% of the total difference, hence there is a medium effect of the lab environment on students' scores. This result means that when students used virtual environment to complete the task (regardless of type of instruction), they demonstrated a higher understanding of series-parallel circuit (higher scores) than when they used physical environment. Although, the result is consistent with the findings from previous studies (Finkelstein et al., 2005; Frederick, 2014; Gorghiu et al., 2009; Gopal et al., 2010), the underlining question is: Why did students score higher in virtual environment when compared with physical environment?

Jaakkola et al. (2011) and Chini et al. (2012) claimed that virtual environment can help learners focus attention on the most important element in the task. This may enable the student to concentrate on performing the task (if appropriately implemented), hereby reducing distractions. For instances, virtual environment may allow students to isolate and observe variables (such as current and voltage) independently for better understanding. Hence, this may explain why students had higher scores in the virtual environment compared with the physical environment.

The virtual environment can allow students to experiment by multiple practice which may be difficult in the physical environment (Nickerson et al., 2007). This may make it easier for students to construct circuits in the virtual environment than in the physical environment (Finkelstein et al., 2005). Similarly, Jaakkola et al. (2011) also argued that virtual environment offers a unique affordance that enables students to

visualize, experiment with circuit construction and measurement (if appropriately implemented). This unique feature of virtual environment may also explain why student performed better in the virtual environment.

Ma and Nickerson (2006) claimed that there are several compounding factors when researchers compare physical and virtual environment. One compounding factor is the assumption surrounding the similarity of both environments. This assumption may need to be revisited. This is because students may actually be interacting with both environments differently. For instance, table 5.1 below shows some differences in how students interacted with the physical and virtual environment when performing the task.

Table 5.1 Students' interacted with Physical and Virtual Environment

Physical Environment	Virtual Environment (Multisim)
Identify and select required resistor checking color codes for the resistance value	In multisim, identify and select the required resistor, virtual DC source, and DC ground
On the breadboard, use the vertical & horizontal holes to connect component to match the series-parallel circuit layout.	Drag and drop components in multisim workspace & connect component to match the series-parallel circuit layout.
Connect power source by observing the polarities and lead wires (red & black)	Connect DC source by observing the polarities (positive & negative side of the source)
Connect voltmeter & ammeter into the circuit on breadboard.	Connect virtual voltmeter & virtual ammeter into the circuit on multisim workspace.
Turn on the power source by pushing the power button & close circuit switch	Ensure the DC source is connected & close virtual circuit switch
Take measurements from physical instrument	Take measurements from virtual instrument

However, instructors may need to exercise caution when using virtual environment in the classroom. This is because Clark (1994) claimed that it is not technology (virtual environment) that causes learning but how it is effectively integrated into instructions. Ma and Nickerson (2006) argued that researchers may also have over-emphasize the success of technology in the classroom. Hence, a well-designed virtual environment might not be effective if it was wrongly implemented.

Research Question 3: What significant interaction (if any) exists between written task instruction and lab environment used?

The statistical analysis that tested the interaction effect between task instructions and lab environment indicated that there was no significant interaction at $p < .05$. The

computed effect size was very small and can only account for 1% of the total difference. Hence, the results suggested that the type of task instructions used in either physical or virtual environment had no different effect on students' score. In essence, the finding indicates that the type of task instructions used does not influence the effect of the environment and vice versa. Hence, the combination of the two factors (task instruction and lab environment) did not create a unique effect on students' score.

In a similar study, Jaakkola et al. (2010) compared the four different conditions: simulation with explicit (SE); simulation with implicit (SI); simulation and physical with explicit (CE); and simulation and physical with implicit (CI). Their study was carried out with 50 elementary school students using a pre and posttest to measure students' learning outcome. At the end of their study, they concluded that the type of instructions used affected students' performance in electronic circuit (De Jong, 2006). There are several reasons that could be responsible for the differences in findings of the Jaakkola et al.'s study and the current study. These reasons may include: the small sample size of the present work; and the age group of study participants— Jaakkola et al.'s study was conducted with elementary school students while the present work used university sophomore students. Therefore, the smaller sample size of the present study may have been responsible for the no significant interaction effect between the type of written instructions and the lab environment used by students in performing the task.

Implications of Findings

Implication for Educators

There are some implications of this study for educators, educational decision makers and policy makers. The findings of this study suggested that teachers and curriculum designers may better meet desired goals— learning or assessment— by understanding how best to integrate written instructions and lab environment to achieve set objectives. For instance, when designing an assessment tool, it is critical for instructors to identify the skill sets or abilities that they intend to measure in the lab. This will help in identifying the most appropriate written instructions to use in order to accomplish their set objectives. Evidence exists in literature to suggest that explicit instructions may be more effective in enhancing practical and equipment handling skills (Abraham, 2011; Tobin, Tippins, & Gallard, 1994). Similarly, Domin (1999) and Riche (2014) both claimed that implicit instruction may enable students to develop a higher thinking ability. Thus, instructors may want to consider using explicit and implicit instructions based specifically on desired learning goals. Therefore, instructors may need to pay closer attention to which type of written instructions will be most appropriate to achieve set goals.

Another implication of this study is that virtual environment (like Multisim) could be a viable tool when students complete electronic circuit task. This is because virtual environment could help students visualize electronic circuit concept, which have been identified as pedagogically challenging (Stavrinides, Taramopoulos, Hatzikraniotis, & Psillos, 2015). However, physical environment may produce similar effects. In both

environments therefore, care must be taken to ensure that instructions are appropriately presented to students. Conversely, introducing virtual environment in schools has its challenges. Virtual environment which mostly involves the use of software could be technically challenging and may require extensive training to operate. Moreover, the virtual environment (software) are mostly not designed to fit into the curriculum of the course. Therefore, instructors that intend to implement virtual environment may need to consider these other factors.

Implication for Research

The implication of this study for future research is that researchers may need to review the notion about the limitations of using explicit instructions (Klahr & Nigam, 2004). This is because explicit instructions may be valuable in helping students develop equipment handling abilities, and to promote low level skills (Riche, 2014). Hence, researchers may need to consider explicit instructions with the aim to providing more empirical data in order to make more factual judgements. Such preliminary empirical data could provide information for instructors about the effect of explicit instructions on students' performance.

Future research that intends to compare the implicit and explicit instructions may need to pay closer attention to the time frame of the experimental session in their study. This is because evidence exists in the literature which suggests that implicit instructions require a longer time of exposure to become obvious in students' performance (Dean & Kuhn, 2007; Kuhn et al., 2000). De Jong (2011) suggested that research which compared the effect of implicit and explicit instructions using a single shot assessment may not

have adequately examined the effect of implicit instructions. Therefore, it is important for future research to design instruments that will assess students' performance over a period of time rather than a one-time shot.

Suggestions for Future Research

Future researchers may wish to further investigate the effect of written instructions and lab environment on students' score with a larger sample size. Future studies may also consider these effect on time taken to complete task. This study initially intended to consider time, but during the data analysis, the time recorded by students was not utilized because of reliability issues arising from the fact that the time recorded by some students were inaccurate. The inclusion of time will enable a better understanding about how written instructions and lab environments can influence students' performance in the lab.

Future research may want to take note of variables that may impact the results of their study. Ma and Nickerson (2006) argued that researchers must attempt to isolate the important factors in their study in order to remove interfering variables. However, he admitted that it may be difficult to isolate all interfering variables. Consequently, future research may need to pay particular attention to the following factors: participants motivation, clarity of study instruments, sample size, and the experimental session timespan.

In addition, there is an opportunity for future researchers to develop a framework for integrating explicit and implicit instructions. This is because De Jong (2006) argued that it is challenging to finding the right balance when combining explicit and implicit

instructions. Finding the right balance may enable instructors answer the question: to what extent should explicit and implicit instructions be implemented in the classroom? Hence, enabling the research community to effectively propose an implementable framework on how explicit instructions can be implemented with implicit instructions.

Limitations of Study

One of the limitations of this study is the small sample size, which was due to the size of the class. Another limitation is the fact that the simulator software (Multisim) that was used may not be applicable to all forms of virtual environment. Additionally, the study was conducted with only technology students, therefore the findings may not be applicable to students in other fields of study.

Conclusion

This study examined the effect of written instructions and lab environment on students' scores in completing an electronic circuit task. The study findings suggest that the lab environment may have an effect on students' scores in the lab. Previous studies indicated that virtual environment may better enable students' concept knowledge. Yet, instructors may need to identify specific learning goals they intend to assess or teach before identifying the most appropriate environment. Findings of this study also suggest that students may perform well using either explicit or implicit instruction when assessing lower level skills.

Research in the past had examined how virtual can replace physical or how implicit can replace explicit instructions. However, more attention should be paid to studying how instructions and environment can be used to effectively complement one

another. This is paramount because of the need to investigate how the unique features of instruction and environment can be integrated to improve students' experience.

Conclusively, this study does not propose that instructors, decision makers, and educators ought to choose between the different lab environments (physical versus virtual), and written instructions (explicit versus implicit). On the contrary, this study recommends the need for educators to identify specific learning goals and then choose the most appropriate lab environment and instruction that will enable them to achieve desired goals.

APPENDICES

Appendix A
Participants Consent Form

Informed Consent Statement

Title of Project:	The Effect of Different Written Task Instructions on Students' Scores in a Physical and Virtual Environment.
Principal Investigator:	Ademola Amida, ademola.amida@NDUS.edu
Co-Investigator(s):	N/A
Advisor:	Dr. David Yearwood, david.yearwood@und.edu

Purpose of the Study:

The purpose of this study was to investigate the effect of different written task instructions (implicit versus explicit) and lab environment (physical versus virtual) on students' scores in completing an electronic circuit task.

Procedures to be followed:

Students will be asked to volunteer for the study through e-mail and/or words of mouth. A class session will be held for the student on series-parallel circuits and, then a short demonstration. A lecture script (handouts) will be given to student to further help in their understanding of series-parallel circuits. All participants experienced the four treatment conditions in the electronics lab at different times in a span of two weeks. The experiment consists of four treatment conditions involving four different activities of similar difficulty levels.

In the first week, participants will use physical environment with implicit instructions to perform activity 1.

The second week, participants will use virtual environment with implicit instructions to perform activity 2.

The third week, participants will use physical environment with explicit instructions to perform activity 3.

And then, in the final week, participants will use virtual environment with explicit instructions to perform activity 4. At the end of each activity, participants will answer record measurements taken.

Risks and Duration:

There are no risks in participating in this research beyond those experienced in everyday life. This study will last about 2 weeks. Each session/treatment should be about 20minutes.

Benefits:

- The study to be conducted will assist instructors in determining the most appropriate interventions (lab environment and written task instructions) needed to better help students achieve the desired learning outcome in electronic circuit course.
- This research might contribute to the body of knowledge and debate on the effectiveness of the difference lab. environment and written instructions in educational settings.

Statement of Confidentiality:

Participants will be asked not to provide their names or any identifying data on the assessment document. Participants in the study will only be identified with a four digit code for data analysis purposes only. All responses will be anonymous and kept confidential. Only the researcher conducting the study will have access to the data.

Right to Ask Questions:

The researcher conducting this study is Ademola Amida. You may ask any questions you have now. If you later have questions, concerns, or complaints about the research please contact Ademola Amida of investigator (at *701-777-3114* during the day.

Advisor contact: Dr. David Yearwood, david.yearwood@und.edu

If you have questions regarding your rights as a research subject, you may contact The University of North Dakota Institutional Review Board at (701) 777-4279. You may also call this number with problems, complaints, or concerns about the research. Please call this number if you cannot reach research staff, or you wish to talk with someone who is an informed individual who is independent of the research team.

General information about being a research subject can be found on the Institutional Review Board website "Information for Research Participants" http://und.edu/research/resources/human-subjects/research-participants.cfm

Compensation:

Voluntary participants will receive three extra credit points for their Tech 201 course at the completion of the experiment. You may withdraw from the study at any time without losing the course points assigned by your instructor. If you choose not to participate, please consult your course instructor on other methods to earn course points.

Voluntary Participation:

You do not have to participate in this research. You can stop your participation at any time. You may refuse to participate or choose to discontinue participation at any time without losing any benefits to which you are otherwise entitled. You do not have to answer any questions you do not want to answer. You must be 18 years of age older to consent to participate in this research study. Completion and return of the experiment document implies that you have read the information in this form and consent to participate in the research. Please keep this form for your records or future reference.

Appendix B

Series-Parallel Circuit Activities

Activity 1: Implicit Task Instruction in a Physical Environment

Objective: This activity is intended to measure students' performance using physical environment with implicit task instructions.

Instructions:

- All submissions are anonymous, and completion of this activity will NOT negatively impact your performance grade in this course. All participants will receive extra credit points for the completion of the entire package of lab activities—a total of four activities.
- Carefully complete the activity in each session of this lab, and record your readings in the table provided below.
- Please record the time taken to understand the instruction (Planning Time) and also record the time taken to execute the activity (Execution Time)

Planning Time: _______ Execution Time: _______

Procedure:

Using the breadboard, construct a circuit such that R_1 and R_2 are in series with a parallel combination of R_3, R_4, and R_5.

Determine the voltage drop V across and current I through each of the resistors using the multimeter. Record your results in Table below. (*This experiment must be completed using ONLY the breadboard*). Resistors values are $R_1 = 2.2k\Omega$, $R_2 = 4.3k\Omega$, $R_3 = 4.7k\Omega$, $R_4 = 1.0k\Omega$ $R_5 = 2.2k\Omega$. Voltage source $V_s = 12V$

Table

	Listed value	Measured Value Ω
R_1	2.2kΩ	
R_2	4.3kΩ	
R_3	4.7kΩ	
R_4	1.0kΩ	
R_5	2.2kΩ	

	V	**I**
R_1		
R_2		
R_3		
R_4		
R_5		

Activity 2: Implicit Task Instruction in a Virtual Environment

Objective: This activity is intended to measure students' performance using virtual environment with implicit task instructions.

Instructions:

- All submissions are anonymous, and completion of this activity will NOT negatively impact your performance grade in this course. All participants will receive extra credit points for the completion of the entire package of lab activities—a total of four activities.
- Carefully complete the activity in each session of this lab, and record your readings in the table provided below.
- Please record the time taken to understand the instruction (Planning Time) and also record the time taken to execute the activity (Execution Time)

Planning Time: _______ Execution Time: _______

Procedure:

Using multisim, construct a circuit such that R_1 and R_2 are parallel to a series combination of R_3, R_4, and R_5.

Determine the voltage drop V across and current I through each of the resistors using a multimeter. Record your results in Table below. (*This experiment must be completed using ONLY multisim software*). Resistors values are $R_1 = 4.7k\Omega$, $R_2 = 1.0k\Omega$, $R_3 = 4.3k\Omega$, $R_4 = 2.2k\Omega$, and $R_5 = 2.2k\Omega$. Voltage source $V_s = 12V$

Table

	V	**I**
R_1		
R_2		
R_3		
R_4		
R_5		

Activity 3: Explicit Task Instruction in a Physical Environment.

Objective: This activity is intended to measure students' performance using physical environment with explicit task instructions.

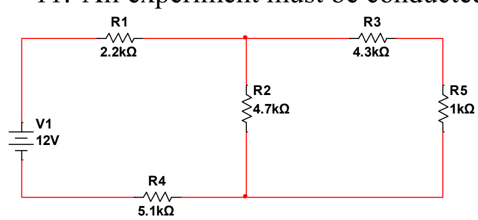
Instructions:

- All submissions are anonymous, and completion of this activity will NOT negatively impact your performance grade in this course. All participants will receive extra credit points for the completion of the entire package of lab activities—a total of four activities.
- Carefully complete the activity in each session of this lab, and record your readings in the table provided below.
- Please record the time taken to understand the instruction (Planning Time) and also record the time taken to execute the activity (Execution Time)

Planning Time: _______ Execution Time: _______

Procedure:

1. Select resistor values 1kΩ, 2.2kΩ, 4.3kΩ, 4.7kΩ, 5.1kΩ and a breadboard for this experiment.
2. Measure the actual resistance value with a multimeter, and record your readings.
3. First connect R_1 in series with the positive side of the source voltage.
4. Connect R_2 parallel with a series combination of R_3 and R_5, all in series with the source voltage and R_1.
5. Then, connect R_4 such that it is in series with the negative side of the source voltage and in parallel with R_2 and R_5.
6. Connect the circuit as shown below.
7. Measure the voltage drop V across each resistor, by placing a voltmeter across the resistors.
8. Record the voltage drops in Table below.
9. Measure the current through each resistor by placing the ammeter directly before each resistor.
10. Record the current values in Table below.
11. All experiment must be conducted using ONLY the breadboard.



Table

	Listed value	Measured Value Ω
R_1	2.2kΩ	
R_2	4.7kΩ	
R_3	4.3kΩ	
R_4	5.1kΩ	
R_5	1.0kΩ	

	V	**I**
R_1		
R_2		
R_3		
R_4		
R_5		

Activity 4: Explicit Instruction in a Virtual Environment

Objective: Objective: This activity is intended to measure students' performance using virtual environment with explicit task instructions.

Instructions:

- All submissions are anonymous, and completion of this activity will NOT negatively impact your performance grade in this course. All participants will receive extra credit points for the completion of the entire package of lab activities—a total of four activities.
- Carefully complete the activity in each session of this lab, and record your readings in the table provided below.
- Please record the time taken to understand the instruction (Planning Time) and also record the time taken to execute the activity (Execution Time)

Planning Time: _______ Execution Time: _______

Procedure:

1. Click on the multisim icon on your desktop. 
2. Open the component catalogue to select a components in multisim.
3. Select resistor values 1kΩ, 2.2kΩ, 3kΩ, 4.3kΩ, 4.7kΩ, in multisim for this experiment.
4. Select a source voltage of 12V and a common ground.
5. Drag and drop all the components, including the source voltage and the ground, in the multisim workspace.
6. First connect R_5 and R_3 in parallel.
7. Connect a parallel combination of R_3 and R_5 in series with R_2 on one side and R_4 on the opposite side.
8. Then, connect all combination of R_3, R_5, R_2, and R4 in parallel with R_1 and the source voltage.
9. Connect the circuit as shown below.
10. Select a voltmeter and ammeter from the component catalogue
11. Measure the voltage drop across each resistor, by placing a voltmeter across each resistor.
12. Record the voltage drops in Table below.
13. Measure the current through each resistor by placing an ammeter directly before each resistor.
14. Record the current values in Table below.
15. All experiment must be conducted using ONLY the multisim software.

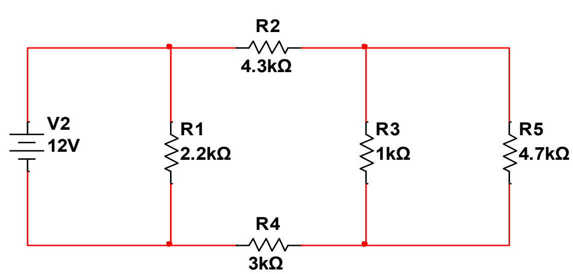


Table		
	V	I
R_1		
R_2		
R_3		
R_4		
R_5		

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