THE CONTRIBUTION OF SIMULATIONS TO THE PRACTICAL WORK OF FOUNDATION PHYSICS STUDENTS AT THE UNIVERSITY OF LIMPOPO

by

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ABSTRACT

Practical work is regarded as an essential part of learning; hence most tertiary institutions have included a practical component in their physics courses. There is a concern about the effectiveness of the practical work in most universities. The present study is a case study that assessed the contributions of simulations on Foundation Physics students' practical work. In assessing the contribution of simulations, two tests, Determining and Interpreting Resistive Electric Circuits Concepts Test (DIRECT) and the Test of Integrated Science Process Skills (TISP) were used. A class test, observations and worksheets from students' practical work were analyzed and interviews with a selected group were conducted. There were 20 Foundation Physics students participating from the University of Limpopo. Results indicated that the simulations contributed positively on students' understanding of electric circuits. However the study revealed that the students who did simulations do not differ from those who did not do the simulations with regards to the development of process skills.

KEY TERMS

Practical work, Simulations, Experiments, Laboratory, Students’ understanding, Foundation Physics, Electric circuits, Conceptual understanding, Science process skills

DECLARATION

I declare that

THE CONTRIBUTION OF SIMULATIONS TO THE PRACTICAL WORK OF FOUNDATION PHYSICS STUDENTS AT THE UNIVERSITY OF LIMPOPO

is my own work and that all the sources that I have used or quoted have been indicated and acknowledged by means of complete references

SIGNATURE DATE
(Motlalepula Rebecca Mhlongo)

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LIST OF FIGURES

TABLE OF CONTENTS

CHAPTER 1

ORIENTATION TO THE STUDY

1.1 Introduction

Foundation programmes in Mathematics and Natural sciences were introduced in many South African tertiary institutions with the aim of upgrading the students who did not perform well in their grade 12 results, and did not meet the required tertiary entrance requirements (Mundalamo, 2006). Entry into tertiary Physics streams is restricted to those students who performed well in Mathematics and Physical Science (Mundalamo, 2006). There is an educational gap that exists between high schools and tertiary institutions, especially the universities in South Africa (Grayson, 1996). Grayson argues that the gap is wider for students coming from black schools. Through support programmes (e.g. Foundation), the institutions can help the students who were not able to meet the entry requirements because of their poor performance (The International Panel, 2004 cited in Mundalamo, 2006). The University of Limpopo is one of the universities that offer a Foundation programme. Foundation Physics is one of the courses offered and students are expected to do practical work as part of their learning.

Some work has been done on the use of laboratories as part of science teaching and learning (Corter *et al.*, 2007). Researchers believe that laboratories play an important role in the education of future scientists and in particular physicists (Corter *et al.*, 2007). Nowadays a productive laboratory is considered to be a learner-centered environment. A good laboratory is one that promotes student curiosity, encourages a student to ask questions, develops creativity and promotes understanding (Aladejana & Aderibigbe, 2007). The laboratory setting is one major avenue for the learner to actively carry out experiments and construct new information onto his/her existing mental framework for meaningful learning to occur (Sherman 1995 cited in Aladejana & Aderibigbe 2007).

Some students feel bored when doing laboratory work because the work done in a laboratory simply verifies something already known to the student. It tends to reduce or eliminate the motivation to investigate (Thomas, 1972). Research has also suggested that while laboratory investigations offer important opportunities to connect science concepts and theories discussed in the lecture rooms and in the textbooks with observations of phenomena and systems, laboratory inquiry alone is not sufficient to enable students to construct the complex conceptual understanding of the contemporary scientific community (Driver, 1995), hence the introduction of computer simulations.

The use of computers in education started some decades back and many institutions in developed countries have adopted the use of computers especially in their laboratories. The number of students entering the field of science is increasing and it is more convenient to work with simulations when the number of students is large (Granland *et al.*, 2000). Research indicated that the use of computer simulations in the laboratory and in classrooms promote learning (Kennepohl, 2001). Simulations have advantages over hands-on experiments because they allow students to do more complicated experiments, obtain reproducible results more quickly and foster a deeper understanding of the experiments (Kennepohl, 2001). Simulations of experiments focus on trying to recreate the results of the real experiments while also duplicating some of the real-life visuals and audio information to students (Kennepohl, 2001).

Simulations normally used in Physics teaching are computer programs that have an implicit model or the behaviour of a physical system and that allows the students to explore and to visualize graphic representation (Concari *et al.,* 2006). The students can interact with the system by changing the parameters to the desired ones and observe the effect made by those changes. Although simulations may be seen as the fastest and the best tool, they cannot substitute real laboratory experiences but they can be used hand in hand with the intention of increasing the understanding of certain concepts (Concari *et al.,* 2006). Properly designed simulations used in the right contexts can be more effective educational tools than real laboratory equipment, both in developing student facility with real equipment and at fostering student conceptual understanding (Finklestein *et al.*, 2005).

This research examines the contribution of computer simulations to the practical work of students in Foundation Physics at the University of Limpopo (UL). The context of this study is the practical work with the Foundation Physics students at the Medunsa Campus of the University of Limpopo (UL). The Medunsa Campus of UL is a twin sister of the Turfloop Campus and they were established on the 1st January 2005 after the merger of the then University of the North (Unin) and the Medical University of South Africa (Medunsa).

1.2 Rationale of the study

The mission statement of the Department of Physics at the Medunsa campus of the University of Limpopo states that: "*We develop human capacity to meet the needs of industry, public sector and community*". In order to meet the needs of industry, science students have to undergo laboratory practice.

The laboratory has been given a central and distinctive role in science education; science educators have agreed that there are more benefits in learning from using laboratory activities than learning from the book only (Hofstein & Lunetta, 1982). In most tertiary institutions students have to do both the theoretical and the practical component in order to pass a physics module. It is widely accepted that science is better taught using the discovery method or the experimental approach (Aladejana & Aderibigbe, 2007). Piaget (1969) for example encouraged children to discover for themselves through spontaneous interaction with the environment.

In most cases the laboratory is the place where more interaction is happening between students, because they work in groups. For learning to occur the laboratory environment has to be favourable or user friendly, because research has shown that laboratory environments affect students' learning outcomes (Aladejana & Aderibigbe, 2007). Improving the quality of the laboratory environment, will improve the academic performance in science and ultimately the enrolment and retaining of learning learners in science (Aladejana & Aderibigbe, 2007).

Research has strongly supported the use of computers as it is regarded as a catalyst for improving and enriching the learning and teaching environment (Kadiyala & Crynes, 1998). In other countries where computers are used, students demonstrated a more favourable attitude towards learning with computers than with direct instruction such as lecture notes, tutorials and traditional way of doing experiments (Chambers & Sprecher, 1980).

1.3 Context of the study

Students at the Medunsa Campus of the University of Limpopo are expected to complete both a practical and theoretical component successfully to be credited Foundation Physics at the end of the year. It is presented within a semester system. The practical component is conducted as a three hours session once a week. Students are provided with a practical manual that outlines what is expected from them, like the laboratory rules and all the experiments that are going to be performed throughout the semester.

The researcher has been observing what was happening in the physics laboratories since 2004. The number of students entering the physics stream has been increasing every year because the university decided to lower the admission requirements due to the merger of the two universities. This makes life difficult in the laboratory because of the limited number of equipment available. Due to this constraint, students end up working in groups of four to five students per group. When students are more than two to three in a group, some become inactive and at the end very little learning occurs; from there the idea of introducing simulations in the laboratory originated.

1.3.1 The goals of practical work at Medunsa

Practical work was done as a standalone module previously at Medunsa. For example, sometimes students were doing electricity in theory but at the same time do mechanics practical work. The goal of the practical work was for students to work in groups in order to develop teamwork and interest in learning, develop experimental skills, like the use of instruments, drawing graphs and writing experimental reports, and not necessarily to develop conceptual understanding.

1.3.2 Procedure of practical work at Medunsa

At the beginning of the practical session, demonstrators will demonstrate the experiment and thereafter the students will perform the experiment. After every practical session students are expected to write a practical report on their own and submit it. This report will be marked by the tutor and at the end the report will contribute 40% towards their final practical mark. Their practical report should include the following:

(i) Aim; a concise statement of the purpose of the experiment.
(ii) Theory; a description of what the literature says about the particular concept in that experiment
(iii) Apparatus; a list of the equipment required and sometimes a diagram showing the setup

(iv) Method / Procedure; a detailed description of the procedure to be followed and data to be collected.

(v) Results and Analysis; detailed procedure for recording the data and applying science concepts and theoretical formulae to achieve the aim of the experiment

(vi) Discussion and Conclusion; instructions for stating concisely what had been learned from the experiment.

One of the changes introduced by this study was to incorporate theory while doing practical work. When the students are doing electricity in class as part of the lectures, they are also doing practical work on electricity because practical work should promote learning and these two components are interrelated. Practical work in science education is designed to promote science learning and is determined by the particular goals and aims of the science education program (Bradley, 2005). The practical work is no longer for skills development only; it is now promoting learning as well.

1.4 Aim of the Research

The aim of this study was to determine the contribution of computer simulations to the practical work of students in Foundation Physics at the University of Limpopo (UL). This study looked at the contribution of the simulations regarding four aspects; students' understanding of electric circuits, development of science process skills, goals of practical work at Medunsa and the use of laboratory apparatus. The reason for choosing electric circuits is because students experience problems with electric circuits. The research was done where 500 university students were given three simple circuits, one circuit had a single bulb; another had two bulbs in series; the third had two bulbs in parallel. Students were asked to rank the five bulbs according to relative brightness and to explain their reasoning. This comparison required no calculations. Only 15% of the students gave the correct ranking (McDermott, 1993). During the second semester the students have to complete the module on Electricity and Magnetism in class; hence I decided to focus this study on electric circuits.

More work was done in the laboratory and this study looked at the use of apparatus and also focused on the development of only five science process skills namely; identifying and controlling variables, stating hypotheses, operational definitions, graphing and interpreting data, and experimental design.

1.5 Research problem and research question

Due to the lack of sufficient apparatus at our campus because of the merger, the group size of students doing experiments has increased and therefore not all students participate in doing the experiments. We have a problem of students not understanding what they are doing because they depend on one another and at the end it affects their performance. Since Granland *et al.* (2000) stated that it is convenient to use simulations when working with a large number of students, therefore this research. The contribution of simulations to the practical work of Foundation Physics students at the University of Limpopo was investigated. This research seeks to answer the following research question:

What is the contribution of simulations to the practical work of Foundation Physics students at the University of Limpopo?

The following are the sub-questions:

(a) In what way could simulations contribute to students' understanding of electric circuits?

(b) In what way could simulations contribute to the development of science process skills?

(c) What contribution could simulations make with regards to the goals of practical work at Medunsa?

(d) Can simulations replace laboratory equipment to alleviate the problem of a large number of students and limited apparatus?

1.6 Definitions of terms

For concepts to carry any meaning within a study, they need to be defined in clear, non-ambiguous and agreed upon-way (Kalanda, 2005). The process of defining concepts is essential because it allows for specific contexts to be described and explained in a manner that pertains to the study (Kalanda, 2005). The words practical work, experiments and laboratory work can be confusing to many. For clarity, in this study, practical work, laboratory work, experiments and simulations will be defined.

1.6.1 Practical work

Practical work is all those teaching and learning activities in science which involve students at some point in handling or observing the objects or materials they are working with (Millar *et al.,* 1999). Kirschner (1991:61) define a practical work as "a powerful method of learning and practicing all activities involved in science".

1.6.2 Laboratory work

Laboratory work has been defined by Hegarty-Hazel (1990) as a "form of practical work taking place in a purposely assigned environment where students engage in planned learning experiences, and interact with materials to observe and understand phenomena".

1.6.3 Experiments

Hegarty-Hazel (1990) presented the experiments as part of the laboratory work. For the purpose of this study I will define experiments as a set of instructions followed by the students with the aim of verifying a certain concept or law. They follow a procedure and set up the apparatus, collect data, apply theory, record the results, draw conclusions and write the experimental report. Experiments assist theory building and theory, in turn, determines the types of experiments that can be performed (Hodson, 1988).

1.6.4 Simulations

Thompson *et al.* (1996) defined simulations as the representation or model of an event, object, or some phenomenon. In science education a computer simulation is the "use of the computer to simulate dynamic systems of objects in a real or imagined world" (Akpan & Andre, 2000). Simulations in this research refer to the computer program which allows visualization of the graphic representation of a real life situation on the computer.

1.7 Summary of the chapter

Due to increasing numbers of students it is difficult to accommodate the students for laboratory work. The contribution of simulations on the practical work of foundation physics students with regards to electric circuits was investigated as well as the contribution of simulations on the development of 5 integrated science process skills. The contribution of simulations based on the goals of practical work at Medunsa and the use of apparatus were also looked at. In this chapter, the background of the study was discussed and the rationale of the study was also outlined. The aim and the question that this study was based on were discussed briefly. Finally the terms were defined. In literature the word practicals was used whereas in this study it was referred to as practical work.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Several years ago Arons (1993:278) cited in Trumper (2003) wrote:

> *"The usefulness and effectiveness of the introductory laboratory have been bones of contention in physics teaching as far as one cares to go back in the literature. Laboratory instruction is costly, and, since its effectiveness has been difficult to substantiate compellingly, some responsible administrators have viewed it is a luxury we cannot afford. Yet most physicists have a deeply rooted, intuitive feeling that laboratory experience is essential to learning and understanding our subject, and they fight hard for maintaining such instruction in the face of frequently expressed doubts and occasionally formidable opposition".*

It is hard to imagine learning to do science, or learning about science, without doing laboratory or fieldwork. Laboratories are wonderful venues for teaching and learning science. They offer students opportunities to think about, discuss, and solve real problems (Trumper, 2003). Over the years, many scientists have argued that science cannot be meaningful to students without worthwhile practical experiences in the laboratory, that is the reason why all the physics I courses in SA have a practical component. Laboratory instruction was considered essential because it provided training in observation, supplied detailed information and aroused students' interest (Moyer, 1976). According to Kirschner (1992) practical work is best suited for the acquisition of cognitive skills. Most scientists believe that the hands-on experience of the science laboratory is a necessary supplement to the relatively passive experiences of reading textbooks and listening to lectures (Edelson *et al.*, 1999). Normative teaching practice in undergraduate physics courses at different institutions in South Africa and other countries used to be characterized by three activities: transmission mode lectures, tutorials and practical work (Buffler & Allie, 1995).

One way to improve learning could be to provide an additional connection between laboratory work and theory through computer simulations (Clark & DiBiasio, 2007). Many scientists and science educators are convinced that laboratory work plays an important role in learning science (Watson, 2000). In this chapter, the history of laboratory work, its role, and the problems experienced in the laboratory will be outlined. Simulations and its disadvantages will also be discussed, and lastly the theoretical framework will be presented.

2.2 History of the laboratory in science

Most of the curricula developed in the 1960s and 1970s were designed to make laboratory experiences the core of the science learning process (Shulman & Tamir 1973). Science in the laboratory was intended to provide experience in the handling of instruments and materials, which was also thought to help students in their conceptual development. Laboratory experiences have been purported to "promote central science education goals including the enhancement of students' understanding of concepts in science and its applications; scientific practical skills and problem solving abilities; scientific 'habits of mind'; understanding of how science and scientists work; interest and motivation" (Hofstein & Mamlok-Naaman, 2007:105). Trumper (2003) defines laboratory as a general name for activities based on observations, tests and experiments done by students. He further states that student laboratories have been an essential element of the physics curriculum for more than a century.

2.3 Role of practical work

Hodson (1988:53) considered that the terms practical work, laboratory work and experiments have been used to cover up confusion that failed to recognize that not all practical work is carried out in a laboratory, and not all laboratory work comprises of experiments. He presented experiments as part of laboratory work. Laboratory work is considered as a subset of practical work that is considered a subset of didactics of science education. (Figure 2.1). These terms were defined in chapter 1.

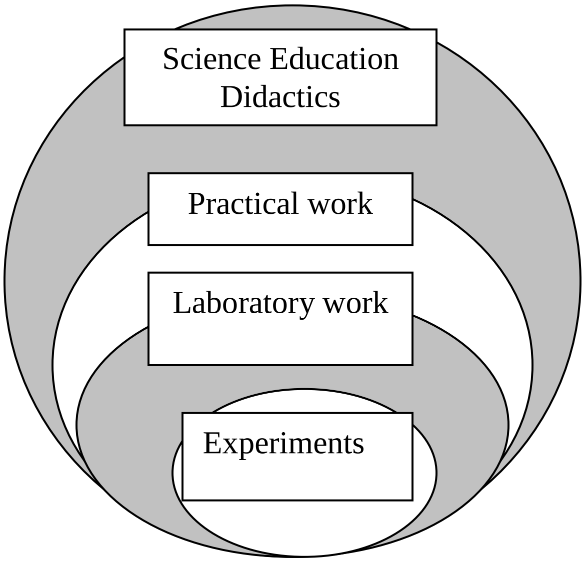


Figure 2.1 The interrelationship between experiments, laboratory work, practical work and didactics of science education (Hodson, 1988:54)

Singer *et al.* (2005:76) summarized the goals of laboratory work as follows:

- *Enhancing mastery of subject matter*. Laboratory experiences may enhance student understanding of specific scientific facts and concepts.
- *Developing scientific reasoning*. Laboratory experiences may promote a student's ability to reason scientifically.
- *Developing practical skills*. In the laboratory, students may learn to use the instruments provided. For example, they may develop skills in using scientific equipment correctly and safely, making observations, taking measurements, and following the procedures outlined.
- *Cultivating interest in science and interest in learning science*. As a result of the laboratory, students may become interested in learning more about science and see it as relevant to everyday life.
- *Developing teamwork abilities*. Laboratory experiences may also promote a student's ability to collaborate effectively with others in carrying out the tasks, to share the work of the task, to assume different roles at different times, and to contribute and respond to ideas.

Some of these goals are in line with the goals of laboratory work at Medunsa as outlined in chapter 1 (see 1.3.1).

2.4 Laboratory environment

A laboratory is a unique learning environment that is different from a lecture room in a way that students can work cooperatively in small groups to investigate scientific relationships (Hofstein, 2004). Furthermore, it fosters a unique mode of instruction, and provides a unique mode of learning environment (Hofstein, 2004). Instructional science laboratories are widely regarded as a key component of science instruction because most sciences are activity-based explorations into the natural world (Bajah, 1983). It is identified that the laboratory environment affects students' learning outcomes (Aladejana & Aderibigbe, 2007).

Lunetta (1998) suggested that laboratory activities have the potential to enable collaborative social relationships as well as positive attitudes towards science. Most of the laboratories have an informal atmosphere whereby students can move around and this creates a kind of atmosphere that enables students' opportunities for more interactions among themselves and their coordinator. It can also give them opportunities to develop their understanding because they can exchange their views. Research has reported that the more informal atmosphere, the more opportunities for more interactions and the healthy learning environment are conducive to meaningful inquiry and collaborative learning (De Carlo & Ruba, 1994, Tobin, 1990 cited in Hofstein & Lunetta, 2004).

Science is better taught using a discovery method or the experimental approach (Bajah, 1983). The learning environment and its determinants play a major role in improving activity-based teaching and learning (Aladejana & Aderibigbe, 2007). An important determinant of student learning is the environment. During inquiry, student social interaction is high, and therefore students must work in a risk-free environment (Brewer & Daane, 2002) where they are encouraged to ask questions, share ideas and engage in dialogue (Wolf & Fraser, 2007). All students must participate equally to ensure equal opportunities for each of them. Springer *et al.* (1999) cited in Benckert and Pettersson (2008:121) showed in a meta-analysis that students in undergraduate courses in science, mathematics, engineering and technology who learn in small groups in general show a greater academic achievement and express more favourable attitudes toward learning than students that have been taught in a more traditional setting.

2.5 Problems with practical work

Research on the use of practical work has shown that one of the major problems with the design and development of practical work in science education is the lack of explicit and valid goals (McDermott, 1991; Kirschner, 1992; Arons, 1993; and Nissani *et al.*, 1994 cited in Cilliers *et al.*, 1996:47). There is an overall agreement that laboratory work provides a poor return of knowledge in proportion to the amount of time and effort invested in it (Kirschner & Meester, 1988). They argued that it does not mean that practical work is not important, but rather that the skills and knowledge gained from this work is small as compared to the time and effort spent to gain this knowledge. The practical work will be meaningless if its goals are not defined.

2.6 Practical manuals

When the practical manuals dictate to students "*what to think*, *how to think*, and *when to think*, lab activities essentially lose impact for learning" (Pushkin, 1997:240). The students tend to have some difficulties with that. Hodson (1993:100) wrote:

> "*Frequently, they (students) are put into the position where they have to understand the nature of the problem and the experimental procedure (neither of which they have been consulted about), assemble the relevant theoretical perspective (with only minimum assistance from the teacher), read, comprehend and follow the experimental directions, handle the apparatus, collect the data, recognize the difference between results obtained and results that "should have been obtained", interpret those results, write an account of the experiment (often in a curiously obscure and impersonal language), and all the time ensure that they get along reasonably well with their partners".*

Every institution develops a practical manual or guide for their students. The guide gives the student the information about the experiments to be conducted. It also focuses students' attention on the questions to be investigated, and the procedure to follow in order to obtain the required results. Many students engage in laboratory activities in which they follow the recipe and gather and record the data as stated in the manual without a clear sense of the purpose (Fisher *et al.*, 1999). Laboratory manuals are filled with step by step recipe-type instructions to the students of a practical procedure which very often either verifies some physical law or demonstrate some physical phenomena (Buffler & Allie, 1995).

Previously at Medunsa the students were given a practical manual with all the experiments they will need to perform during the semester (See 1.3.2). The change that was introduced is to supply the specific worksheets to be used when doing the corresponding experiment. Those worksheets are developed in such a way that they will have to complete while doing an experiment, without having to submit the practical report.

2.7 Simulations

Since the introduction of the microcomputer several decades ago, researchers and educators have developed some mechanisms for using computers in the classrooms or in the laboratories (Finkelstein *et al.*, 2005). Sabelli (1995:7) cited in Trumper (2003) claims:

> "*We teach as we were taught. But what and how we learn have always depended on the tools available to students and teachers and should change with significant changes in the tools available. As the affordability of powerful microcomputers increases, educators become responsible for exploring the profound pedagogical implications of the changes brought about by technology on the practice of science*".

This use of computers in education has rapidly changed the way that students learn in a short period of time (Hodorowicz, 2000). An appropriate way for simulations in science education is to use them as supplementary material (McKinney, 1997).

2.7.1 Effectiveness of simulations

In an educational context, "a simulation is a powerful technique that teaches about some aspect of the world by imitating or replicating it. Students are not only motivated by simulations, but learn by interacting with them in a manner similar to the way they would react in real situations" (Alessi & Trollip, 1991:119).

Interactive simulations might bridge prior knowledge of learners and the learning of new concepts through an active reformulation of misconceptions (Jimoyiannis & Komis, 2001). Alessi and Trollip (1991) emphasized that a simulation simplifies reality by omitting or changing detail. In their study, Grabe and Grabe (1996:82) indicated that "the simplification allowed by simulations can help learners focus on critical information or skills and make learning easier". Simulations provide controlled learning environments that replicate key elements of real world environments and a simplified version of the real world that allows the student to learn a topic or skill very efficiently (Grabe & Grabe, 1996).

Simulations may be used as tools for scaffolding gender differences in instructional settings (Sahin, 2006). For example Choi and Gennaro (1987) in their study found that on hands–on laboratory experiences, males performed better on the post-test than females while when using the computer simulation in the learning of displacement concept there were no significant differences in performance when comparing males with females.

Though it is believed that most educators prefer real-life laboratory activities over using simulations, the simulation technology can provide the learner with numerous advantages. Michael (2001) mentioned the advantages of computer simulations. Simulations can:

- *Provide the students with the opportunity to engage in activities that may otherwise be unattainable.*
- *Enhance academic performance and learning achievement levels of students.* In a study conducted by Betz (1996), it was found that students who supplemented their class readings with the use of a computer simulator, performed better in their examination.
- *Be equally as effective as real life hands-on laboratory experiences.* Choi and Gennaro (1987) found that a computer-simulated activity was as effective as a hands-on laboratory activity in teaching the volume displacement concept.
- *Foster peer interaction.* Middle and high school students from surrounding school systems in Calgary, Canada volunteered to come one night a week to the University of Calgary. The exact number of participants was not specified in the report. The students spent an average of sixty hours with various computer simulations and reported their experiences in a log (Bilan, 1992). In their finding, the researchers noted that simulations were able to keep students of various abilities challenged and interested. The researchers also reported that students participating in the study often sought out peers to discuss problems, lend help, and share their experiences.

- *Provide students with immediate and reliable feedback.* By manipulating certain variables in the simulations, students can quickly obtain reliable data pertaining to lift and drag. Simulations of this type can also save students' time.

2.7.2 Disadvantages of simulations

Despite the advantages of simulation presented above, simulations do have their drawbacks. Though the advantages of computer simulations are encouraging, after an extensive review of the literature, no studies have been found addressing the effects of simulation technology on creativity (Michael 2001). Simulations do not encourage creativity (Michael 2001). Computer simulations emphasize discovery learning and the learner gains little from "discovery learning" from computer simulations (Min, 2001). The constructivists argue that computer simulations "oversimplify the complexities of real-life situations", giving the learner a "false understanding" of a real life problem or system (Heinich, *et. al.*, 1999). Finally, development of computer simulations may involve extensive planning and require significant investment of labour and financial resources.

2.7.3 PhET simulations

The Physics Education Technology (PhET) Project, known for its interactive computer simulations for teaching and learning physics, based at the University of Colorado in Boulder is a library of more than 80 free online educational simulations created for teachers and students that demonstrate principles in physics, chemistry, biology, earth science and mathematics (Perkins *et al.,* 2004). These engaging interactive simulations can be used in a classroom or in laboratories.

PhET simulations are developed using the results of education research and feedback from educators, and are tested in student interviews and classroom studies (McKagan *et al.,* 2008). Research by the PhET project on design and use of simulations in a variety of educational settings (Wieman *et al*., 2008) found that students doing a 2-hour exercise using the "Circuit Construction Kit" simulation in a one-semester course demonstrated higher mastery of the concepts of current and voltage on the final exam than students who did a parallel laboratory exercise with real electrical equipment.

The PhET project is an ongoing effort to provide an extensive suite of simulations for teaching and learning. The simulations are animated, interactive, and game-like environments in which students learn through exploration (Perkins *et al.*, 2004). The goals for PhET simulations are to increase student engagement in learning and improved learning. The simulations are designed to present an appealing environment to literally invite the students to interact and explore in an open-style play area. All controls are simple and intuitive, e.g., click-and-drag manipulation (Perkins *et al.*, 2004).

The PhET simulations are easy to use and user friendly because some students were using a computer for the first time, and were able to do the simulations. PhET group made their simulations available to everyone, because the simulations are written in either Java or Flash so that they can be run directly from the website using a standard web browser. In addition, they can be downloaded and installed (the entire website) onto any local machine for use offline. This is particularly convenient when student computer labs or lecture halls do not have an internet connection.

The simulations are able to show students what is not visible with the naked eye, for example the electric circuit simulation whereby a student can be able to see the flow of current (Finkelstein *et al.*, 2005). The circuit construction kit simulates the behaviour of simple electric circuits and provides an open space where students can manipulate the resistors, light bulbs, wires and batteries (Finkelstein *et al.*, 2005). A presentation of a screen is given in figure 2.2.

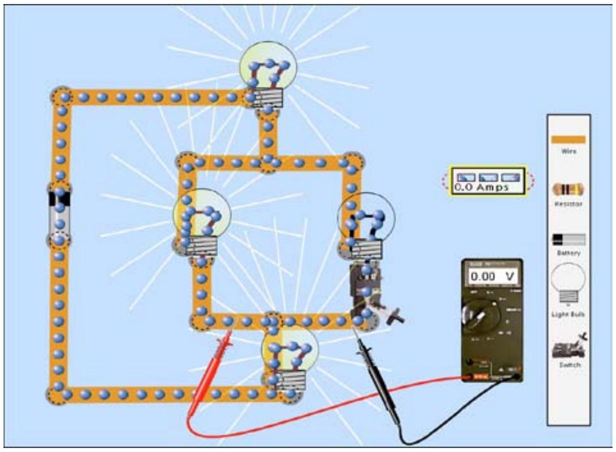


Figure 2.2 A simple electric circuit (Finkelstein *et al.*, 2005).

2.8 Instruments used to measure electric circuits concepts

Widespread test instruments such as the Force Concept Inventory (FCI) and the test of Understanding Graphs in Kinematics (TUG-K) have brought a new way of evaluating students' conceptual understanding (Engelhardt & Beichner, 2004:98). They felt that more instruments need to be developed in some other areas in order to allow instructors to evaluate their students' understanding of physics concepts. Therefore the Determining and Interpreting Resistive Electric Circuit Concepts Test (DIRECT) was developed to evaluate students' understanding of variety of direct current (DC) resistive electric circuits concepts (see appendix A). In their study, Engelhardt & Beichner (2004:99) mentioned that tests on DC resistive electric circuits do exist, but they have mostly been developed as either a research tool or curriculum assessment instrument, not as a general assessment tool. Hence, there are some limitations with many of these tests. The reliability and validity of the test is discussed in 3.5.

The development of DIRECT was motivated by the fact that, research revealed that students view electric circuits diagrams as a system of pipes within which a fluid flows that they refer to as electricity. Students have difficulty identifying series and parallel connections in diagrams. Students do not understand and do not correctly apply the concept of a complete circuit (Engelhardt & Beichner, 2004:98). DIRECT was developed to address the problem.

2.9 Process skills

Process skills are a means for learning and are essential to the conduct of science (Georgia Department of Education, 1999). Simulations can activate science process skills of students, which are the basic skills for scientific inquiry (Roth & Roychoudhury, 1993). These skills are classified in two main groups: basic science process skills and integrated science process skills. Padilla (1990) listed basic science process skills as observing, inferring, measuring, communicating, classifying, and predicting. According to Padilla (1990) the integrated science process skills are identifying and controlling variables, operational definitions, stating hypotheses, graphing and interpreting data, and experimental design.

Physics is an experimental science, observation, measuring and theoretical speculations are processes that cannot be separated from the physical knowledge construction (Concari *et al.*, 2006). Concari *et al.* (2006) continued to state that simulations should not be conceived as substitutes of the real laboratory experiences. Students should do both simulations and hands-on experiments in the laboratory to experience and develop the use of science process skills. Harlen (1999) suggested that science process skills should be a major goal of science education because science education requires learners to learn with understanding. It is for this reason we introduced simulations at Medunsa to see what contributions they have on the development of integrated science process skills.

2.9.1 Science process skills tests developed outside South Africa

Several researchers developed instruments to measure the process skills that are associated with inquiry and investigative abilities, as defined by Science: a Process Approach (SAPA), and the Science Curriculum Improvement Study (SCIS) (Dillashaw and Okey, 1980 cited in Kazeni, 2005). Tests were developed for different levels. Dillashaw and Okey (1980) developed a test to assess secondary school learners' competence in methods and procedures of science. Tannenbaum (1971) developed a test for use in middle and secondary school levels (grade seven – grade nine). This test assessed skills of observing, comparing, classifying, quantifying, measuring, experimenting, predicting and inferring. Dillashaw and Okey (1980) developed a more comprehensive Test of Integrated Science Process Skills (TIPS), which included the integrated science process skills, such as identifying and controlling variables, stating the hypotheses, designing experiments, graphing and interpreting data, and operational definitions. In 1985 Burns, Okey and Wise made a follow up on TIPS and developed a similar test with 36 items called Test of Integrated science Process Skills II (TIPS II).

2.9.2 Science process skills tests developed in South Africa

There was a need for the development of a science process skills test in South Africa because most of the tests available were not developed in South Africa. Prior to 2005 there was no published test developed and validated in South Africa. According to Kazeni (2005:19) it became imperative to develop and validate the test instrument that "would help access learners' acquisition of those skills as a diagnostic measure, as well as a competence one". Kazeni (2005) developed a valid and reliable test that has the characteristics that fall within the accepted range of values of validity, reliability, discrimination index, index of difficulty, readability, and that is not biased against any designated sub-group of test takers. The developed instrument is called the Test of Integrated Science Process skills (TISP) developed for further education and training (FET) learners (see appendix B).

Kazeni (2005:82) argued that, “though the foreign developed tests of science process skills such as the Test of Integrated science Process Skills (TIPS) are valid and reliable when used for the target population; they are likely to disadvantage South African learners in a number of ways. The main disadvantage being that, the technical language and the examples used in these tests are sometimes unfamiliar to the South African beginning science learners. As a result, learners may perform poorly, not because they are incompetent in the science process skills being tested, but because they are unable to relate in a meaningful way to the language and examples of the tests”. TISP developed by Kazeni (2005) was adopted in this study because the language and the examples used are relevant for the South Africans.

2.10 Students’ understanding

The events in science curriculum consist of many types of concrete concepts. If students do not understand these concepts as scientists do, these conditions are described as misconceptions, preconceptions, alternative concepts and children’s science (Lee & Law, 2001) and they are mostly grasped before formal education (Osborne & Freyberg, 1985). However, the correct understanding of main science concepts is not possible by using mathematical equation and formulas in explaining concepts (Frederiksen & White, 2000). Research on students understanding of science showed that students have wide range of misconceptions in the area of simple electric circuits (McDermott, 1993).

One of the most important goals of teaching is to help students understand the course material, and the goals for science students is to obtain a grade that will facilitate academic and professional advancement. Most of science education researches have focused on the question of which teaching strategies are best for improving students’ learning and overall course performance (Soto & Anand, 2009). Soto & Anand (2009) in their study “factors influencing academic performance of students enrolled in a lower division Cell Biology core course” found that the laboratory component might have been an important instructional tool, as most students who performed well in this component passed the course**.** That is, students who performed well in the lecture also performed well in the lab. It is for this reason that laboratory work should be done concurrently with the theory.

2.11 Foundation programme

Teaching of mathematics, physics and chemistry in many South African schools is in a critical state and many students go to the university with an academic disadvantaged background (Mundalamo, 2006). These students have to go through a form of preparation before they can be admitted into the mainstream courses. At the University of Kwa-Zulu Natal the Science Foundation Programme is a one year access program for students from disadvantaged schools who are interested in a science degree but do not meet the entry requirements for it and do not have matriculation exemption. Those who are admitted are provided with a full year of foundational pre-university level modules, which currently include Mathematics, Physics, Chemistry, Biology and Communication in Science. The then University of the North Foundation Year (UNIFY) and the University of Pretoria Foundation Year (UPFY) are examples of Foundation programmes that run for one full academic year (Netshisaulu, 2002). The aim of the Foundation Programme at Medunsa is to equip students with both theory and practical work so that they can meet the demands of a Physics I course. The structure and the admission criterion of the foundation programs differ from institution to institution based on the goals of the institution.

2.12 Theoretical framework

This study has adopted the Theoretical Model for Science Practical work as developed by Bradley (2005:74). The model has evolved from the theoretical framework provided by Ausubel (1963), Novak (1978), and Elton (1987) quoted in Bradley (2005).

From this theoretical model, eight types of science practical work have been identified, namely:
Open Inquiry/Problem Solving, Undirected Activity, Directed Inquiry/Problem Solving, Laboratory Experiment, Skill Development, Demonstration, Directed Activity and Creative Feedback. Each type of practical can be located in one of the quadrants: MEANINGFUL/ DISCOVERY, DISCOVERY/ROTE, ROTE/RECEPTION, or RECEPTION/MEANINGFUL (Bradley, 2005:74).

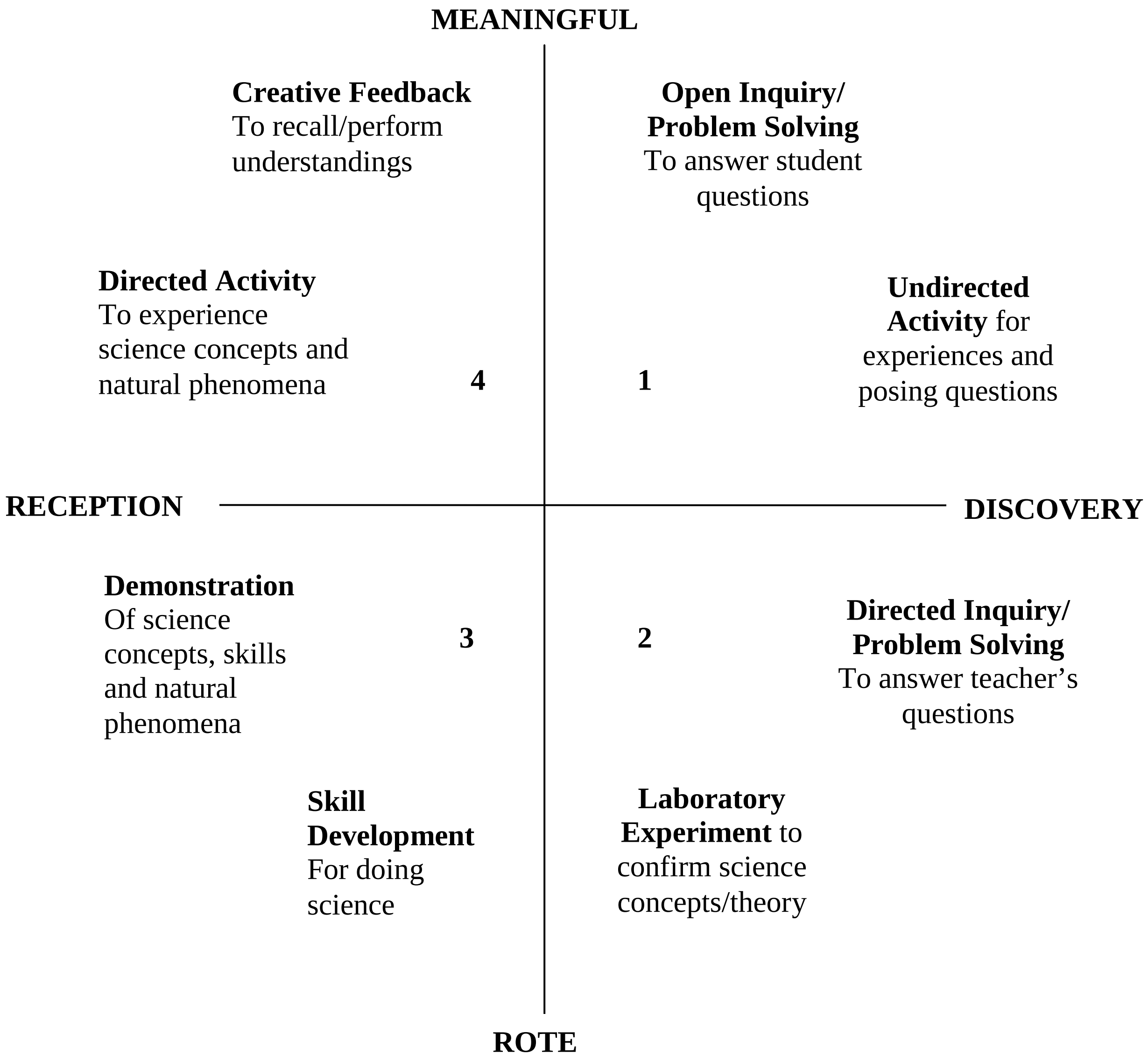


Figure 2.3. The Theoretical Model for Science Practicals, after Ausubel, Novak and Elton (Bradley, 2005:74).

Bradley (2005) in his PhD work discussed the 8 types of practical work as follows:

1. Open Inquiry/Problem Solving is the active search for understanding, to answer questions raised, or resolve problems posed, by students. The students plan the inquiry/problem solution, carry out the inquiry/trial, and answer the question/solve the problem.

2. Undirected Activity is informal hands-on activities, including, for example, play, trial and error, and tinkering; to increase student experience of science phenomena, leading to the posing of questions and identification of problems.
3. Directed Inquiry / Problem Solving is when students seek understanding by answering the teacher's questions. The teacher sets the inquiry question, then the students plan the inquiry solution, carry out the inquiry/trial, and answer the question/solve the problem.
4. Laboratory Experiment is associated with students performing an experiment given a practical manual with the procedure in order to confirm science concepts.
5. Skill Development is when the students uses the science process skills such as to observe, measure, infer, classify, collect and record data.
6. Demonstration is where the expert demonstrates to the learner how the practical should be done.
7. Directed Activity is where the learner is presented with the content to be learned.
8. Creative Feedback is when students demonstrate their understanding through performance activities, such as group discussions, investigation reports, problem solution reports and construction of charts.

Presently at Medunsa, from the eight types of science practical work on the theoretical model only four are utilised, namely: Laboratory Experiment, Skill Development, Demonstration, and Directed Activity. Looking at the theoretical model in figure 2.3 and comparing it with what is done at Medunsa, it is acknowledged that in the 1st quadrant, there is no practical activity, in the 2nd quadrant, only one type namely 'laboratory experiment, in the 3rd quadrant, all the practical types and in the 4th quadrant the only type is 'directed activity'. The model used at Medunsa is represented in figure 2.4 below. The basis of practical work at this university is therefore mostly of a role/reception nature. The TF model can address the question of in what way could the simulation contribute to students' understanding. Simulations can be used in the second quadrant to verify the laws or confirm the science concepts. They can also be used in conjunction with laboratory experiments in the second quadrant as skill development as well as demonstration. Demonstration does not require independent discovery by the learner, the demonstrator will demonstrate first before the students can do the simulations themselves. Directed activity in the fourth quadrant requires direct action by the students through simple practical activities. Students will record their observations on the worksheets provided.

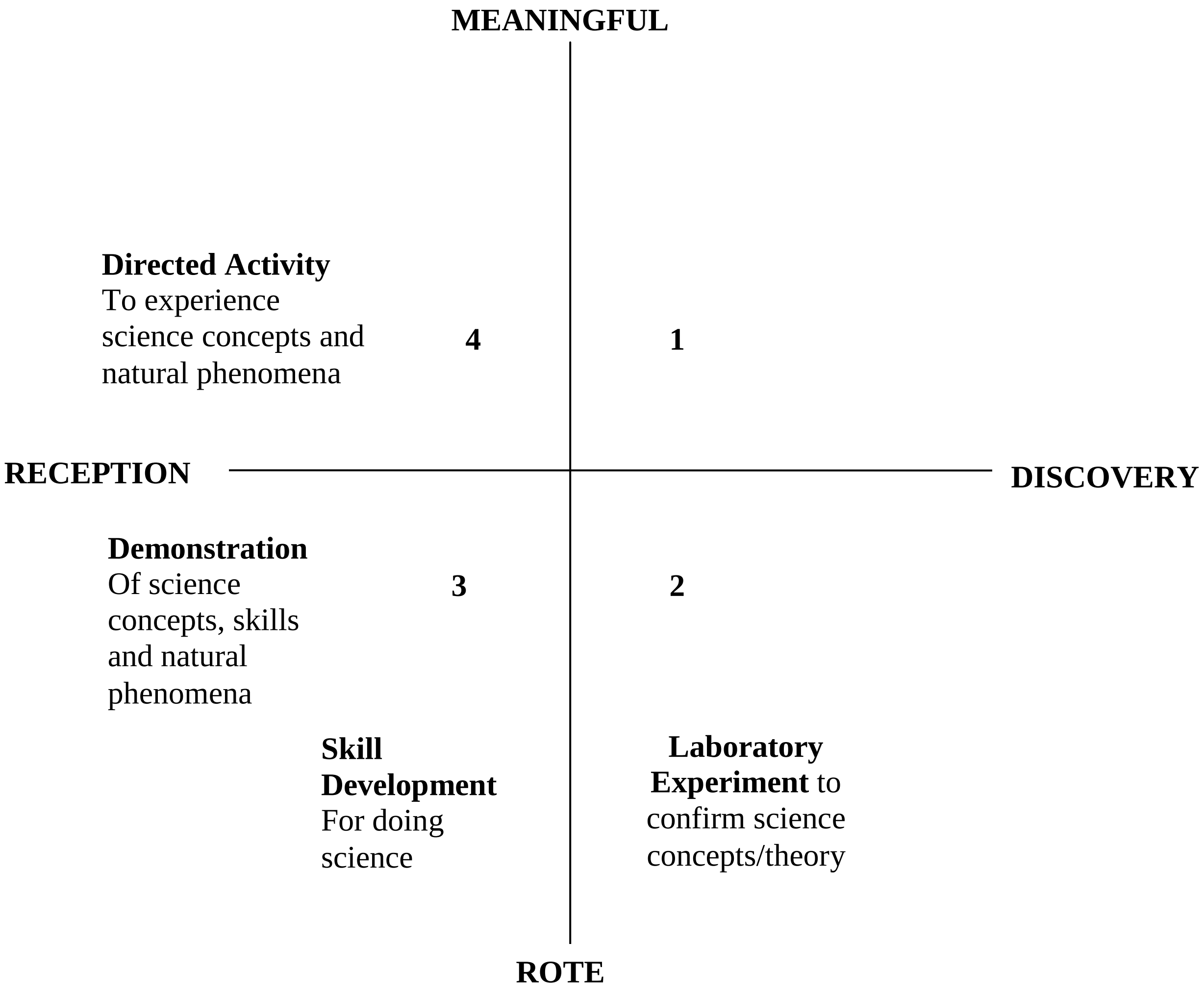


Figure 2.4. The Theoretical Model for Science Practicals at Medunsa.

2.13 Summary of the chapter

This chapter discussed the history of the laboratory and the role that the laboratory plays in science. Even though the practical work might seem important in science studies, it has its own problems. Therefore this chapter outlined the problems experienced in the laboratory. Simulations seemed to be a part of the solution for the problems in the laboratories and they were discussed together with their disadvantages. The theoretical framework model adopted by this study was developed by Bradley (2005).

CHAPTER 3

RESEARCH DESIGN AND METHODS

3.1 Introduction

The research began with a literature review on the interrelationship between experiments, laboratory work and practical work. This chapter presents the research design, sample, data collection instruments and procedure followed when collecting data. The methods for data analyses are discussed. The research methods were based on the aim and the research questions as outlined in chapter 1 (see 1.5).

3.2 Research sample

The population for this study is all the Foundation Physics students at Medunsa. Fifty two students were enrolled for Foundation physics. These students were divided into two groups during the practical work, one group (24) were doing electric circuits whereas (28) were doing magnetism. The available sample was 24 students. From the 24 students, 23 volunteered to take part in the research but 3 students did not come for all the tests. The other students lost interest along the way, hence the researcher ended up with 20 students. The twenty students were then randomly selected by arranging their surnames in alphabetical order and the first one was taken to the experimental group and the second one to the control group until the last one; at the end ten were in the experimental group and the other ten in the control group. This study focused on two groups, one group that received a treatment (the experimental group) and the other group that did not receive a treatment (the control group). Both the experimental and control groups wrote all the tests that will be discussed later. The experimental group did two experiments with simulations. After the intervention both groups went to the laboratory to do the laboratory work. Simulations were the treatment that the experimental group received. Because this study is based on electric circuits, the practical work was limited to two experiments on electric circuits. The experiments were “series and parallel connection of resistors, and Ohm’s law”. The duration for each experiment was three hours. Both experiments were also done in the laboratory with real apparatus.

3.3 Research design

A research design is guided by what the researcher wants to know and how data will be collected (Mark, 1996:28). According to Bless and Higson-Smith (1995:63), a research design is the planning of any scientific research from the first to the last step as for example shown in the flow chart (see figure 3.1). It is pertinent in a research study that the researcher specifies the major procedures he/she adopted. The study adopted the case study design. In the light of this research, a case study design was the most appropriate design to successfully investigate the problem and to serve the purpose of this study. The case is a unit of analysis: it can be an individual, a family, a work team, a resource or an institution. Each case has within it a set of inter-relationships which both bind it together and shape it, but also interact with the external world (Edwards & Talbot, 1999:51).

This case study describes the Foundation Physics students at the University of Limpopo who are doing practical work. A case study is an “empirical enquiry that explores a contemporary phenomenon within its real-life context when the boundaries between the phenomenon and context are not clearly evident and in which multiple sources of evidence is used” (Yin, 1994:13). Creswell (2003:15) define case study as “researcher explores in depth a program, an event, an activity, a process, or one or more individuals”. A case study should have a defined time frame; therefore this study was done for a period of six months.

3.4 Data collection instruments and procedure

Data was collected from the two groups. The students were initially given the DIRECT test to evaluate their prior knowledge of electric circuits as well as their understanding (see 3.4.1). This test was used as baseline information to evaluate their understanding before the electricity module was introduced in class. On the test the space was provided where students had to indicate their reason for selecting their answer. Those reasons were analyzed. The second test was TISP (see 3.4.2), to test their integrated science process skills namely; identifying and controlling variables, stating hypotheses, operational definitions, graphing and interpreting data and experimental design. This test does not concentrate on physics only; it concentrates on science in general. The intention was to test whether the students can for example identify the variable given a statement before they do the practical work. Prior to the laboratory sessions, the experimental group went to the computer laboratory to do simulations and completed the worksheets (see appendix C).

Afterwards, both groups did the experiments in the laboratory and completed the same worksheets. While doing the experiments in the laboratory the researcher was observing the two groups by using an observation schedule (see table 4.2). DIRECT and TISP were administered as post tests by both groups after attending theory classes and completing the practical work. Again their reasoning on the DIRECT test was evaluated. In addition a class test (see appendix D) which consisted of conceptual questions was written in class. Finally, six students were identified for the interviews, to supplement the data collected. The students were selected for the interviews based on their performance on the DIRECT pre test. The procedure followed is shown in figure 3.1 and the instruments used are discussed next.

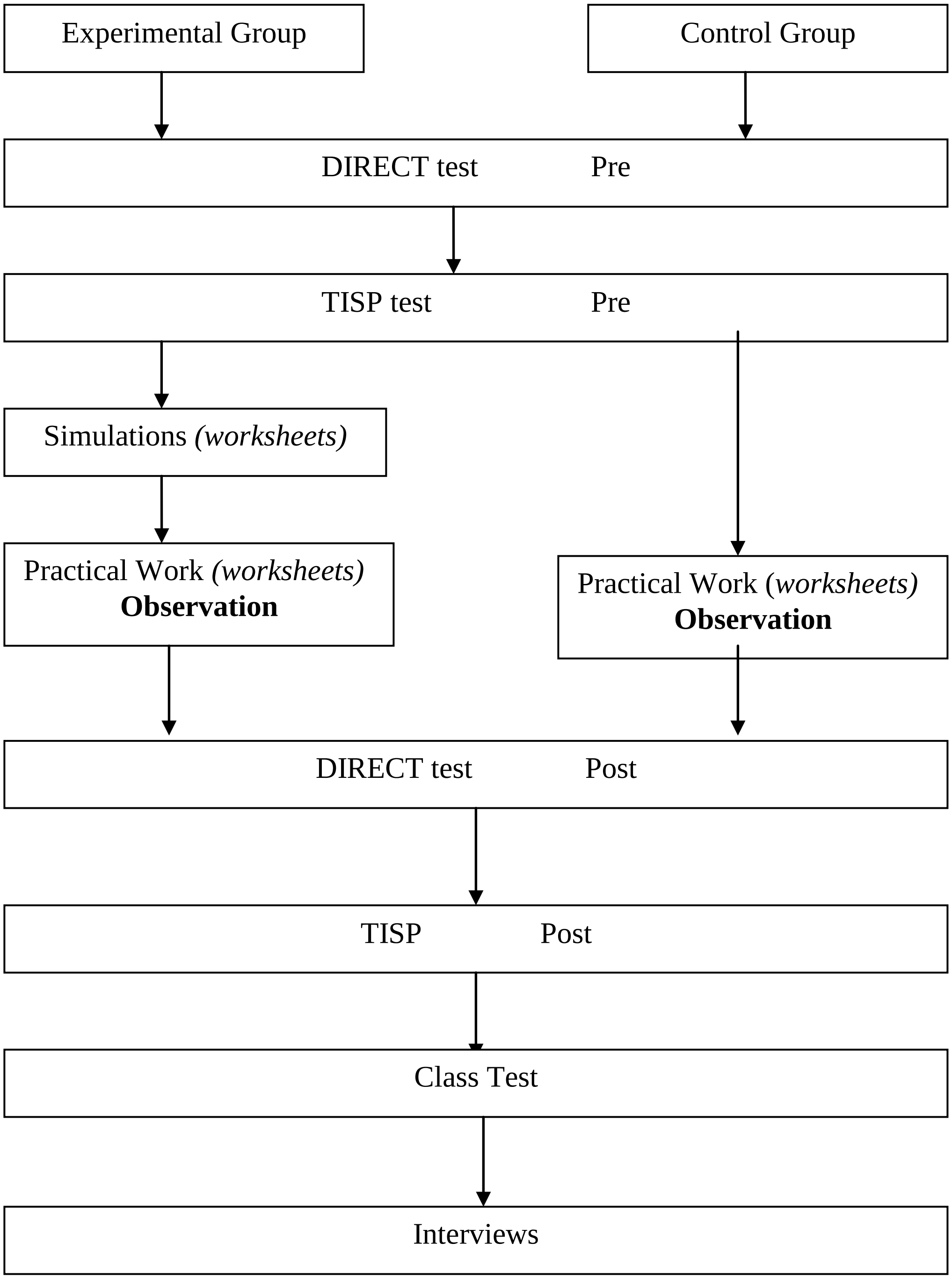


Figure 3.1 Research procedure

3.4.1 DIRECT

The Determining and Interpreting Resistive Electric Circuit Concepts Test (DIRECT) was developed to "evaluate students' understanding of a variety of direct current resistive electric circuits concepts" (Appendix A). The DIRECT test has been designed for use with high school and college/university students (Engelhardt & Beichner, 2004). The test consists of 29 multiple choice questions but in this study the researcher gave the students an option to explain their choices in order to see that students do not just guess the correct answer but can motivate their option as well as evaluate their level of understanding. In the beginning of the semester students from the control and the experimental groups wrote the DIRECT to test their prior knowledge and understanding on electric circuits. At the end, after the intervention, the students wrote the same DIRECT as a post test as indicated in figure 3.1.

3.4.2 TISP

In this study TISP developed by Kazeni (2005) was used and the reason for using TISP is to test students' integrated science process skills and because it is developed in South Africa it does not use foreign examples and technical terms (Appendix B). From the theoretical model (see figure 2.3) skills development is part of quadrant 3. The students are expected to develop some skills in the laboratory when performing the experiments and then write the TISP post test. The integrated science process skills that TISP tests are:

- Stating Hypotheses - stating the proposed solutions or expected outcomes for experiments. For example, the students were expected to state what will happen to the current when the resistors are connected in series and in parallel.
- Identifying and Controlling Variables - stating the changeable factors that can affect an experiment. It is important to change only the variable being tested and keep the rest constant. The one being manipulated is the independent variable; the one being measured to determine its response is the dependent variable; and all variables that do not change and may be potential independent variables are constants. For example in the Ohm's law experiment, the resistance of a resistor was kept constant and the potential difference across the resistor was varied and the value of the current was recorded.

- Experimental Design - carrying out an experiment by carefully following directions of the procedure so the results can be verified by repeating the procedure several times.
- Graphing and Interpreting Data - interpreting data statistically, identifying human mistakes and experimental errors, evaluating the hypothesis, formulating conclusions, and recommending further testing where necessary. For example, the students were required to draw three graphs on the same axes and determine the value of the resistor from the graphs. They had to draw a conclusion from those graphs.
- Operational Definitions - explaining how to measure a variable in an experiment.

3.4.3 Worksheets

The students have to take a module on Electricity and Magnetism during the second semester of the academic year. The researcher developed the worksheets (see appendix C) for the practical work of this module. The same worksheets were used for both simulations and laboratory work with the intention of looking at the contribution of simulations on the experimental group. Indicated in quadrants 2, 3, and 4 of the theoretical framework model (figure 2.3), the laboratory work was purposefully done to address the components, lab experiment, skill development, demonstration and directed activity. The questions on the worksheets were testing students' conceptual understanding rather than calculations. This was another change that was introduced.

3.4.4 Observations

During the practical work in the laboratory where students were performing the experiments, the researcher made some observation to check whether there was a difference between the two groups in terms of the development of science process skills. The basic process skills were also checked but this study was focusing mainly on the five that were mentioned earlier (see 3.4.2). An observation schedule was drafted to include both experimental and control group. These two groups were compared at the end.

3.4.5 Class test

The students did electricity and magnetism as part of their theory module. The researcher was not teaching the theory, but asked the lecturer concerned to allow her to suggest test questions when the students wrote their class test on electricity. The class test was written to see whether the students can transfer what they did in the laboratory to class and whether they can relate theory and practical work. The class test falls in the reception/meaningful quadrant of the theoretical framework. The role of the class test was to check whether the students can give a creative feedback after the directed activity. The experimental group was compared with the control group on the class test.

3.4.6 Interviews

Interviews were selected as one of the research tools in this study as indicated in figure 3.1 to verify the data. Follow up questions were also taken into consideration when interviews were conducted since "interviews can encourage respondents to develop their own ideas, feelings, insights, expectations or attitudes, and it allows respondents to say what they think" (Richardson, nd).

During the interviews the researcher was taking notes. Trustworthiness of the interview can be interpreted as the cooperativeness, consistency, and confidence of the participants/ interviewees in responding to the questions asked. The interviews consisted of open ended questions in order to elicit richer, more complex responses and they are perceived as less threatening (Richardson, nd). The interviews were conducted in the laboratory where they were doing their experiment because the researcher thought that the environment was non threatening, and the students were encouraged to respond as freely as possible and they were assured that their responses would not affect their academic results because their marks were already submitted to the head of the department.

3.5 Reliability and validity of the instruments

Reliability and validity are crucial criteria in assessing the quality of a research study (Seale, 2004). All the instruments used in a study should be tested for their reliability and their validity as Engelhardt & Beichner (2004:102) stated "for the test to be useful and its results to be accurately applied and interpreted, it must be reliable and valid". Even though the reliability and the validity of the instruments used in this study were tested by their developers, it was taken into consideration that the tests were used in another context, and then reliability and validity were checked. The tests were given to the two physics lecturers and a chemistry lecturer to check the content. The tests were also given to the physics I group to check whether they are familiar with the language used and whether they can finish writing within the time frame given. Reliability relates to the "extent to which an instrument provides similar results every time it is administered to the same sample at different times" (Engelhardt & Beichner, 2004:102). Validity is the "extent to which a test measures what it claims to measure and is not a quality that can be established in a single measurement, but accumulated via several measurements" (Engelhardt & Beichner, 2004:103).

3.5.1 DIRECT

The test used in this study was administered twice to the same groups at different times, so the test-retest method as well as the internal consistency method was established by the Kuder-Richardson formula 20 (KR-20). The developers of DIRECT 1.0 found the KR-20 to be above 0.70 which is the acceptable value for the test to be reliable (Engelhardt & Beichner, 2004:102).

Validity of an instrument may be shown through content validity and construct validity (McMillan & Schumacher, 2001). During the development of the test, content validity was established by presenting the test and objectives to an independent panel of experts to ensure that the domain was adequately covered (Engelhardt & Beichner, 2004:103). The construct validity of DIRECT was evaluated through factor analysis and interviews; the factor analysis analyzes the interrelationships within the data and can be used to select groups of items that seem to measure the same idea (Engelhardt & Beichner, 2004:103).

The validation of DIRECT was done as follows: firstly experts were given the test to check the content; secondly a detailed factor analysis was performed to create and verify existing categories of questions; lastly the students were interviewed to confirm the clarity and meaning of questions (Engelhardt & Beichner, 2004:104).

3.5.2 TISP

Kazeni (2005) determined the reliability of this test instrument in two ways: firstly, the internal consistency reliability of the test by using the split half method secondly, the alternative form reliability by correlating scores from TISP and TIPS using the Pearson product–moment coefficient.

According to the test developer (Kazeni, 2005) the instrument was tested for content validity by six peer evaluators (raters) who comprised two Biology lecturers, two Physics lecturers, and two Chemistry lecturers from the University of Limpopo. The raters were given the test items and a list of objectives, to check the construct validity of the test by matching the items with the corresponding objectives. The test is intended for students, the lectures are only checking the validity. Other factors such as its discrimination power, the difficulty level, its reliability, and the different forms of bias may affect the validity of a test and those factors were determined during the development of the test (Kazeni, 2005).

3.5.3 Worksheets

The worksheets were compiled by the researcher looking at the worksheets compiled at Colorado by the PhET group. The questions selected for the worksheets were to test their understanding of the basic electric circuits' concepts. If the students understand the basic concepts, it could be easy to understand the rest of the module. After the worksheet questions were finalised, it was taken to the theory lecturer and the head of the department who was lecturing Physics I group to check the content. It was then given to students from the Physics I group to complete in order to see whether they can finish in time and understand what is required in terms of the language used. This worksheet was given as their pre experiment and they did not know that it was meant for the Foundation students.

3.5.4 Class test

The class test was developed by the researcher after observing the students in the laboratory. The researcher noticed that most students have a problem of interpreting the diagrams and graphs. An inability to interpret equations, diagrams and graphs underlies many conceptual and reasoning difficulties (McDermott, 1993). The researcher chose the questions in the class test to check whether the students understood what they did when they were doing practical work and whether they can be able to relate it with what they did in class. The questions had diagrams to see whether the students can interpret them and give the correct explanations of those diagrams. Research has shown that traditional instruction does not challenge but tends to reinforce a perception of physics as a collection of facts and formulas. Students often do not recognize the critical role of reasoning in physics, nor do they understand what constitutes an explanation. They need practice in solving qualitative problems and in explaining their reasoning (McDermott, 1993). That was the reason why the class test questions were more on explanation than on calculations. The class test was also given to their theory lecturer and the head of the department to check the content as done with the worksheets.

3.6 Data Analysis

As the aim of the study is to look at the contribution of simulations to the practical work of Foundation Physics students at the University of Limpopo, the research question was answered by data collected by all the instruments used in the study namely: DIRECT and TISP pre and post tests, worksheets, observations, class test, and interviews. The data was analyzed qualitatively. The quantitative data was used as a supplement to the data analysed qualitatively. The interviews were used to verify the data collected by other instruments.

3.7 Ethical Issues

Ethical principle “requires that participants should be kept informed about the aim of the research and researchers should protect the participants from harm” (Gay & Airasian, 2003). For this study the students who agreed to take part were informed about the purpose of the study in class. The researcher also attached the cover letter on the test instrument which states the purpose of the research. Students were assured confidentiality and that the interviews were only meant for research purposes. All the marks were submitted before the interviews were conducted.

3.8 Summary of the chapter

The study was conducted at Medunsa in the Physics Department. The study is a case study and the researcher chose to give a treatment to a certain group of students in the class. Two instruments, TISP and DIRECT were used to collect data before and after the intervention. The DIRECT test comprised two parts namely, multiple choice and reasoning part. The latter part was used to analyze the data qualitatively. The data from the worksheets for simulations and practical work as well as the class test were also analyzed qualitatively. Observations were made while the students were doing the experiments in the laboratory. All the instruments used for data collection supplemented each other so that four types of practical work (directed activity, demonstration, skill development and laboratory experiment) from the theoretical framework model were fulfilled. The students were interviewed to verify the data collected. The flow chart gives an indication of the procedure followed when collecting data. The fact that the experimental group had more exposure of the content done “by means of simulations” than the control group, they tend to do better because they were exposed to the same worksheets twice. To avoid the design flaw in future studies, all the groups should be exposed to the same treatment if a study is a case study, unless if it is a comparison study and the researcher wants to see if the treatment can work or not.

CHAPTER 4

RESULTS AND DATA ANALYSIS

4.1 Introduction

This chapter presents the results and analysis of the data. Data was collected by pre and post tests (TISP and DIRECT), laboratory work worksheets and simulations worksheets, observations, a class test, and interviews with both the experimental and control group.

4.2 DIRECT

4.2.1 Pre test

The highest overall score was 45% and the lowest score was 14%. The mean value for the experimental group was 34% whereas the mean for the control group was 29%. The overall mean for all twenty students was 32%. Table 4.1 and figure 4.1 below indicate the performance of students from both the experimental group and the control group on each item. It is clear from the table that items 1, 4, 10, 11, 12, 17, 18, 22, 23 and 24 were regarded as being difficult for both the experimental and control group because they did not manage a good score. Most students scored 20% or less on most of the items. Item 7 was regarded the easiest because the students managed to score 90%. In items 19 and 25 the two groups scored 60% and 70% respectively. The experimental group managed to score more than the control group on most of the items. Due to the small sample size conclusions cannot be made based on the scores only, therefore the reasoning part on the test will be discussed later (4.2.2) and it was decided to do a more detailed analysis of six students, three from the experimental group and another three from the control group. The selection of these students was done by considering their scores in the pre and post test of DIRECT (see tables 4.1 and 4.4 in pages 36 and 61). The reason for choosing DIRECT test for selection is because of the conceptual questions. Therefore two students were selected (one from the experimental Ei and one from the control Ci) who showed an increase in performance in these tests, two students whose performance stayed the same (Es and Cs) and then the third group whose performance decreased in both tests (Ed and Cd). In this study Ei is E_1, Es is E_6, Ed is E_9 and Ci is C_1, Cs is C_4 and Cd is C_7 from table 4.5 (page 62).

Table 4.1 Results of the DIRECT pre test for experimental and control group [correct answer is in **bold**]

(a) Experimental Group

Item No	A	B	C	D	E
1	0.60	0.10	0.10	**0.20**	0.00
2	0.20	**0.50**	0.30	0.00	0.00
3	0.10	0.20	**0.30**	0.10	0.30
4	0.00	0.00	0.90	**0.10**	0.00
5	0.10	**0.60**	0.30	0.00	0.00
6	0.00	0.10	0.00	0.40	**0.50**
7	**0.90**	0.00	0.10	0.00	0.00
8	0.30	0.10	**0.60**	0.00	0.00
9	0.70	0.00	0.10	**0.20**	0.00
10	0.20	0.00	0.80	0.00	**0.00**
11	**0.10**	0.10	0.30	0.50	0.00
12	0.60	0.20	0.10	**0.10**	0.00
13	**0.40**	0.10	0.10	0.30	0.10
14	0.50	**0.30**	0.20	0.00	0.00
15	0.60	0.00	**0.40**	0.00	0.00
16	0.10	0.50	**0.40**	0.00	0.00
17	0.10	0.10	0.70	**0.10**	0.00
18	0.10	0.10	**0.10**	0.70	0.00
19	0.20	0.20	**0.60**	0.00	0.00
20	0.20	0.10	0.40	**0.30**	0.00
21	0.10	0.10	0.30	**0.40**	0.10
22	0.10	**0.10**	0.20	0.20	0.40
23	0.20	0.40	**0.10**	0.30	0.00
24	0.30	0.30	0.10	**0.20**	0.10
25	**0.70**	0.00	0.30	0.00	0.00
26	0.30	0.00	0.40	**0.30**	0.00
27	0.30	**0.30**	0.10	0.20	0.10
28	0.00	0.10	0.50	**0.40**	0.00
29	0.10	**0.30**	0.30	0.20	0.10

(b) Control Group

Item No	A	B	C	D	E
1	0.40	0.20	0.40	**0.00**	0.00
2	0.30	**0.20**	0.50	0.00	0.00
3	0.00	0.40	**0.30**	0.10	0.20
4	0.00	0.00	0.80	**0.10**	0.10
5	0.30	**0.50**	0.20	0.00	0.00
6	0.00	0.00	0.40	0.40	**0.20**
7	**1.00**	0.00	0.00	0.00	0.00
8	0.40	0.00	**0.60**	0.00	0.00
9	0.30	0.00	0.10	**0.60**	0.00
10	0.00	0.10	0.90	0.00	**0.00**
11	**0.00**	0.20	0.10	0.70	0.00
12	0.50	0.10	0.30	**0.10**	0.00
13	**0.60**	0.10	0.10	0.20	0.00
14	0.50	**0.30**	0.20	0.00	0.00
15	0.70	0.10	**0.20**	0.00	0.00
16	0.30	0.30	**0.40**	0.00	0.00
17	0.20	0.10	0.40	**0.20**	0.10
18	0.10	0.00	**0.10**	0.80	0.00
19	0.10	0.10	**0.70**	0.00	0.10
20	0.20	0.10	0.40	**0.30**	0.00
21	0.00	0.20	0.30	**0.30**	0.20
22	0.00	**0.10**	0.20	0.40	0.30
23	0.20	0.30	**0.20**	0.30	0.00
24	0.60	0.30	0.10	**0.00**	0.00
25	**0.60**	0.00	0.40	0.00	0.00
26	0.20	0.00	0.50	**0.20**	0.10
27	0.20	**0.20**	0.50	0.10	0.00
28	0.20	0.10	0.50	**0.20**	0.00
29	0.30	**0.20**	0.20	0.00	0.30

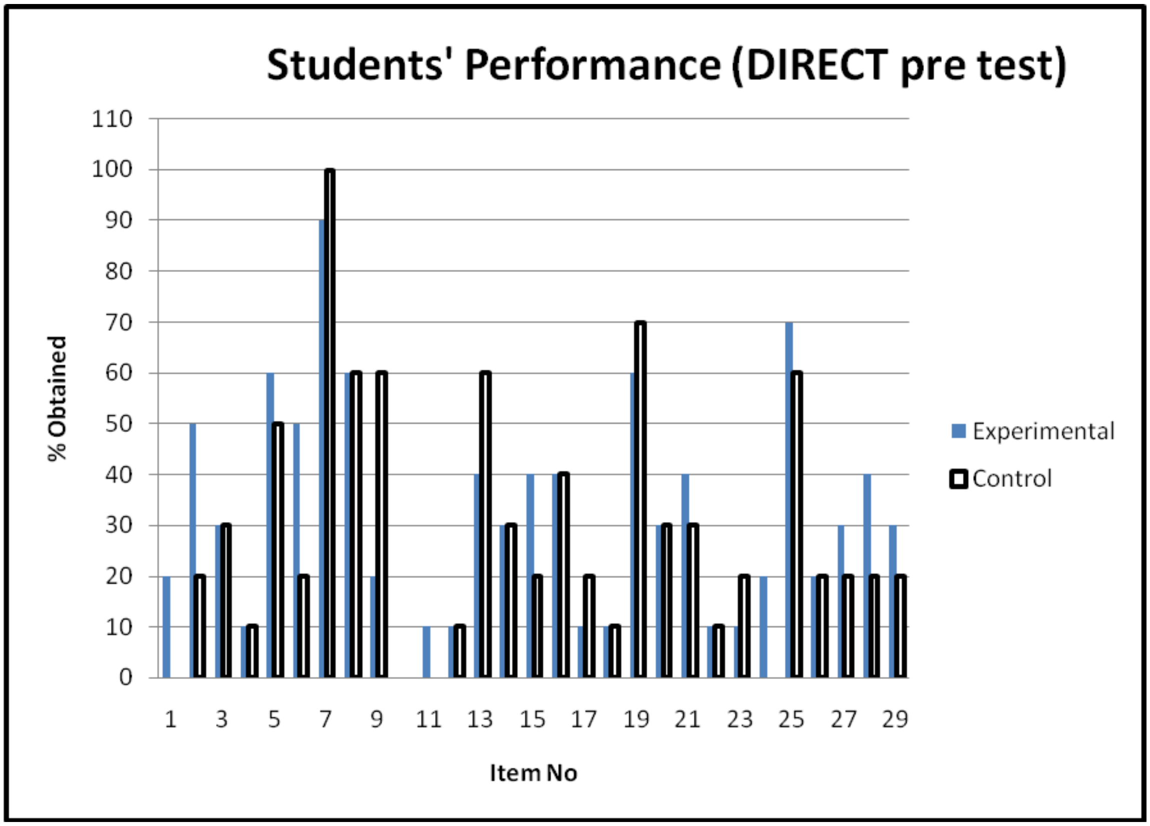


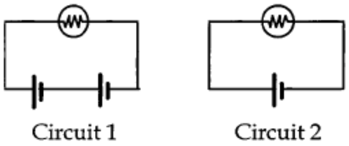
Figure 4.1 The performance of students (experimental & control group) per item on DIRECT pre test

4.2.2 Analysis of questions from DIRECT

The reasoning of students was taken into consideration and were analyzed. Students scored differently in the items because some of the items were regarded as being difficult and some as being easy. Items where no students or no group scored anything are also classified as very difficult. The items were classified as follows.

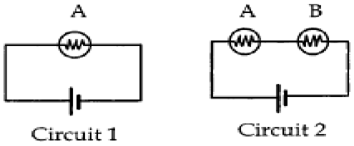
Very difficult	**Difficult**	**Moderate**	**Easy**	**Very easy**
0% - 20%	21% - 40%	41% - 60%	61% - 80%	81% – 100%

Item 7 was regarded as being very easy. This was the item whereby the students had to compare the brightness of the bulb in circuit 1 with that in circuit 2. They had to indicate which bulb was brighter.



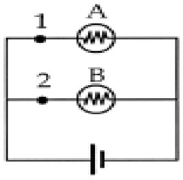
All the students from the experimental group and 90% from the control group managed to give the correct answer. The reasoning of students was based on the number of batteries that the circuit have: "*The more the batteries, the more power the circuit will have and therefore it will be more brighter when it has more than one battery. Therefore the bulb in circuit 1 is brighter because of two cells"*. Their reasoning agrees with Bryan and Stuessy (2006) in their paper "The 'Brightness Rules' alternative conception for light bulb circuits", they confirmed that students reasoned that the total brightness available to the bulb or bulbs in a circuit is dependent on the power supply.

Item 25 required the students to compare the brightness of bulb A in circuit 1 with bulb A in circuit 2. They had to indicate which bulb is brighter.



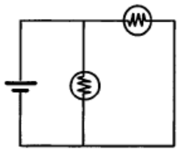
The question was regarded as easy because the average score was 65%. It was easy for the experimental group and moderate for the control group because 70% of the experimental group and 60% of the control group gave the correct answer. All those who gave the wrong answer chose option C as shown in table 4.1. Option C said all the bulbs have the same brightness. Student Ed who chose option C said " *they will have the same brightness because all of them are connected to one battery"*. Student Cd said "*they are all connected in series form and series means same current"*. The understanding was because both circuits have one cell and therefore the brightness will be the same. The overall reasoning for those who got the correct answer was bulb A in circuit 1 will be brighter because *it is one bulb and one battery and in circuit 2 there are two bulbs and one battery. The bulbs in circuit 2 will have the same brightness but it will not be as bright as in circuit 1 because they are sharing the power from one battery. The brightness in circuit 2 will be half the brightness in circuit 1.*

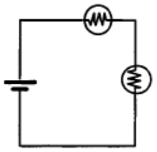
Item 19, was also one of the easy items, it required the students to state what will happen to the brightness of bulbs A and B when the wire is connected between points 1 and 2?

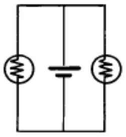


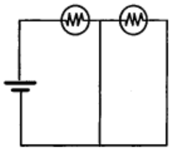
From this item 65% chose the correct answer, they stated that it will stay the same. Their reason for saying it will stay the same was because the wire will not make any difference, it will not affect the brightness of the bulbs. One of the students (Ed) chose option B, which states that the brightness will decrease. Ed said the reason it will decrease is because “*the current breaks when it reach point 1 and 2*”.

There were items where both groups scored 10% and those items are classified as being very difficult. Students scored 10% in items 4, 12, 18 and 22. Item 4 consisted of 4 circuits, and the students had to show the circuit(s) that consist(s) of two bulbs in parallel with a battery.


A

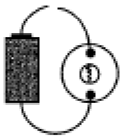

B

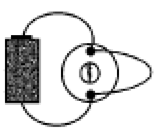

C

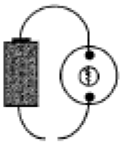

D

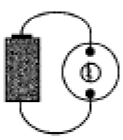
All the students from the experimental group and 80% from the control group who didn’t score anything in this item, chose option C, which states that circuit C is the correct whereas circuit A and C are the correct ones. They stated that the reason why they thought that C is the correct answer is because of the position of the battery. When the battery is in the middle, the current will flow from the battery and when it reaches the junction, half will flow to the left and another half to the right. The current splits only in a parallel connection.

Item 18 consisted of 4 circuits whereby students had to identify the circuit that will light the bulb.


A

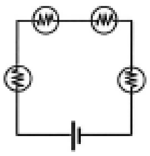

B

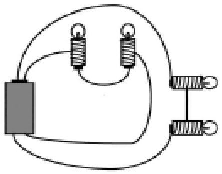

C


D

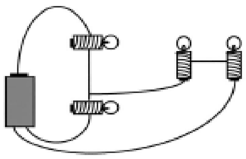
The two groups scored 10% each in this item, and 70% and 80% from the experimental and control respectively chose option D which states that circuit B and D will light the bulb,whereas only circuit D will. Most students managed to recognise that circuit A and C are not complete, that is why they chose circuits B and D. They stated that the circuits in option B and D are closed circuits, therefore their bulbs will light and circuits A and C are not closed circuits. It is true that when the circuit is closed the current will flow, but in circuit B there is a wire that causes the current to flow through that wire and not through the bulb, hence the bulb will not light.

Item 22 was a schematic diagram and students had to show the realistic circuit that represents that schematic diagram.

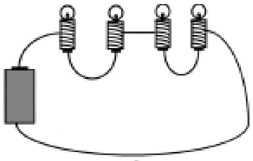




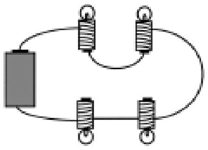
A



B



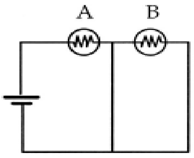
C



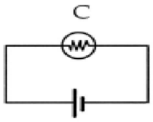
D

Both groups scored 10%. 40% of the experimental group chose circuits C and D. Those who chose circuits C and D said it is because all 4 bulbs in those circuits are connected in series with the battery, therefore they represent the schematic diagram. They didn't notice the difference between the two circuits. The two bulbs facing down in circuit D are not properly connected. The wire connecting the bulbs should connect at the bottom of the bulb like in circuit C.

Item 10 required the sudents to compare the brightness of bulbs A and B in circuit 1 with the brightness of bulb C in circuit 2. They had to indicate which bulb or bulbs are the brightest.



Circuit 1



Circuit 2

All the students failed to get the correct answer. Most students thought that bulb C in circuit 2 will be the brightest as indicated in table 4.1. One of the reasons presented was that because A and B have only one battery each and the two bulbs are depending on that battery therefore they will be equally bright but their brightness will be less than the brightness of bulb C in circuit 2 because it has one battery and one bulb.

Item 11 asked students why do the lights in their homes come on almost instanteneously. All the students from the control group got this item wrong. 70 % of them chose option D, which states that the circuits in their homes are wired in parallel and the current is already flowing hence the light will come on instanteneously. From the experimental group only 50% thought their homes are wired in parallel. The students who chose the correct option said it is because charges are already in the wire, so it will not take a lot of time for lights to come on instanteneously.

Students performed badly in item 1. The question was whether the charges used up in the light bulb are converted into light? 60% of the students in the experimental group knew that charges moving through the filament produce friction which heats up the filament and produces light. Their problem is they think that charge is converted to light, whereas charge is conserved. 40% of students from the control group think that charge is conserved, but it is simply converted to another form such as heat and light.

Item 24 was asking if the current through a battery is doubled whether the potential difference across the battery will be doubled? 20% of students from the experimental group and 0% from the control group scored item 24 correctly. 60% of students from the control group chose option A, which relates it to Ohm' law R = V/I, of which the correct answer is NO, the potential difference will not double if you double the current because the potential difference is a property of the battery. The majority of the students from the control group chose option A and they reasoned from Ohm's law by saying V and I are directly proportional and by doubling one it means doubling the other. Those who chose the correct answer said it is not possible to increase or decrease the current, the only thing that you can vary is the potential difference that will either increase or decrease the current.

4.3 TISP

4.3.1 Pre test

The students from both groups wrote the TISP test after writing DIRECT. The TISP test was given to the students as a pre test to evaluate their science process skills before any formal class or laboratory activity started on electricity. The test consists of 30 items. On this test the control group performed better than the experimental group because the overall mean for the experimental group is 57% and 63% for the control group.

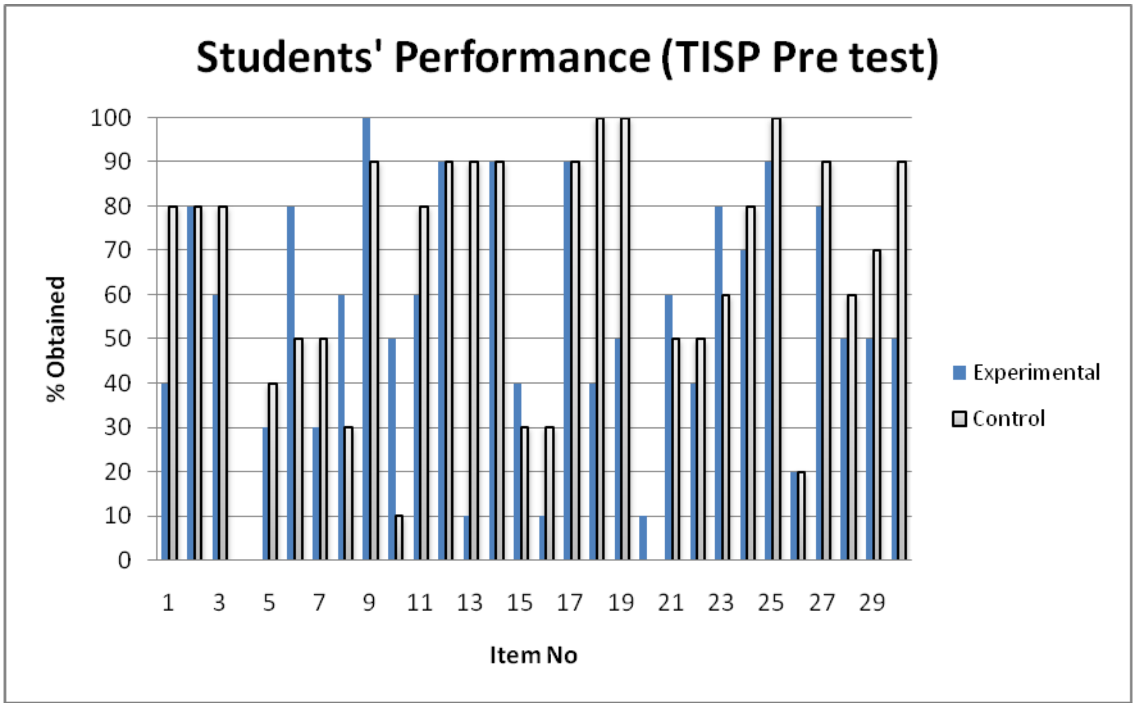


Figure 4.2 The performance of students (experimental & control group) per item on the TISP pre test

4.3.2 Analysis of questions from TISP

The groups were compared on 5 process skills as shown in figure 4.3 below. The items were classified as being difficult or easy. They were classified as follows:

Difficult	Moderate	Easy
0% – 39%	40% – 69%	70% – 100%

In the TISP test, items 18, 19 and 25 were the easiest because the control group managed to score 100% whereas the experimental group scored 100% in item 9. The control group scored 90% on items 9, 12, 13, 14, 17, 25, 27, and 30. The difficult items for the experimental group were items 13, 16, and 20 because they scored 10% whereas the control group scored 10% on item 10 and 0% on item 20. Both groups did not score on item 4. In all 5 skills, the control group outperformed the experimental group. Students did best on the stating of hypotheses. On the identifying of variables and graphing and interpreting data, the performance was similar.

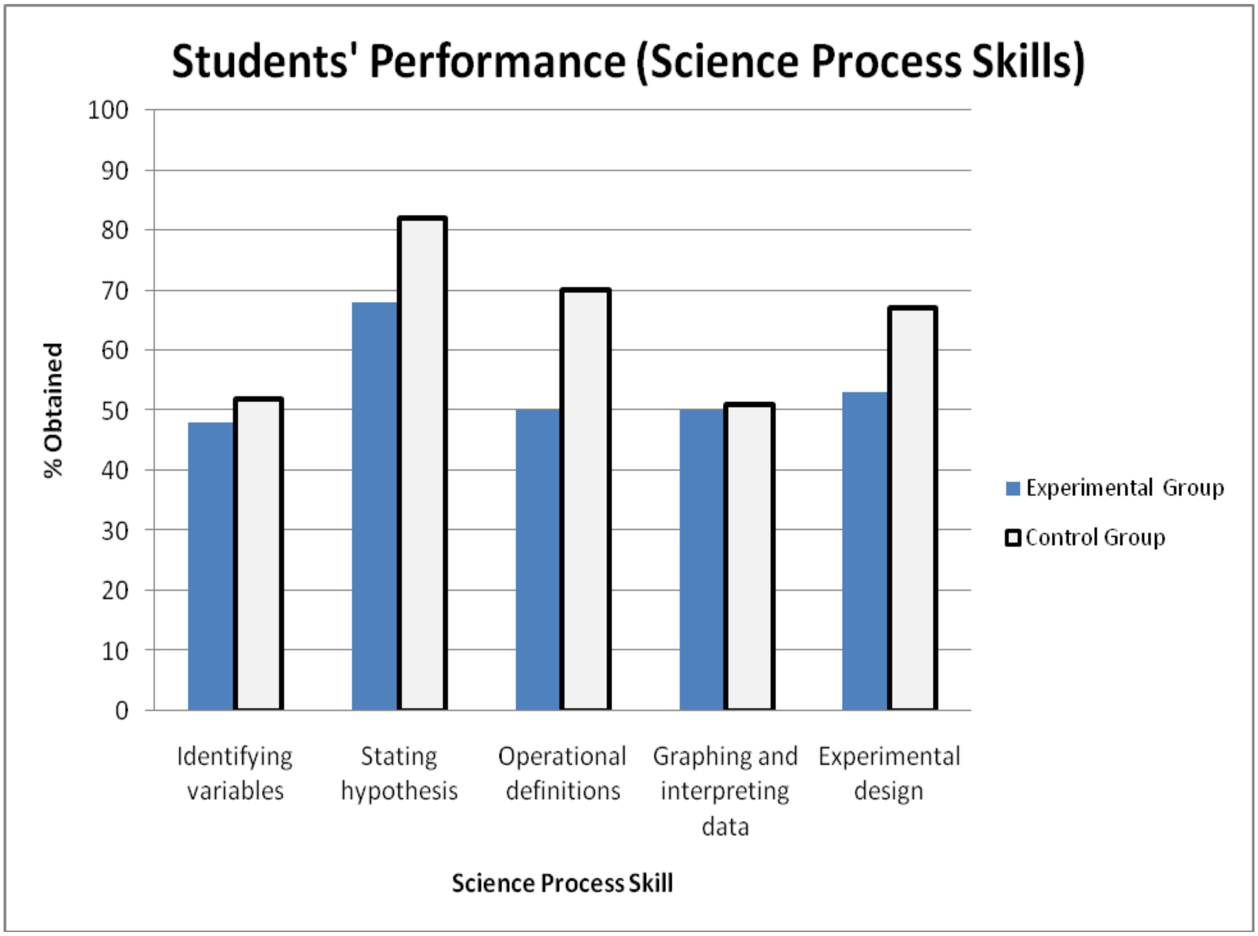


Figure 4.3 The performance of students on the science process skill test.

Figures 4.2 and 4.3 showed that the control group outperformed the experimental group. The test was written before the simulations were done therefore both groups were not exposed to any extra activity, hence it can be concluded that the difference were made by prior knowledge.

4.4 Worksheets

The same worksheets were given to the students in the laboratory for practical work and computer laboratory for simulations. These worksheets were developed by the researcher with the aim of testing conceptual understanding. The worksheet space was provided for the students where they could explain their answers in details.

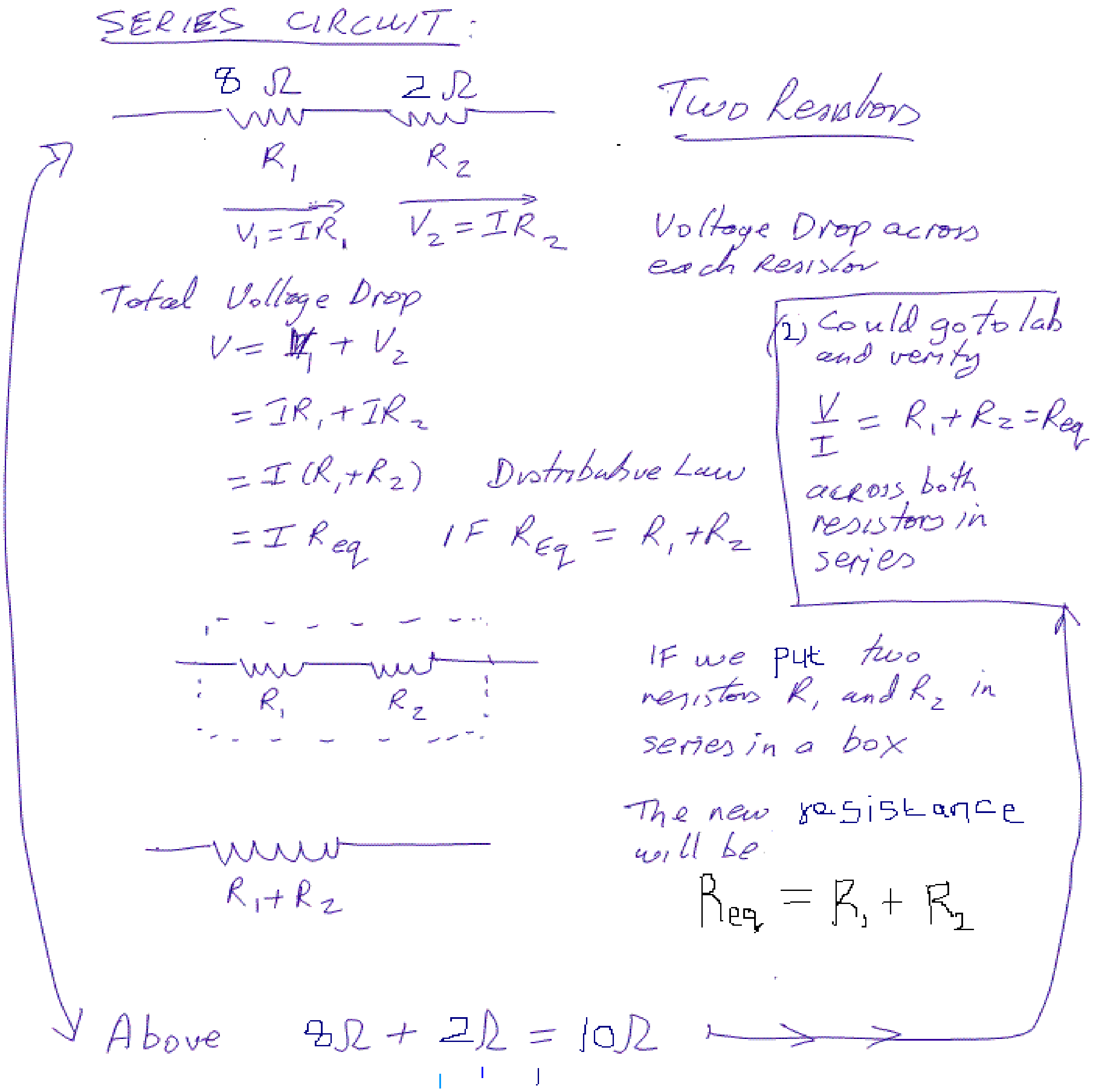
4.4.1 Simulations

It is shown in figure 3.1 that after writing DIRECT and TISP, the two groups were separated. The experimental group did the simulations to confirm electricity concepts using computers. The students were provided with the worksheets (see appendix C). They had to answer the questions asked while they were doing simulations and submit the worksheets after they have finished in the computer lab. The experiments were about the series and parallel connections of resistors and Ohm’s law.

4.4.2 Laboratory work

The aim of the practical work at Medunsa is to confirm science concepts, for skills development, and to experience science concepts and natural phenomena as indicated in the second, third and the fourth quadrant of the theoretical model (see fig 2.3 in page 21). While doing theory during lectures, some of the science concepts were addressed. The following example as shown in example 4.1 indicates how a series circuit was explained by the theory lecturer. The lecturer was explaining the equivalent resistance and how the voltage behaves when two or more resistors are connected in series. The lecturer was explaining the relationship between the potential difference and the current. It was shown in the example that the V/I is equal to the equivalence resistance. The students were told that they were going to verify whatever they did in class in the laboratory. The main aim was to connect the concepts done in class with the laboratory work.

After addressing these concepts during class time the students were required to do hands on experiments in the laboratory on series and parallel connection of resistors. In the laboratory the demonstrator did a demonstration of the particular work they had to do for the first ten minutes. After the demonstration the students did the experiment themselves. In addition, the aim of the practical session as part of the laboratory work were to develop the following skills; identifying and controlling variables, experimental design, graphing and interpreting graphs.



Two Resistors

$V_1 = IR_1$ $V_2 = IR_2$

Voltage Drop across each Resistor

Total Voltage Drop

$$V = \cancel{V_1} + V_2$$
$$= IR_1 + IR_2$$
$$= I(R_1 + R_2) \quad \text{Distributive Law}$$
$$= I R_{eq} \quad \text{IF } R_{Eq} = R_1 + R_2$$

(2) Could go to lab and verify

$$\frac{V}{I} = R_1 + R_2 = R_{eq}$$

across both resistors in series

IF we put two resistors R_1 and R_2 in series in a box

The new resistance will be

$$R_{eq} = R_1 + R_2$$

Above $8\Omega + 2\Omega = 10\Omega$

Example 4.1 Example of how a series circuit was explained in class.

While the experimental and control groups were doing the experiments in the laboratory, the researcher did observations by using the observation schedule (see 4.4.3). Both groups were able to identify the apparatus. They managed (for example) to differentiate between the ammeter and the voltmeter. During the connection of series and parallel circuits, it was easy for both groups to connect the resistors in series however most students from the control group were struggling to connect the resistors in parallel. All the groups were able to read the instruments correctly. The examples of how the students recorded data, drew graphs and answered the questions will be discussed in the analysis of worksheets.

4.4.3 Observations

During the practical work the researcher made some observations on how the students handle the apparatus, how they connect the equipment and how they record data. The main focus was on the 5 integrated process skills. The two groups were observed and the observation sheet was filled in as indicated in table 4.2. The process skills were rated on a scale from 1 to 5, where 1 is very poor and 5 is very good. When the students entered the laboratory, they were observed by two demonstrators and the researcher as they were performing the experiment. The first thing they did was to connect the circuit as required and call the demonstrator to check the connection before they could continue with the entire experiment. The demonstrators and the researcher checked and asked them some questions like to name the instruments and why they connected them the way they did just to check whether they understand what they are doing. After checking they filled the observation sheet individually. Other skills like drawing of tables were observed as the students were performing the experiment. The drawing and interpretation of graphs, like labeling correctly, determining the value of the resistor were checked at the end when they were done. At the end the average was determined based on the researcher and demonstrators' sheets. The results were as shown in table 4.2.

Table 4.2 Ratings on the observation schedule

Experimental group

	Process Skill					
		1	**2**	**3**	**4**	**5**
1	Identifying Variables					**X**
2	Stating Hypothesis			**X**		
3	Operational Definitions			**X**		
4	Graphing and interpreting data				**X**	
5	Experimental design					**X**

Control group

	Process Skill					
		1	**2**	**3**	**4**	**5**
1	Identifying Variables				**X**	
2	Stating Hypothesis				**X**	
3	Operational Definitions				**X**	
4	Graphing and interpreting data			**X**		
5	Experimental design					**X**

It is shown in table 4.2 that the two groups were not much different in terms of the development of the process skills. Comparing the observation and the performance on the TISP test in figure 4.3, the control group performed better in TISP than the experimental group whereas in the observations the performance was the same for the two groups.

4.4.4 Analysis of laboratory worksheets

Experiment 1: series and parallel connection

One of the aims of the experiment on series and parallel connections was to confirm science concepts and to develop their skills to connect a battery, ammeter and one resistor. This was in line with our theoretical model in fig 2.3 to confirm the electric circuits concepts done in class. They had to start with one resistor, add another resistor and record the current in the circuit and explain what was happening with both series and parallel connections. An example of the data they had to record is shown in the examples 4.4 to 4.7 below. This example was for three resistors connected in series.

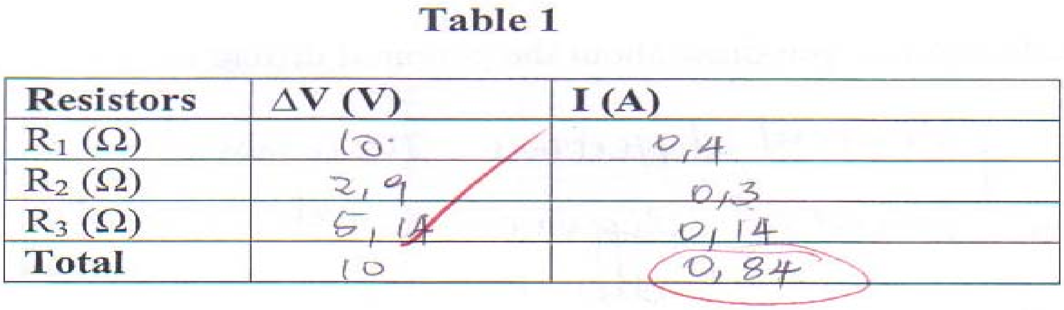


Table 1

Resistors	ΔV (V)	I (A)
R_1 (Ω)	10·	0,4
R_2 (Ω)	2,9	0,3
R_3 (Ω)	5,14	0,14
Total	10	0,84

Example 4.2 Student Ei

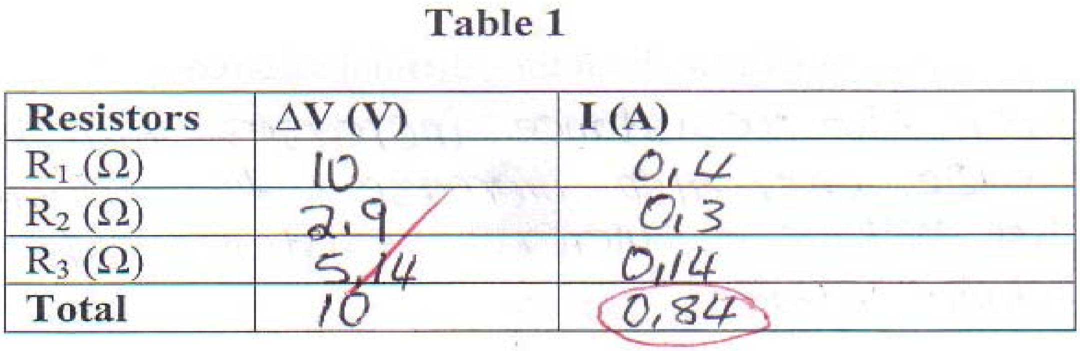


Table 1

Resistors	ΔV (V)	I (A)
R_1 (Ω)	10	0,4
R_2 (Ω)	2,9	0,3
R_3 (Ω)	5,14	0,14
Total	10	0,84

Example 4.3 Student Es

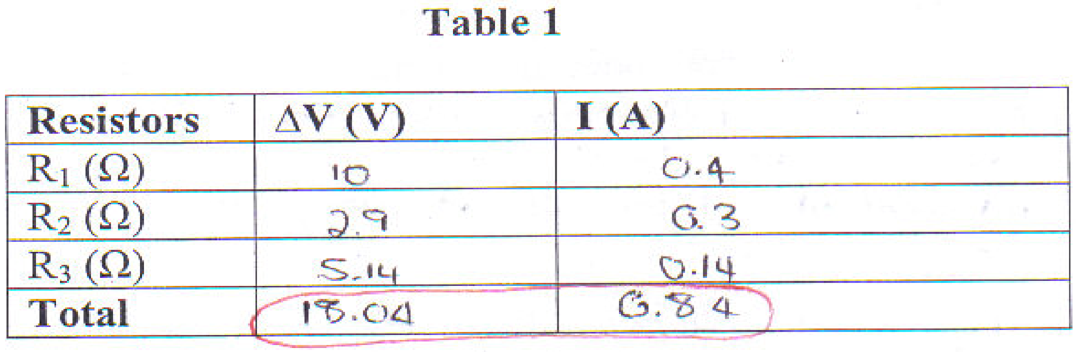


Table 1

Resistors	ΔV (V)	I (A)
R_1 (Ω)	10	0.4
R_2 (Ω)	2.9	0.3
R_3 (Ω)	5.14	0.14
Total	18.04	0.84

Example 4.4 Student Ed

All three students from the experimental group managed to record ΔV and I for all the resistors but failled to record the total current for all 3 resistors. The students didn't realise that after adding the third resistor R_3, the total current will be equal to the current passing through R_3. Student Ei and Es managed to record the correct total voltage whereas student Ed added all the 3 voltages. It shows that the students didn't interpret the final answer, because they started with 10V as their input voltage and it is impossible to get an output that is more than the input.

All the students from the control group reacted the same as the experimental group when recording the total current that passes through all the resistors. They didn't understand that after adding the R_3 the total number of resistors are three and the current that passes through R_3 is the total current of the circuit. Ci managed to get the total voltage correct, Cs did not give the total voltage whereas Cd gave the same answer as Ed.

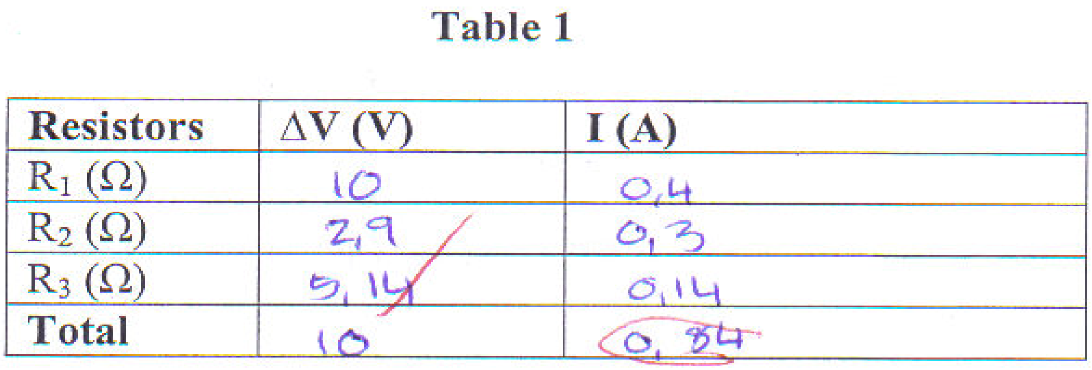


Table 1

Resistors	ΔV (V)	I (A)
R_1 (Ω)	10	0,4
R_2 (Ω)	2,9	0,3
R_3 (Ω)	5,14	0,14
Total	10	0,84

Example 4.5 Student Ci

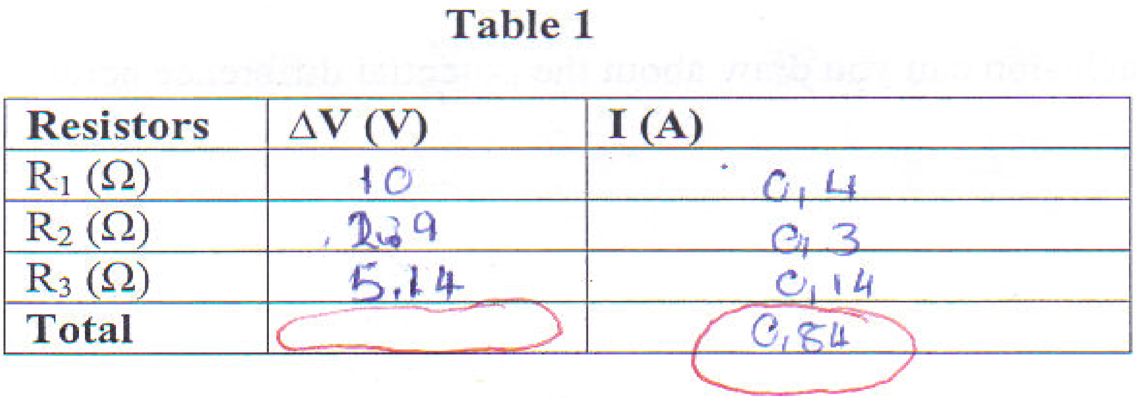


Table 1

Resistors	ΔV (V)	I (A)
R_1 (Ω)	10	0,4
R_2 (Ω)	2,9	0,3
R_3 (Ω)	5,14	0,14
Total		0,84

Example 4.6 Student Cs

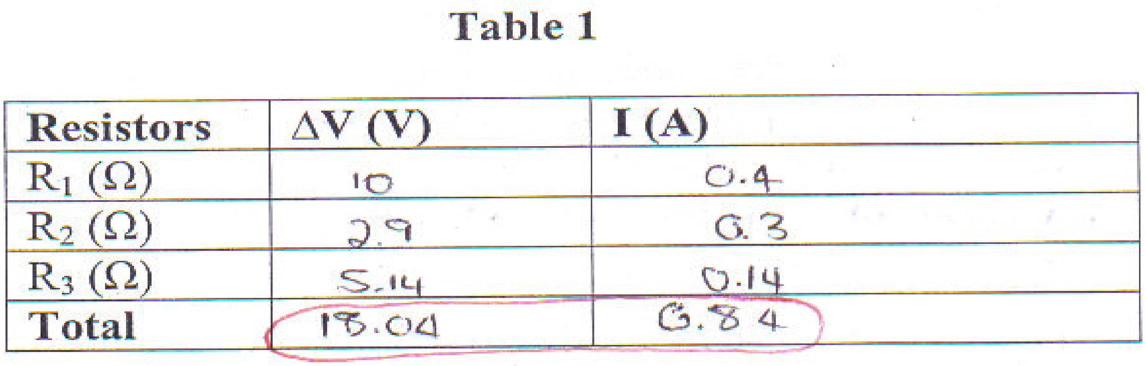
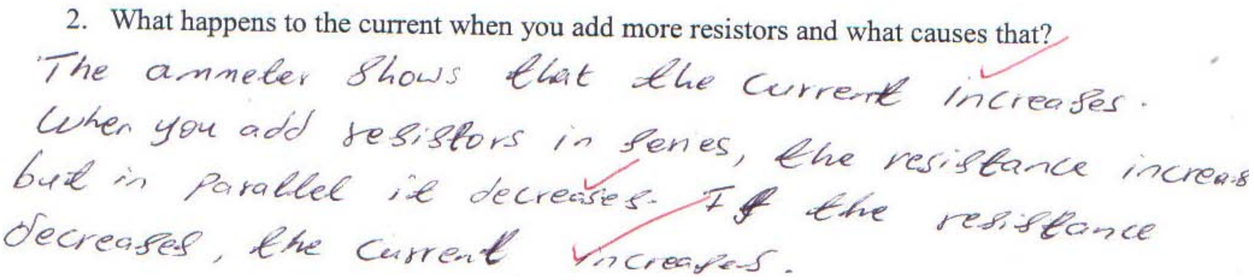


Table 1

Resistors	ΔV (V)	I (A)
R_1 (Ω)	10	0.4
R_2 (Ω)	2.9	0.3
R_3 (Ω)	5.14	0.14
Total	18.04	0.84

Example 4.7 Student Cd

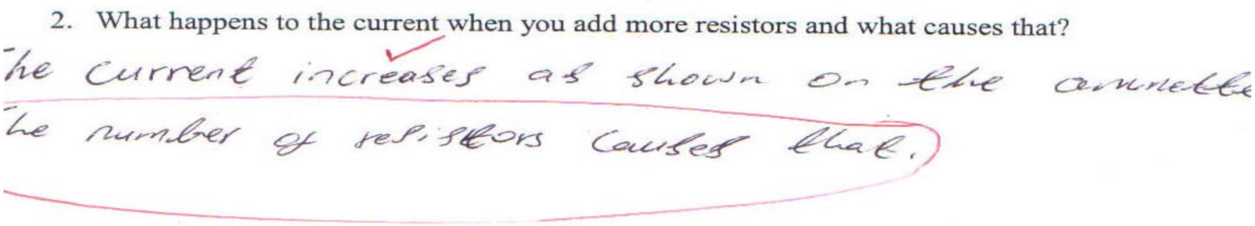
The next question the students were asked was “what happens to the current when you add more resistors in parallel and what causes that”. Their responses are shown in the examples 4.8 to 4.13 below.



2. What happens to the current when you add more resistors and what causes that?

The ammeter shows that the current increases. When you add resistors in series, the resistance increas but in parallel it decreases. If the resistance decreases, the current increases.

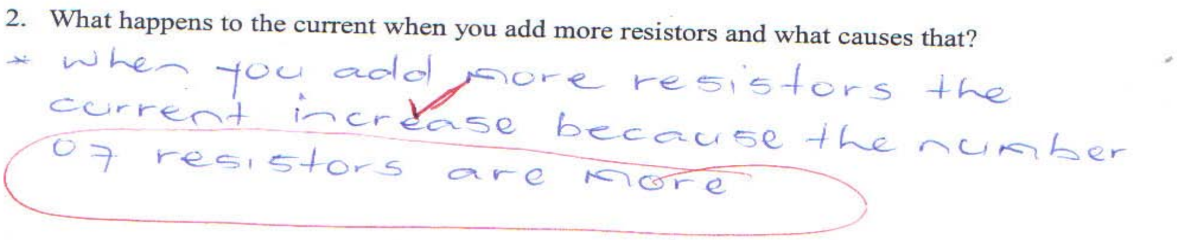
Example 4.8 Student Ei



2. What happens to the current when you add more resistors and what causes that?

The current increases as shown on the ammette
The number of resistors causes that.

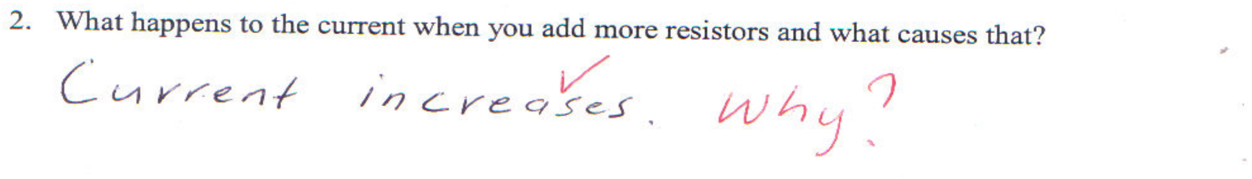
Example 4.9 Student Es



2. What happens to the current when you add more resistors and what causes that?

* when you add more resistors the current increase because the number of resistors are more

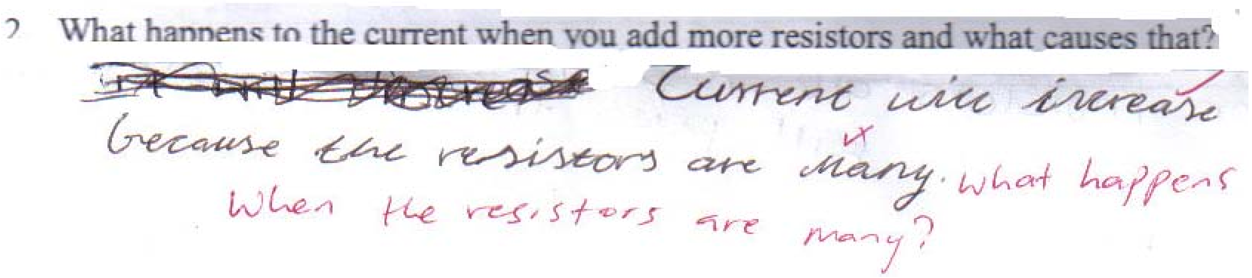
Example 4.10 Student Ed



2. What happens to the current when you add more resistors and what causes that?

Current increases. Why?

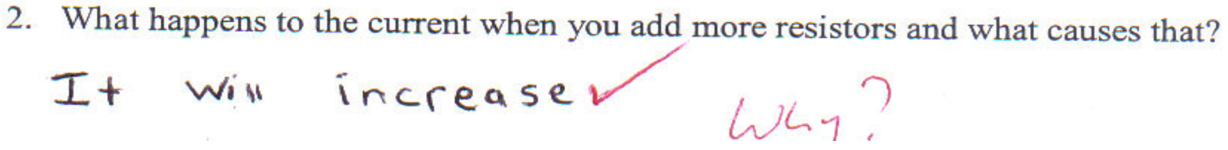
__Example 4.11__ Student Ci



2. What happens to the current when you add more resistors and what causes that?

~~It will decrease~~ Current will increase because the resistors are many. what happens When the resistors are many?

__Example 4.12__ Student Cs



2. What happens to the current when you add more resistors and what causes that?

It will increase Why?

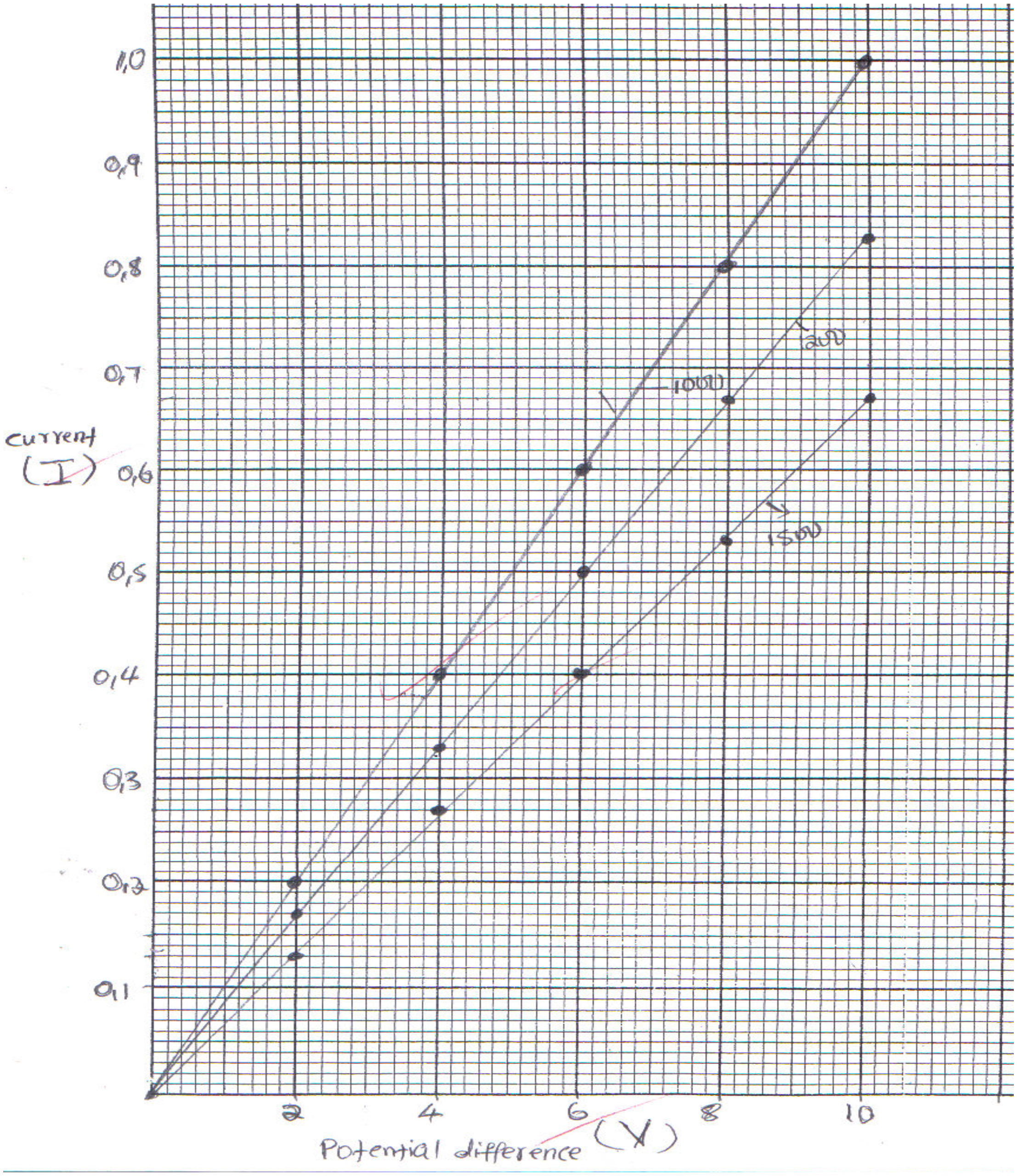
__Example 4.13__ Student Cd

All the students were able to give the correct answer but failed to explain why or failed to justify their answers. In example 4.9, student Es was able to read the answer from the ammeter; was able to see that the current was increasing but did not know the reason. Student Ci was also able to see that the current increases but did not provide the reason. In example 4.8 student Ei was able to explain why the current increases, the student did not only gave the reason, he even gave the difference between a series and parallel connection of resistors.

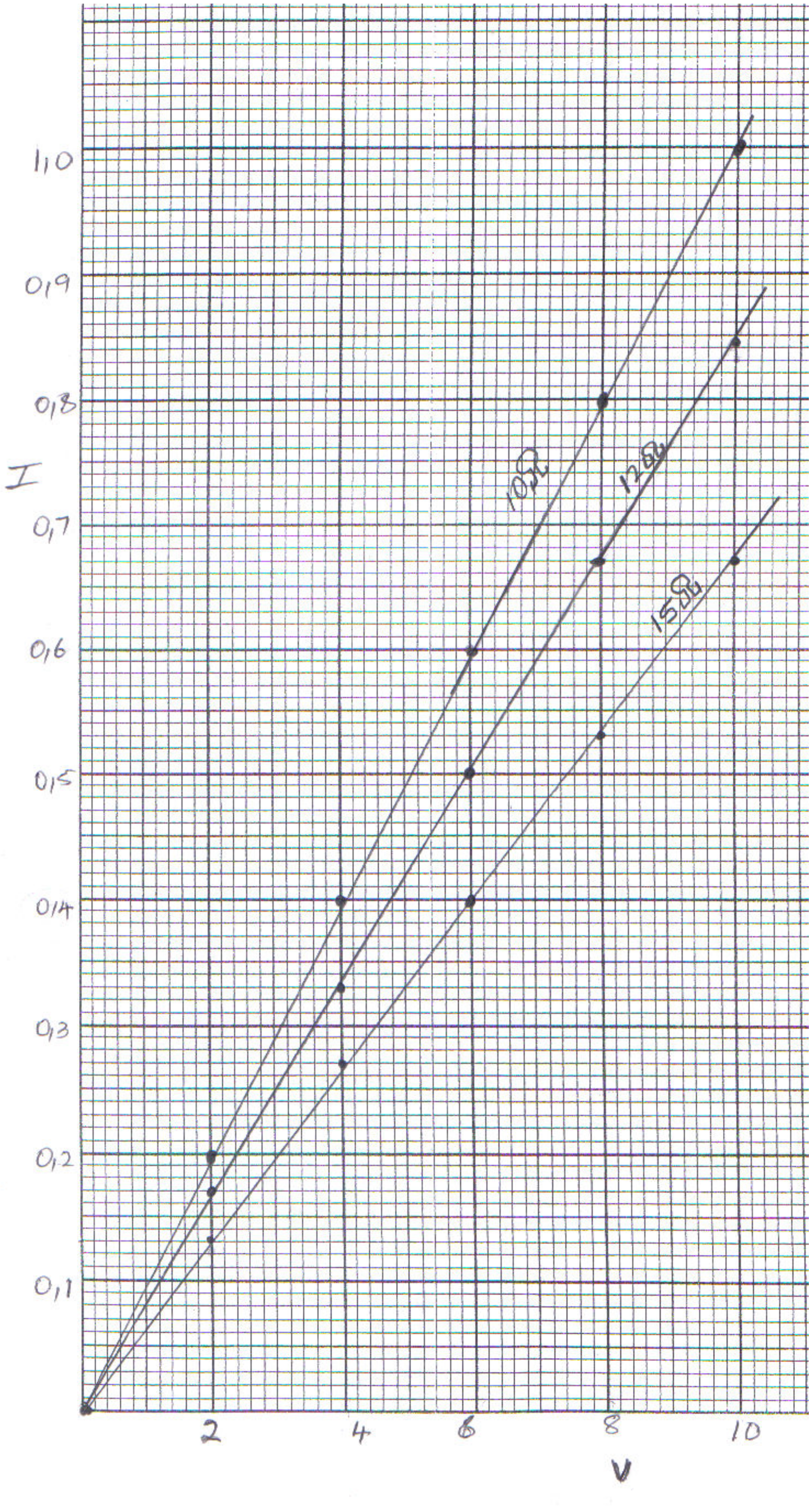
Students frequently fail to develop a coherent conceptual model of electric circuits in a typical introductory physics course. In particular, many students do not develop a good understanding of the concept of potential difference and are unable to distinguish between current and potential difference (Rosenthal & Henderson, 2006). This study showed that the students who did the simulations were better than those who did not do them in terms of understanding the concepts of potential difference and current.

Experiment 2: Ohm’s law

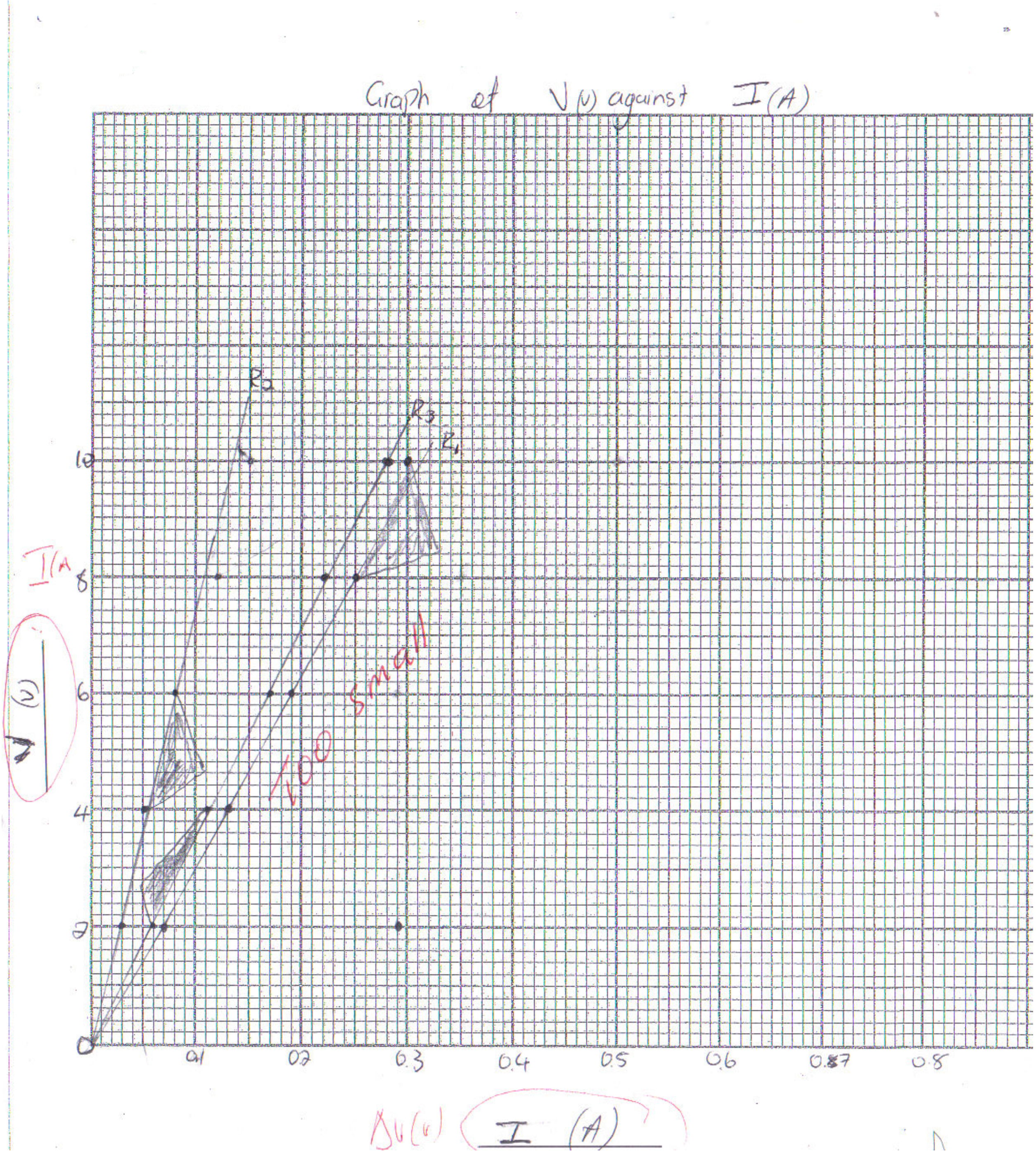
The purpose of the experiment was to verify Ohm’s law, and prove that irrespective of the value of the resistance, the relationship between the potential difference and the current will be linear. In the Ohm’s law experiment, the students were expected to draw a graph of current I(A) against the potential difference $\Delta V(V)$ after performing the experiment. They had to draw three graphs on the same axes and calculate the value of the resistance of the resistor from each of the 3 graphs. The two groups were able to scale the graph correctly. Examples of these graphs are shown below.



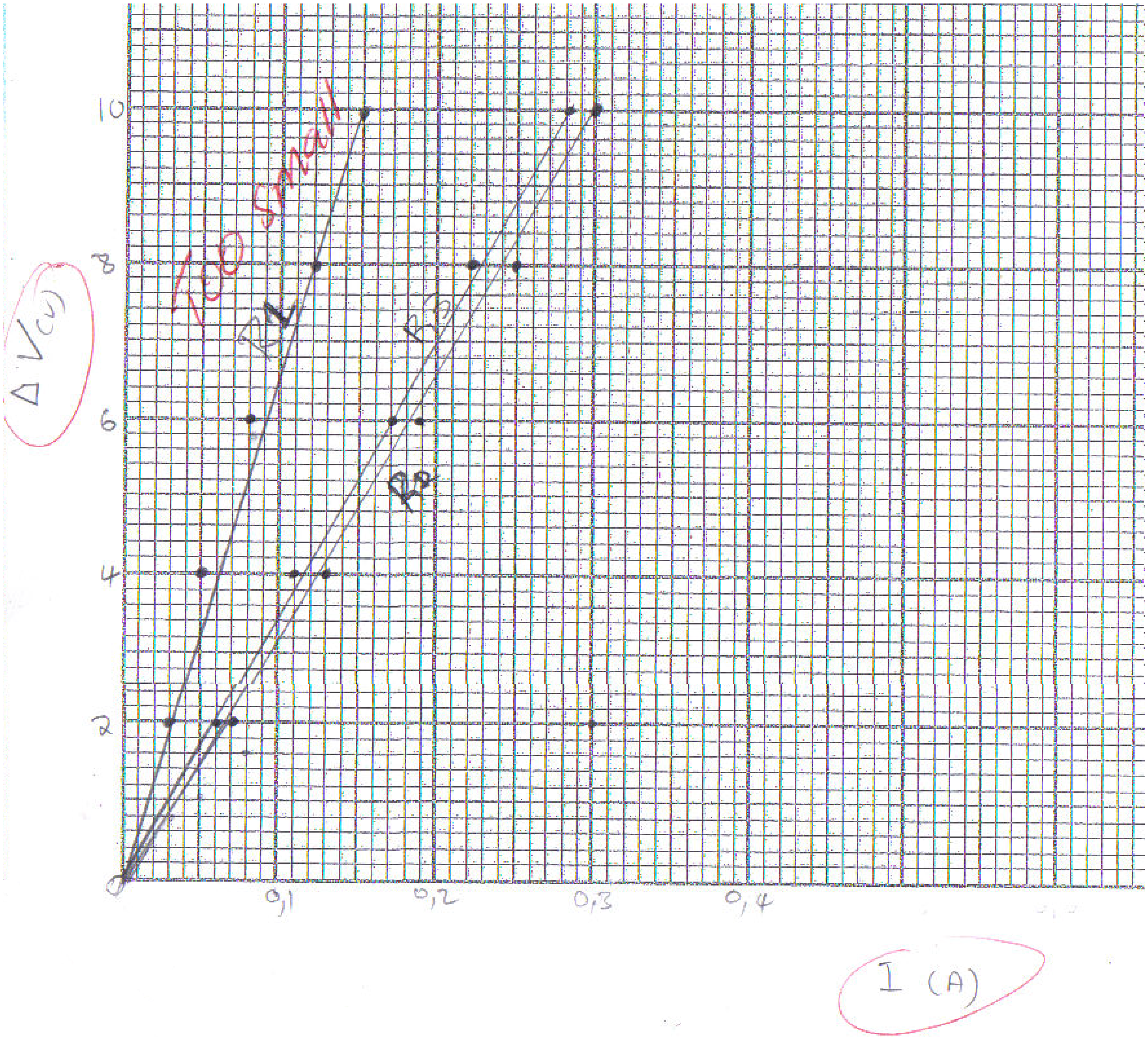
Example 4.14 Student Ei



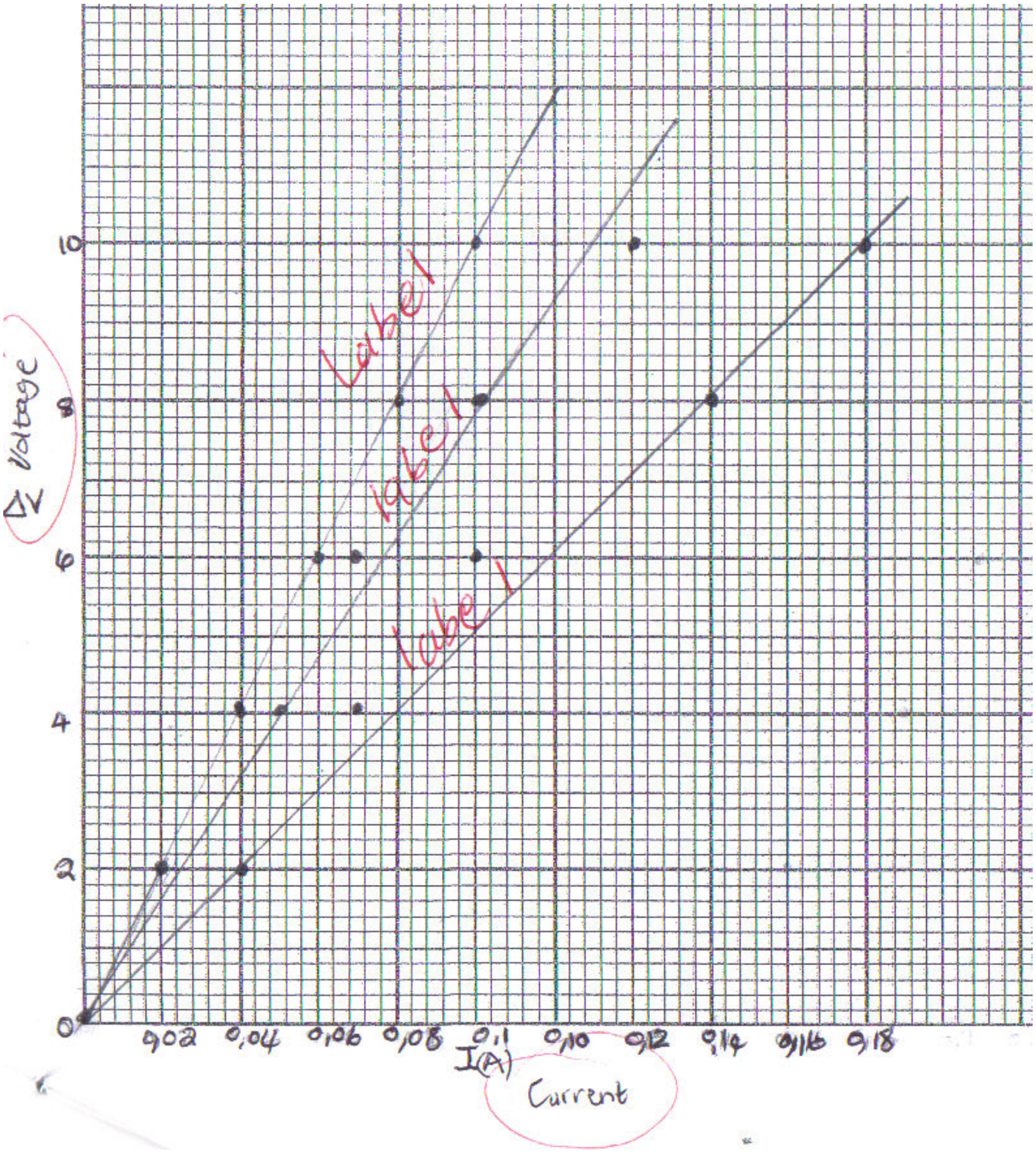
Example 4.15 Student Es



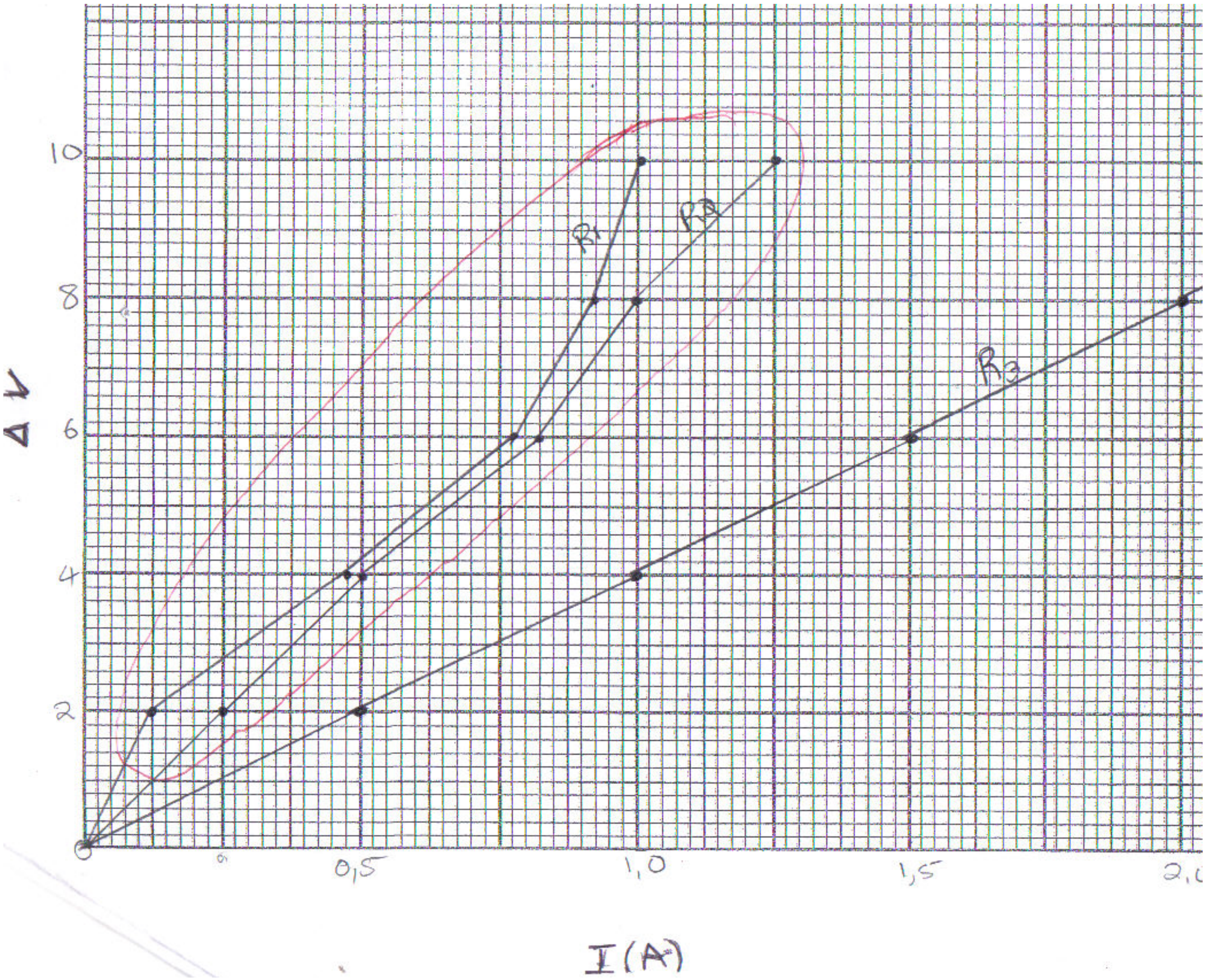
Example 4.16 Student Ed



Example 4.17 Student Ci



Example 4.18 Student Cs



Example 4.19 Student Cd

Students Ei and Es were able to draw the graph and they labelled the graphs accordingly. Cs in example 4.18 has drawn three graphs on the same axes but did not label them. It was difficult to see which one is R_1 or R_2. Student Cd in example 4.19 was unable to label the axis correctly. Current is the dependent variable and was supposed to be plotted on the y axis and the potential difference as the independent variable was supposed to be plotted on the x axis. The problem when the axis are not labelled correctly is that they are not going to get the correct value of the resistance of the resistor from the graph. The points from the graph were not joined correctly, the student was tracing every point, whereas was supposed to draw a straight line between the majority of points.

At the end the worksheets were marked. The students got marks for recording the data, plotting the graph and answering the questions correctly. The results of the laboratory worksheets are shown in table 4.3 for both groups.

Table 4.3 Worksheets results for both groups

EXPERIMENTAL GROUP			**CONTROL GROUP**	
	Simulations	**Laboratory Work**		**Laboratory Work**
E_1 (Ei)	**60%**	**64%**	**C_1 (Ci)**	**48%**
E_2	58%	61%	C_2	56%
E_3	65%	63%	C_3	70%
E_4	50%	44%	**C_4 (Cs)**	**68%**
E_5	78%	79%	C_5	55%
E_6 (Es)	**66%**	**72%**	C_6	71%
E_7	48%	55%	**C_7 (Cd)**	**48%**
E_8	72%	70%	C_8	62%
E_9 (Ed)	**67%**	**69%**	C_9	44%
E_{10}	70%	76%	C_{10}	57%
MEAN	63%	65%		58%

Table 4.3 shows that the experimental group performed 2% better during the laboratory work than in the simulations. All three students from the experimental group (Ei, Es and Ed) showed an increase in performance when doing the laboratory work. The experimental group was better than the control group as shown by their higher average of the simulations worksheets.

4.4.5 Explanations and Summary of the worksheets

The first group to use the worksheets was the experimental group when doing the simulations. The students were able to do the simulations very easily. It was not difficult for them to see what was happening and they developed curiosity. They were asking questions whenever something happened and they wanted to know the reason why; for example if the bulb started to burn, they wanted to know the reason. The demonstrators were helping whenever they asked questions. The reasoning shown on the worksheets was improving. When comparing the explanations of the experimental group during the simulations and their explanations during the practical work in the laboratory, there was a difference in reasoning. It means that the simulations gave the group an idea of what was happening. The control group was exposed to the same worksheets during the practical work in the laboratory. They were able to answer the questions on the worksheets. The explanations they gave differed slightly from the experimental group. The way the experimental group was asking questions, it showed that they wanted to understand the concepts. They were more interested on the cause rather than on the answer itself. For example when the resistors were connected in parallel the current increases, they were interested in why the current increases and not decrease because more resistors were added. The control group was fine after observing the difference between series and parallel connection; they were not interested in knowing what causes the difference. It can be concluded that the experimental group was qualitatively different from the control group in terms of reasoning and questioning based on the worksheets.

The problem with the worksheets was the part where they were supposed to draw graphs. Both groups experienced the same problem. The common problem experienced was that the students did not know the difference between the dependent and the independent variable when they were plotting a graph. They didn’t know where to put the dependent variable and where to put the independent variable. The responses from the worksheets showed that the students had an idea of what was happening to the current even though they could not explain their answer. It shows that they were able to read the instrument and record the answer as given on the instrument which was also seen when doing observations. On average the experimental group showed an improvement, because they did better in the same worksheets when doing the practical work in the laboratory (see table 4.3).

4.5 DIRECT Post test

The post test was conducted with all twenty students who wrote the DIRECT pre test. The highest overall score was 56% and the lowest score was 34% for the experimental group. The mean value for the experimental group was 43%. The highest score for the control group was 48% and the lowest score was 16% whereas the mean value is 33%. The overall mean for all twenty students from both groups was 38%. Figure 4.4 and table 4.4 below show the results of both groups per item.

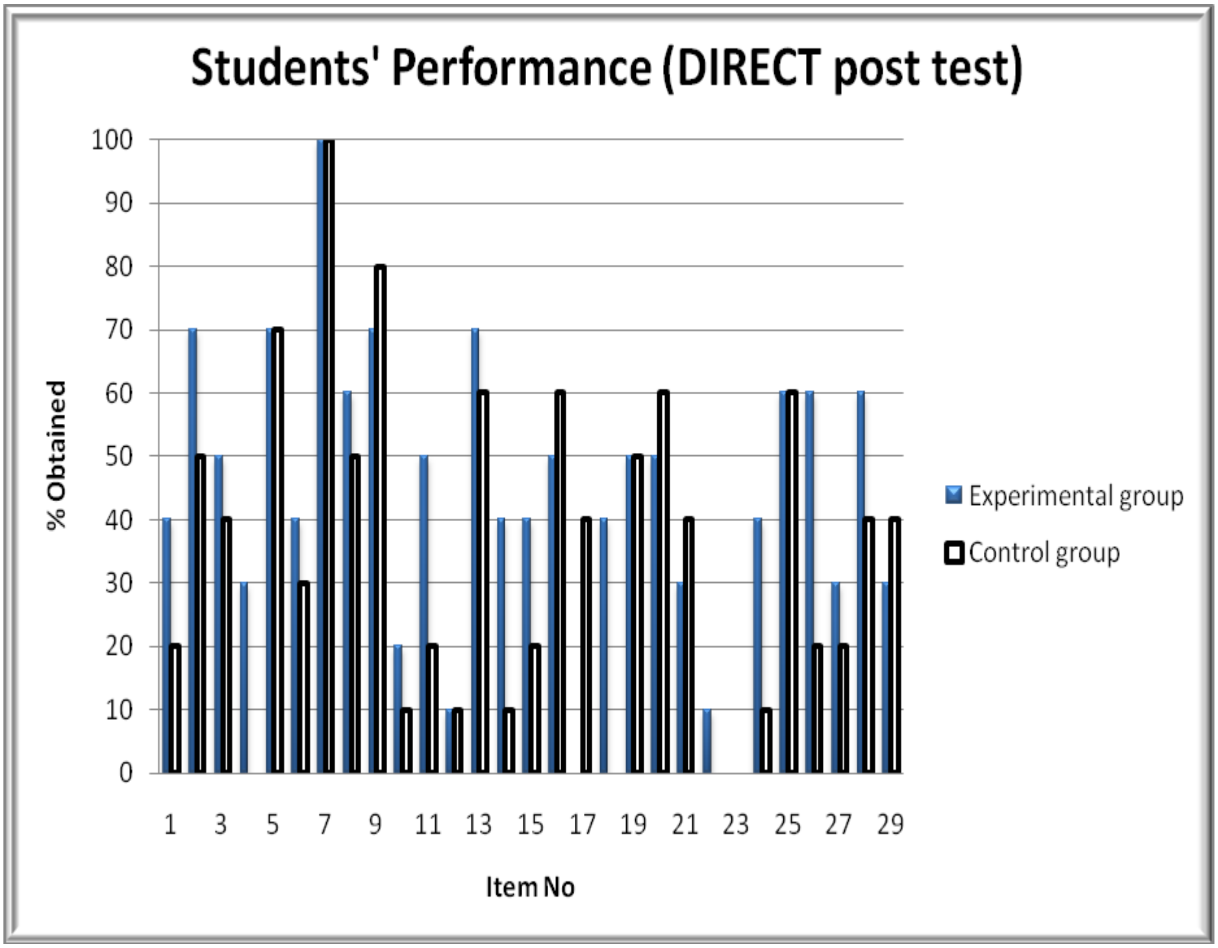


Figure 4.4 The performance of students (experimental & control group) per item on the DIRECT post test

Table 4.4 Results of the DIRECT post test for experimental and control group [correct letter is in **bold**]

(a) Experimental Group

Item No	A	B	C	D	E
1	0.40	0.00	0.20	**0.40**	0.00
2	0.10	**0.70**	0.20	0.00	0.00
3	0.00	0.10	**0.50**	0.00	0.40
4	0.10	0.00	0.60	**0.30**	0.00
5	0.10	**0.70**	0.20	0.00	0.00
6	0.20	0.30	0.10	0.00	**0.40**
7	**1.00**	0.20	0.20	0.00	0.00
8	0.10	0.30	**0.60**	0.00	0.00
9	0.20	0.00	0.00	**0.70**	0.00
10	0.00	0.00	0.80	0.00	**0.20**
11	**0.50**	0.00	0.10	0.40	0.00
12	0.50	0.30	0.00	**0.10**	0.10
13	**0.70**	0.20	0.00	0.10	0.00
14	0.30	**0.40**	0.20	0.10	0.00
15	0.30	0.10	**0.40**	0.00	0.20
16	0.00	0.50	**0.50**	0.00	0.00
17	0.20	0.20	0.40	**0.00**	0.20
18	0.00	0.10	**0.40**	0.50	0.00
19	0.10	0.00	**0.50**	0.00	0.40
20	0.10	0.30	0.10	**0.50**	0.00
21	0.10	0.10	0.20	**0.30**	0.30
22	0.10	**0.10**	0.00	0.40	0.40
23	0.00	0.80	**0.00**	0.20	0.00
24	0.30	0.10	0.20	**0.40**	0.00
25	**0.60**	0.00	0.20	0.00	0.00
26	0.40	0.00	0.00	**0.60**	0.00
27	0.30	**0.30**	0.10	0.30	0.00
28	0.00	0.20	0.20	**0.60**	0.00
29	0.00	**0.30**	0.40	0.10	0.10

(b) Control Group

Item No	A	B	C	D	E
1	0.20	0.40	0.20	**0.20**	0.00
2	0.10	**0.50**	0.30	0.00	0.10
3	0.50	0.10	**0.40**	0.00	0.00
4	0.00	0.10	0.80	**0.00**	0.10
5	0.20	**0.70**	0.10	0.00	0.00
6	0.00	0.00	0.40	0.30	**0.30**
7	**1.00**	0.10	0.00	0.20	0.00
8	0.00	0.30	**0.50**	0.20	0.00
9	0.20	0.00	0.00	**0.80**	0.00
10	0.00	0.00	0.90	0.00	**0.10**
11	**0.20**	0.30	0.00	0.30	0.20
12	0.20	0.50	0.10	**0.10**	0.10
13	**0.60**	0.20	0.10	0.10	0.00
14	0.40	**0.10**	0.50	0.00	0.00
15	0.80	0.00	**0.20**	0.00	0.00
16	0.10	0.30	**0.50**	0.00	0.00
17	0.20	0.30	0.10	**0.40**	0.00
18	0.20	0.10	**0.00**	0.60	0.10
19	0.00	0.30	**0.50**	0.10	0.10
20	0.30	0.10	0.00	**0.60**	0.00
21	0.40	0.00	0.20	**0.40**	0.00
22	0.00	**0.00**	0.60	0.40	0.00
23	0.50	0.30	**0.00**	0.20	0.00
24	0.40	0.30	0.20	**0.10**	0.00
25	**0.60**	0.20	0.10	0.10	0.00
26	0.30	0.40	0.10	**0.20**	0.00
27	0.10	**0.20**	0.40	0.30	0.00
28	0.30	0.00	0.30	**0.40**	0.00
29	0.10	**0.40**	0.00	0.30	0.20

4.5.1 Comparing pre and post test results of DIRECT

In order to see the effect of the intervention, it is imperative to look at different representations of the same data; where the same items on DIRECT in the pre-test are measured against the same items in the post-test.

Table 4.5 The results of DIRECT pre & post test for both groups

DIRECT					
EXPERIMENTAL GROUP			**CONTROL GROUP**		
STUDENT	Pre test	Post test	STUDENT	Pre test	Post test
E_1 (Ei)	**14%**	**42%**	**C_1 (Ci)**	**17%**	**30%**
E_2	34%	41%	C_2	45%	48%
E_3	31%	44%	C_3	41%	46%
E_4	28%	36%	**C_4 (Cs)**	**24%**	**24%**
E_5	38%	45%	C_5	17%	16%
E_6 (Es)	**34%**	**34%**	C_6	28%	35%
E_7	28%	39%	**C_7 (Cd)**	**28%**	**25%**
E_8	45%	51%	C_8	28%	40%
E_9 (Ed)	**41%**	**38%**	C_9	31%	34%
E_{10}	45%	56%	C_{10}	31%	35%
MEAN	**34%**	**43%**	MEAN	**29%**	**33%**

Table 4.5 shows that the mean of the experimental group increased by 9% while the mean of the control group increased by 4%. Even though the mean in both groups increased, there are individual students who did not perform well in the post test. Student Ei was the lowest with 14% in the group for the pre test, and managed to score 42% in the post test, with an increase of 28%. Student Es scored the same in both the pre test and the post test, whereas student Ed dropped from 41% to 38% (3% decrease). In the control group, student Ci did better in the post test because the student was one of the lowest in the pre test but managed to increase the performance by 13%. Student Cs's performance remained the same and student Cd experienced a decrease of 3%. The increase in the experimental group scores is more than in the control group. The lowest increase in the control group is 1%. The

increase in the mean in the post tests for both groups means that the theory classes together with the practical work made a difference in terms of understanding electric circuits. The experimental group got extra practice because of the simulations hence they had shown more improvement as compared to the control group.

The figure below shows the performance of the experimental group during the DIRECT pre test and the post test.

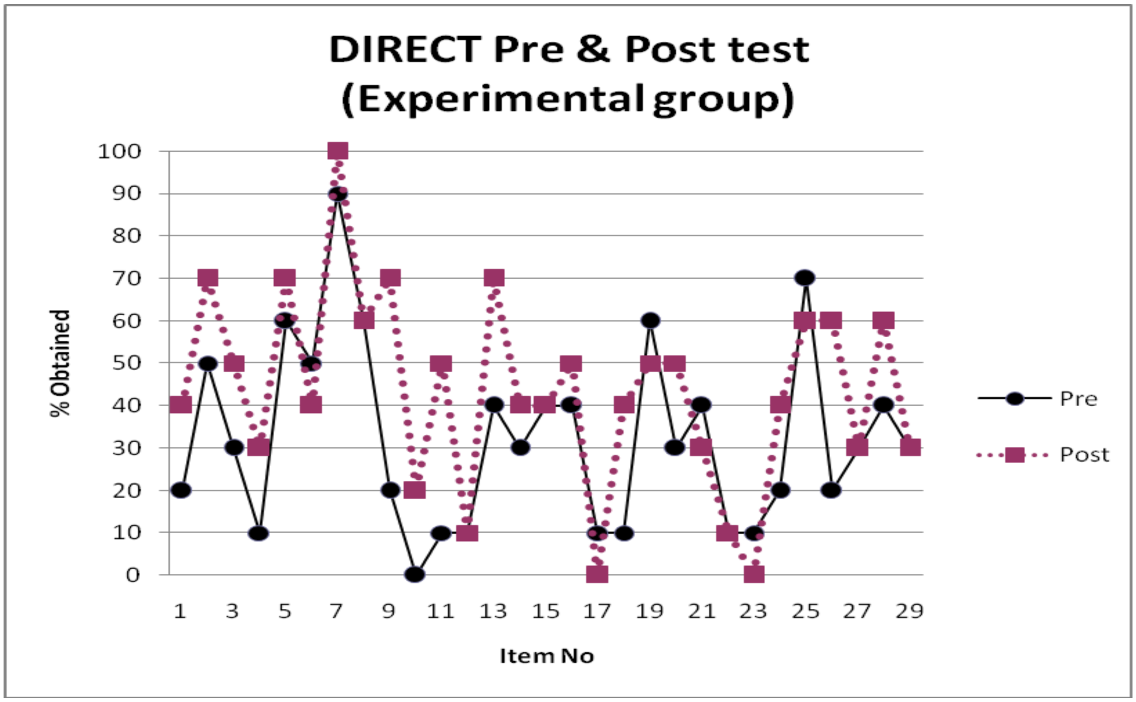


Figure 4.5 The performance of the experimental group in DIRECT pre test and post test

In items 17, 19, 21, 23, and 25 the students did better in the pre than in the post test. The reason might be that when they were writing the post test, they had many things to do for example other tests to write and they did not give their best. Another reason might be that the students did not understand the concepts. They scored zero in items 17 and 23 in the post test as compared to the pre test where they scored 10% in both items. The gap between the pre test results and the post test results in items 1, 2, 3, 9, 10, 11, 13, 18, 24, 26 and 28 is 20% and above. This could indicate an improvement because the students did the simulations, laboratory work as well as attended lectures on electric circuits. Due to the fact that the group got extra practice on electric circuits, it might have contributed to the improvement.

The performance of the control group during the DIRECT pre test and post test was also compared and their results are shown in figure 4.6 below.

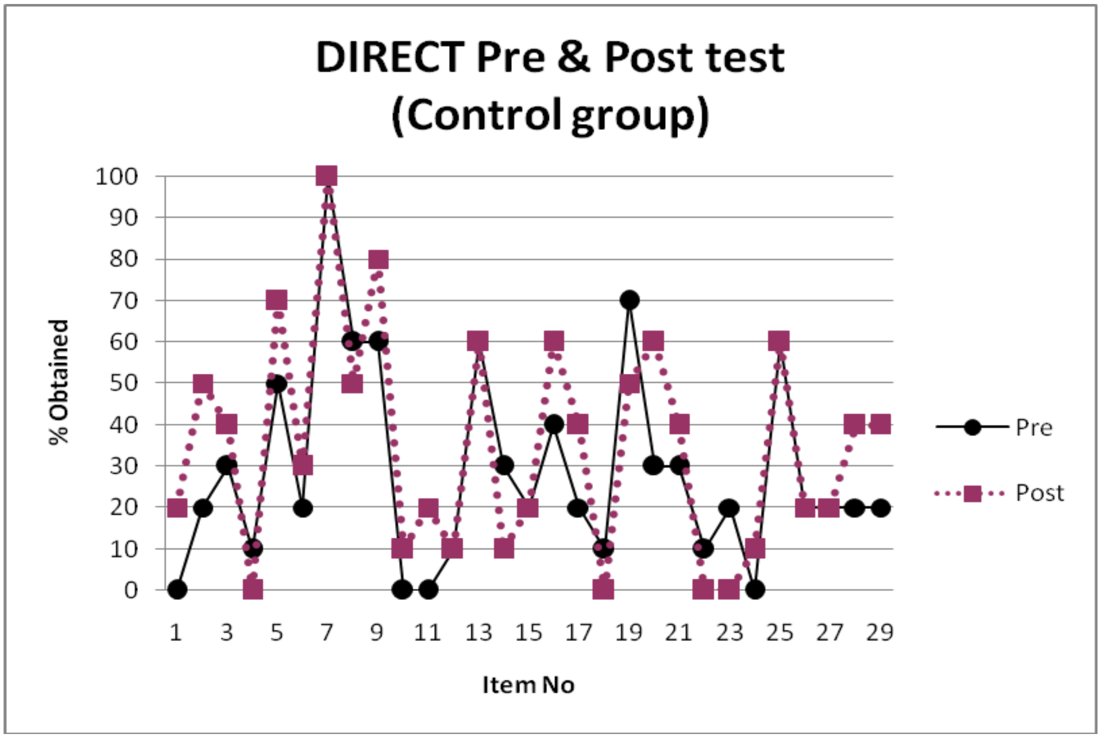


Figure 4.6 The performance of the control group in DIRECT pre test and post test

There are items whereby the students did better in the pre than in the post test, for example in items 4, 18, 22, and 23. In these cases the students did not score anything for the post test whereas for the pre test they scored 10% to 20%. It might be because sometimes the students do not read the question for understanding and maybe during the pre test they didn't know the correct answer they just guessed because it was multiple choice questions. In some cases they did not give an explanation. There was consistency in item 7 because the score was 100% in both the tests as well as in items 13 and 25 where the score was 60% in both tests. The consistency might mean that the students do have an idea of how electric circuit work, they did understand and they have learned. Figures 4.7 and 4.8 below show the DIRECT test results of the three students selected from each group. The data (figures 4.7 and 4.8) showed that conclusions cannot be made based on the average of all students. If the average for all students revealed that the performance of the post test was better than the pre test, it cannot be concluded that all the students performed better in the post test.

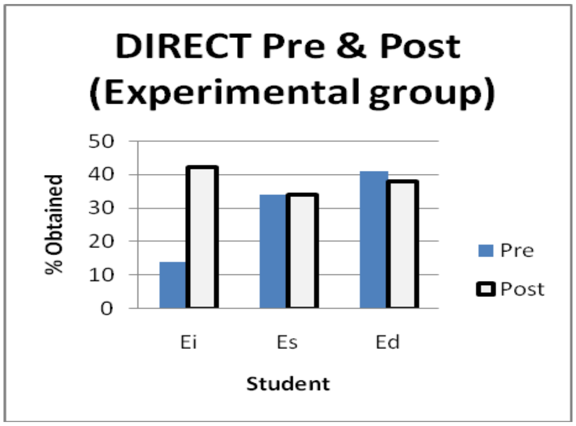


Figure 4.7 DIRECT Pre and Post test for 3 students from the experimental group

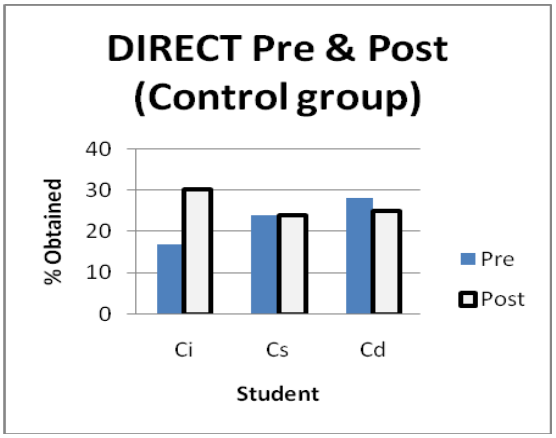


Figure 4.8 DIRECT Pre and Post test for 3 students from the control group

The explanations of students in the pre test were analysed. The same items that were analysed in pre test (see 4.2.2 in page 37) were considered in the post test in order to see if there was any improvement. The items that were analysed were items 1, 4, 7, 10, 11, 18, 19, 22, 24 and 25. During the post test item 7 remained very easy because all the students got the correct answer. All of them were able to explain it correctly in terms of when the potential difference increases, the current increases and therefore in the circuit with two batteries and one bulb, the bulb will be brighter than in the circuit with one battery and one bulb. The students did well in terms of explanations in both pre and post tests.

The answers to items 25 and 19, varied from easy to moderate. In the pre test their explanations were classified as easy and in the post test they were classified as moderate. Item 25 consisted of two circuits where the first circuit was one battery with one bulb and the second was one battery with two bulbs. The question was which bulb will be brighter. The reasoning of those who chose the wrong option was based on the fact that all the bulbs will be the same. They argued that the two bulbs in circuit 2 are connected in series with the battery hence the brightness will be the same and it will be the same as the one in circuit one because they both have one battery. The students' explanations in the pre test were not different from the explanations in the post test in these items.

Items 4, 10, 18 and 22 remained as very difficult. Even though the classification did not change, there was a change in terms of the performance and explanations in these items. During the pre test no student managed to score on item 10. During the post test there was at least 10% to 20% who managed a score. The score was more guess work than understanding because those who scored did not give any explanation. Most of the students, even those who chose the wrong option did not explain their choice, they left an empty space.

Items 1, 11 and 24 changed from very difficult to difficult. Students had difficulties in answering item 24. The question they had to answer was if you double the current through a battery whether the potential difference will double or not. The response of those who chose the correct option was that the potential difference will not double because it does not depend on the current.

4.5.2 Summary of the DIRECT pre and post tests results

The students were given an option of explaining their answers after each multiple choice question. The explanations were analyzed. During the pre test, the two groups did not show a big difference in the way the responded to the questions. In some cases they showed common mistakes. The literature indicates that students have a difficulty in identifying series and parallel connections in circuit diagrams and they do not understand and correctly apply the concept of a complete circuit (Engelhardt & Beichner, 2004). During the post test, both groups showed an improvement in performance even though on average the experimental group showed more improvement than the control group. The analysis of the explanations showed that the two groups showed an understanding of electric circuits, it might be because the two groups were exposed to the laboratory work and the lectures where misconceptions were addressed. The reasoning of the students was more conceptual in the post than in the pre test. They showed better understanding when answering some questions.

Students were able to translate from a realistic representation of a circuit to the corresponding schematic diagram. Students had difficulty making the reverse translation (see 4.2.2 item 22 in page 37). However, this result may be more indicative of their difficulty identifying shorts within circuits or of deficiencies in their knowledge regarding the contacts for light bulbs.

4.6 TISP Post test

The two groups wrote the TISP post test after they had done the laboratory work (see figure 3.1). The performance of both groups is shown in figure 4.9 below. Generally the performance of the groups is acceptable because in most items at least one of the groups managed to score 70% and above.

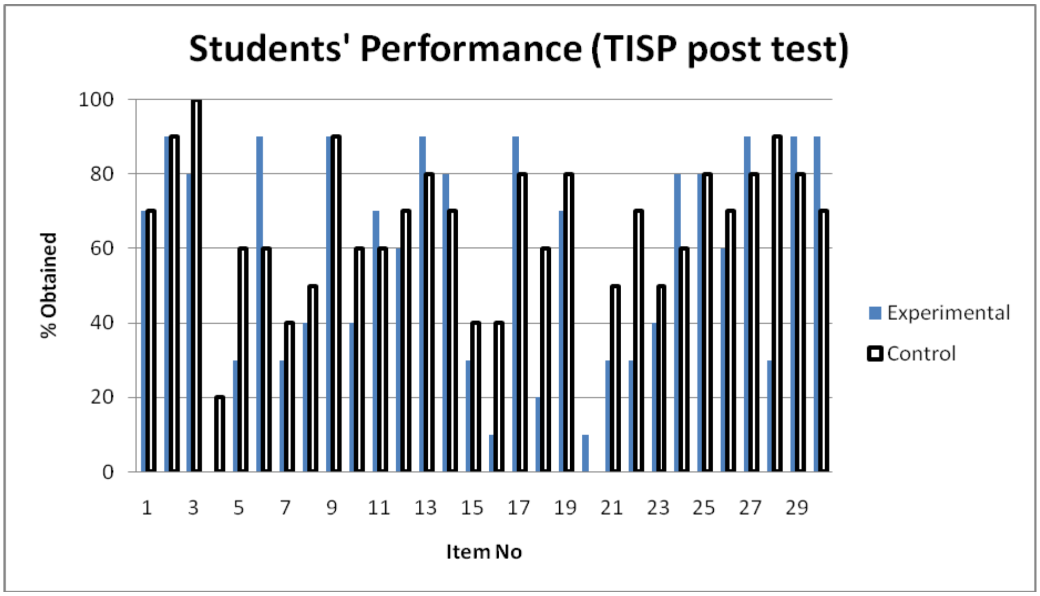


Figure 4.9 The performance of students (experimental & control group) per item on TISP post test

The TISP test was testing 5 process skills. These skills are shown in figure 4.10 below. The experimental group did better than the control group in two skills, identifying variables and stating hypothesis. In the other three skills, the control group performed better. During the observations, it was observed that the control group did better than the experimental group in stating the hypothesis whereas the experimental group did better in graphing and interpreting data. The two groups performed the same on the experimental design. In identifying variables and operational definitions, the observation schedule agrees with the TISP results. Even though the control group did better than the experimental group, it cannot be concluded that the intervention failed because in figure 4.10 the experimental group outperformed the control group as compared to figure 4.3 (page 43). It shows that the intervention helped the experimental group to perform better than the control group on other skills because at the beginning the control group did well on all the skills.

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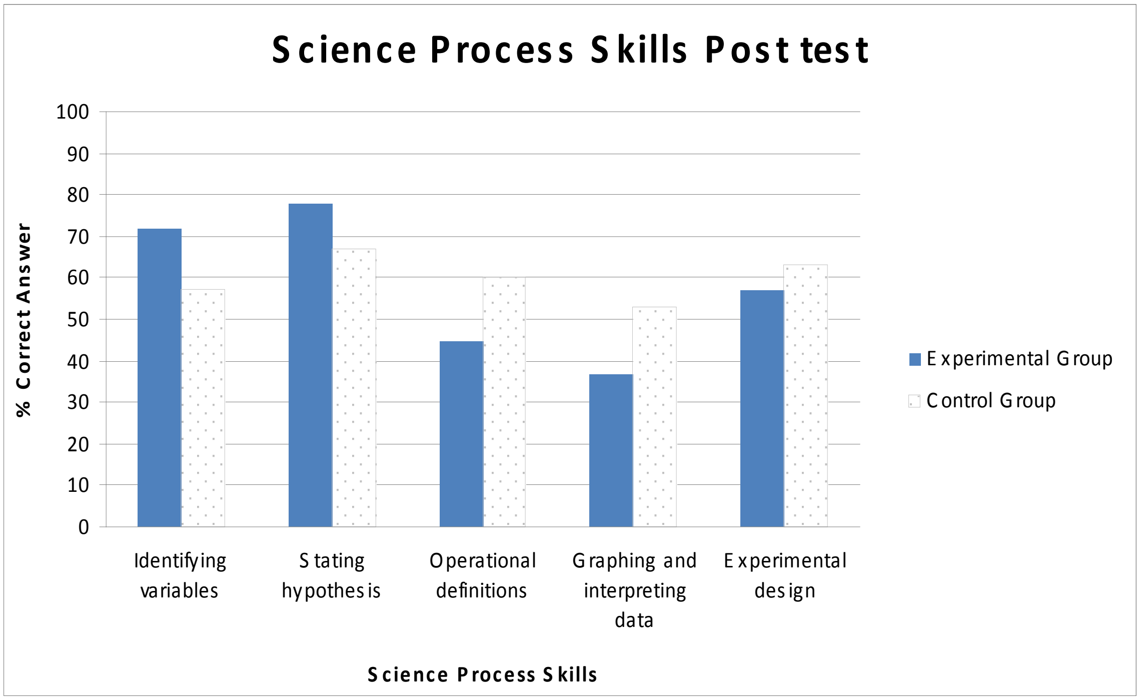


Figure 4.10 Science process skills tested during post test

4.6.1 Comparing pre and post test results of TISP

The results of the analysis from table 4.6 provide the answer to the question of whether the simulations did contribute to the development of process skills. Table 4.6 shows the comparison between the two groups based on the pre and post test of TISP. The score of student Ed decreased from 57% to 54%. Student Ei managed to increase the performance by 2%. These two students show consistency because they are the same students who decreased and increased respectively when writing the DIRECT test. Es has shown an increase of 1%. There is an improvement because in the DIRECT test the performance was the same. Student Ci scored 4% better than in the pre test. Cd has shown an increase of 1%. Cs stayed the same just like in DIRECT. The overall results on the performance of the experimental group did not change; the score remained at 57% whereas there was a change of 1% (from 63% to 64%) in control group. The data in table 4.6 is presented in figure 4.13 and figure 4.14 below.

Table 4.6 The results of TISP pre & post test for both groups

TISP					
EXPERIMENTAL GROUP			**CONTROL GROUP**		
STUDENT	Pre test	Post test	STUDENT	Pre test	Post test
E_1 (Ei)	**50%**	**52%**	**C_1 (Ci)**	**70%**	**74%**
E_2	60%	63%	C_2	77%	78%
E_3	43%	45%	C_3	67%	63%
E_4	63%	65%	**C_4 (Cs)**	**57%**	**57%**
E_5	50%	52%	C_5	83%	81%
E_6 (Es)	**60%**	**61%**	C_6	67%	69%
E_7	63%	63%	**C_7 (Cd)**	**47%**	**48%**
E_8	53%	54%	C_8	57%	60%
E_9 (Ed)	**57%**	**54%**	C_9	50%	56%
E_{10}	67%	65%	C_{10}	57%	58%
MEAN	**57%**	**57%**	MEAN	**63%**	**64%**

The difference between the pre and the post test results for both groups is not meaningful as shown in figures 4.11 and 4.12 respectively.

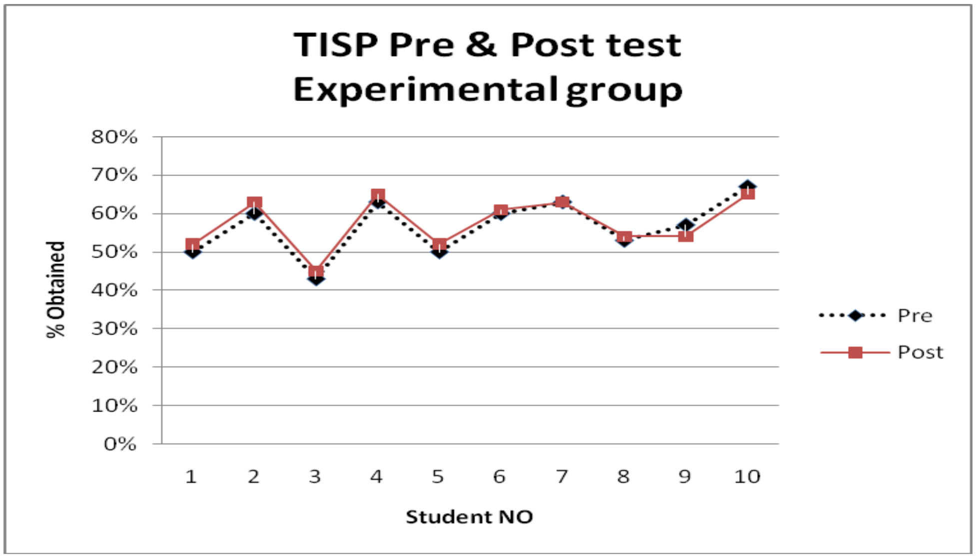


Figure 4.11 Comparison of the TISP pre test and post test for the experimental group

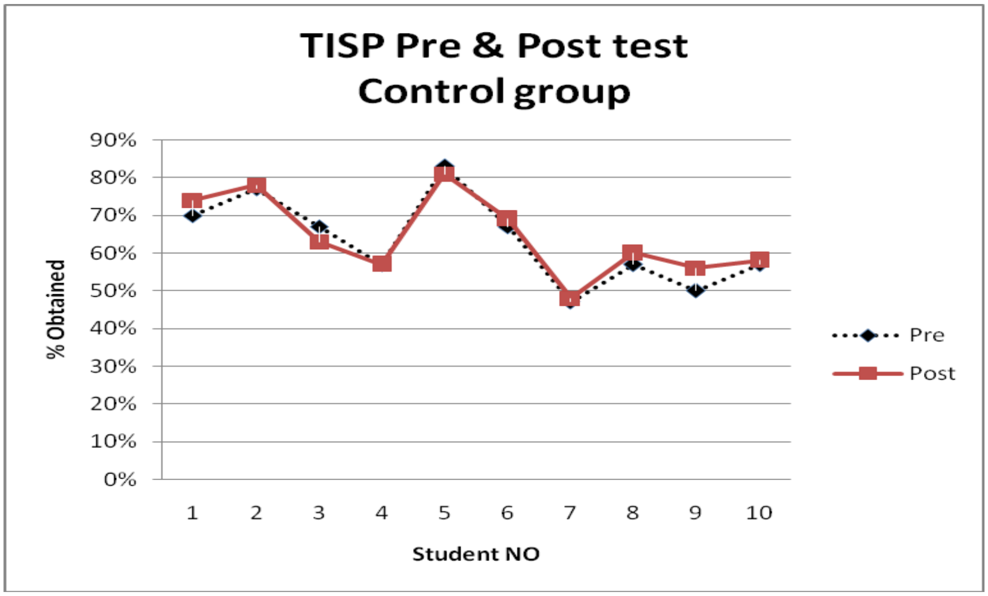


Figure 4.12 Comparison of the TISP pre test and post test for the control group

The three students from each group were compared and it was found that they did not show the same charecteristics they showed in DIRECT tests. The students whose performance stayed the same in the DIRECT tests did not stay the same and the student whose performance decreased in DIRECT tests did not decrease (see figures 4.13 and 4.14).

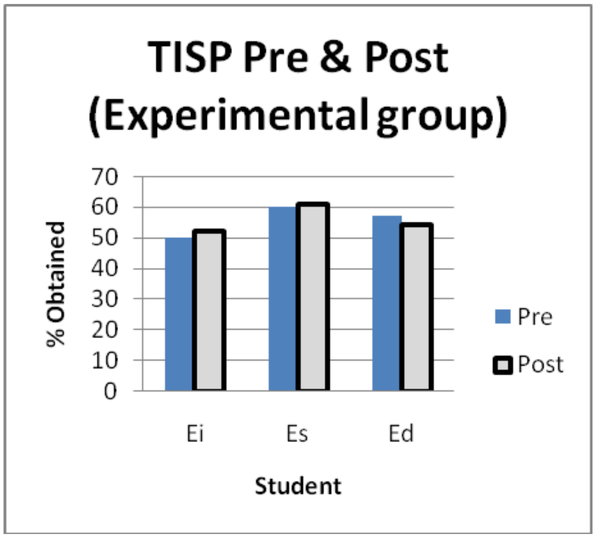


Figure 4.13 TISP Pre and Post test for 3 students from the experimental group

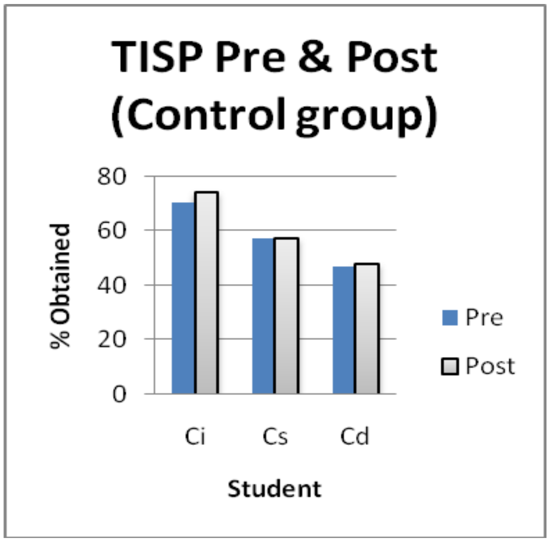


Figure 4.14 TISP Pre and Post test for 3 students from the control group

4.6.2 Summary of the TISP pre and post tests results

The students from the experimental group performed the same even after the intervention; this shows that the lectures on electricity and simulations did not have any effect on the development of the process skills. The three students that were chosen based on their performance on the DIRECT test did not perform the same as in DIRECT. During the TISP post test, student Es has increased instead of staying the same as in DIRECT. All three students from the control group's performance have increased. The difference in the pre and post tests is not substantial and therefore we can conclude that there was no significant change in the development of process skills. This was verified by the observations made during the laboratory work.

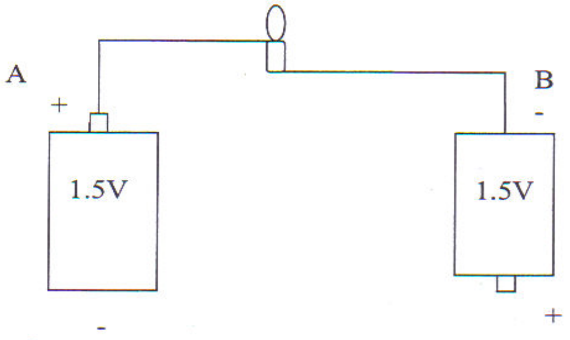
4.7 Class test

The students were given a class test after completing the Electricity and Magnetism module. The reason for giving them the class test was to check whether they can apply the concepts they did in the laboratory in class. In quadrant 4 of the theoretical model (figure 2.3), the students should be able to give creative feedback after the directed activity. The class test was to test creative feedback and conceptual understanding. Four of the questions in the class test were developed to determine their conceptual understanding and two on calculations (see appendix D).

4.8 Analysis of questions from Class test

In question 1, six students (see table 4.7 in page 80) from the control group answered yes and their reasoning was that the bulb will light because the first battery is connected to the positive terminal and it ended up connected to the negative terminal of the second battery. It starts from positive and ends on negative hence it will light. The three students from the experimental group responded differently to the same question. Student Ei was able to get the correct answer, the student realized that the circuit is not complete and the current will not flow hence the bulb will not glow. Student Es's reasoning was based on the terminals of the batteries, even if the bulb is connected between the correct terminals the bulb will not glow because of the incomplete circuit. Student Ed was correct by saying the bulb won't glow but was not sure of the reason why. The students' responses are given in example 4.20 to 4.28 that follow. Student E_i answered correctly.

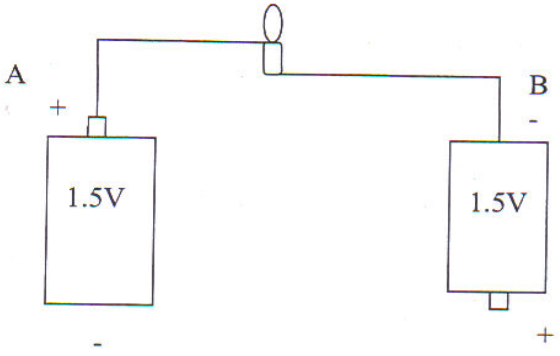
Question 1: Is the bulb lit? Yes No Why?



No. It is not possible for the bulb to light because for the current to flow the circuit should be complete, in this case there wont be any flow of current

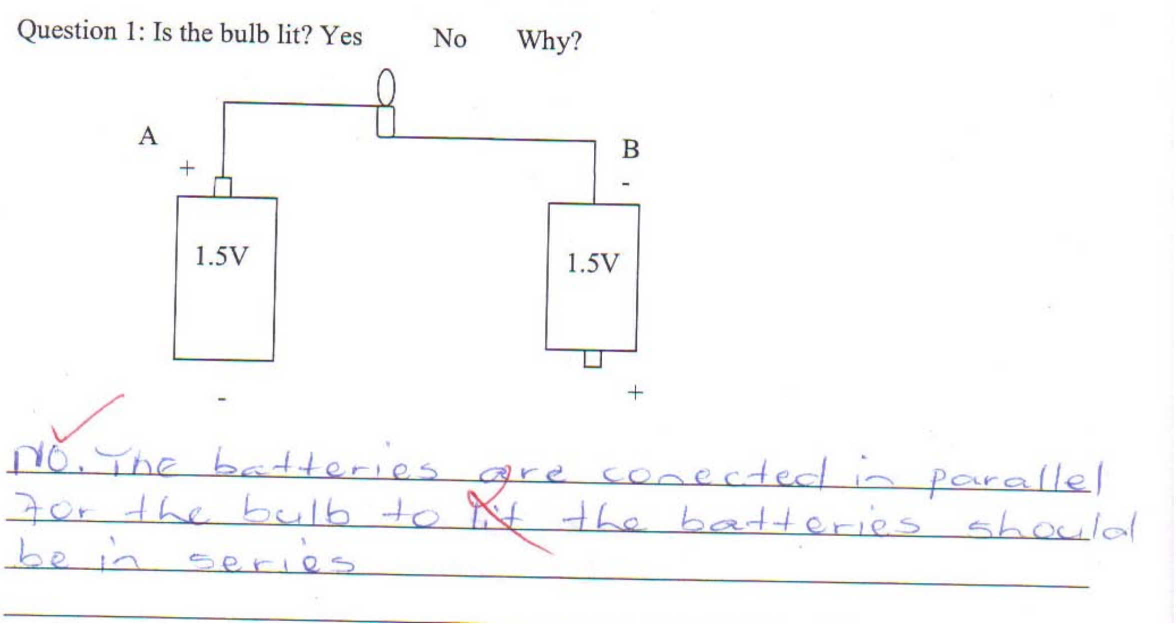
Example 4.20 Student Ei

Question 1: Is the bulb lit? Yes No Why?



Yes. For the bulb to light it should be connected to a positive terminal and a negative terminal of the battery. It will be very bright because it is connected to two batteries

Example 4.21 Student Es

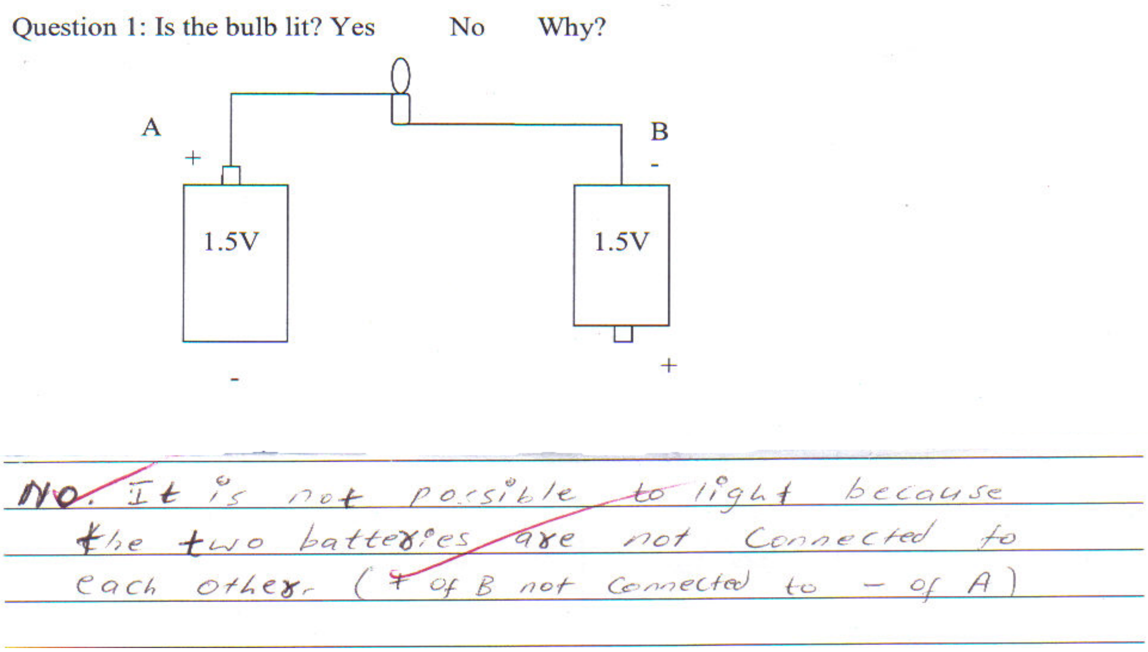


Question 1: Is the bulb lit? Yes No Why?

NO. The batteries are conected in parallel for the bulb to lit the batteries should be in series

Example 4.22 Student Ed

The three students from the control group gave their answers to question 1 and student Ci responded positively to the question. Student Cs's response was based on the fact that he is not sure whether the batteries are fully charged or not, the student said if the batteries are full the bulb will glow. Student Cd's argument was on the drawing itself, the student highlighted that the drawing should give the direction of whether the bulb is on or off.

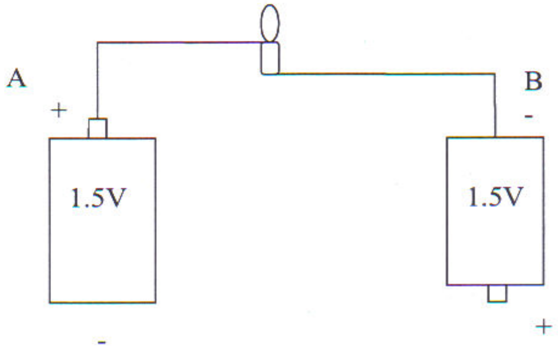


Question 1: Is the bulb lit? Yes No Why?

No. It is not possible to light because the two batteries are not connected to each other. (+ of B not connected to - of A)

Example 4.23 Student Ci

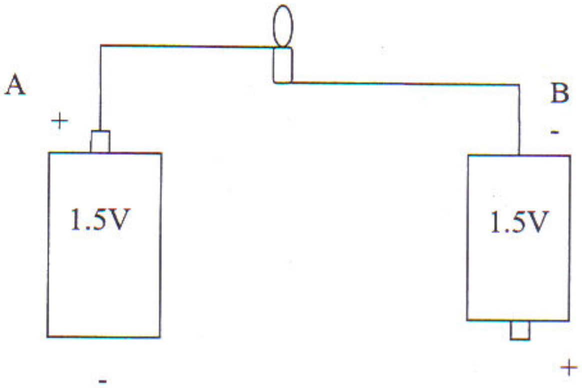
Question 1: Is the bulb lit? Yes No Why?



Yes. The bulb is conected to the batteries. If the batteries are full it will be on, if they are empty the bulb will be off.

__Example 4.24__ Student Cs

Question 1: Is the bulb lit? Yes No Why?

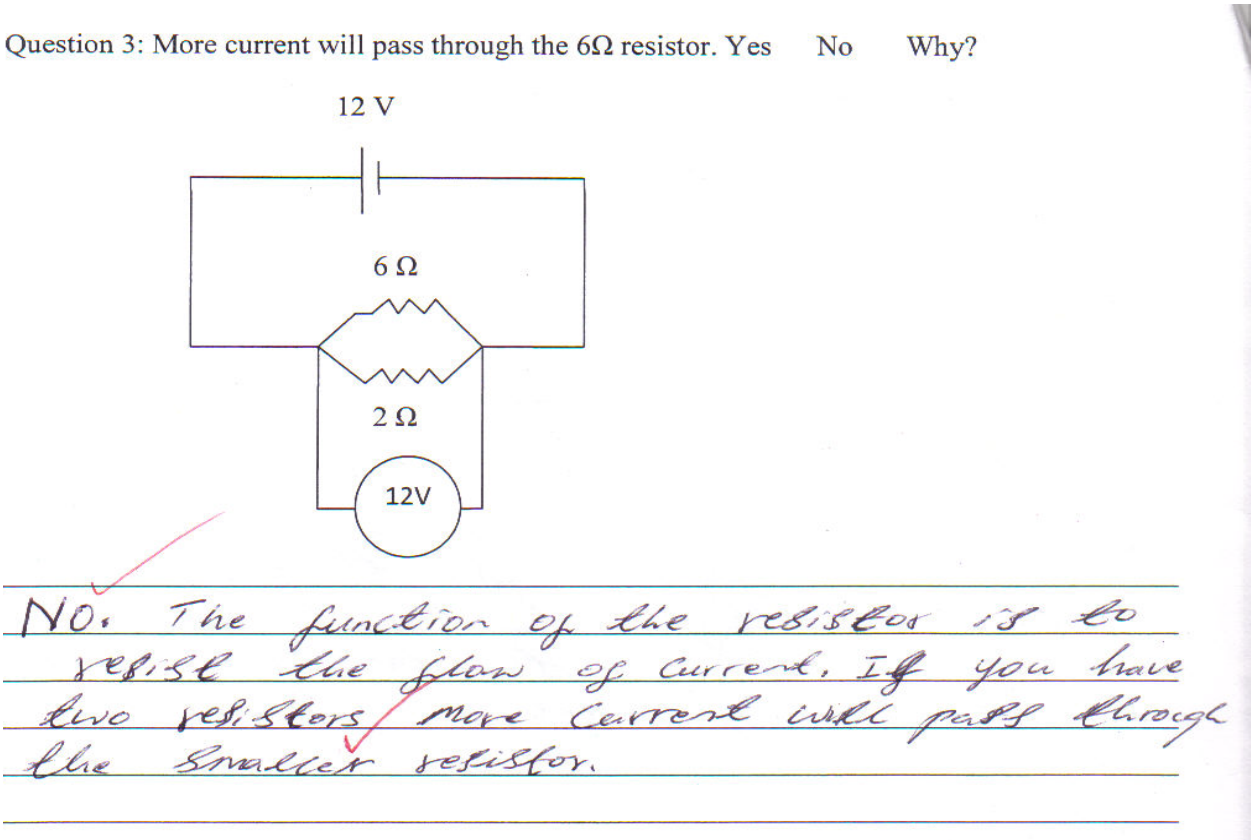


No. When the bulb lits it should show on the drawing  .

*__Example 4.25__*Student Cd

In question 2, seven students from the experimental group got the correct answer. The other three students reasoned that the bulb will not light because it is connected between two batteries that are connected in parallel. There were five students from the control group who got the correct answer. The control group students who did not get this question correct, reasoned that the batteries should be of the same size.

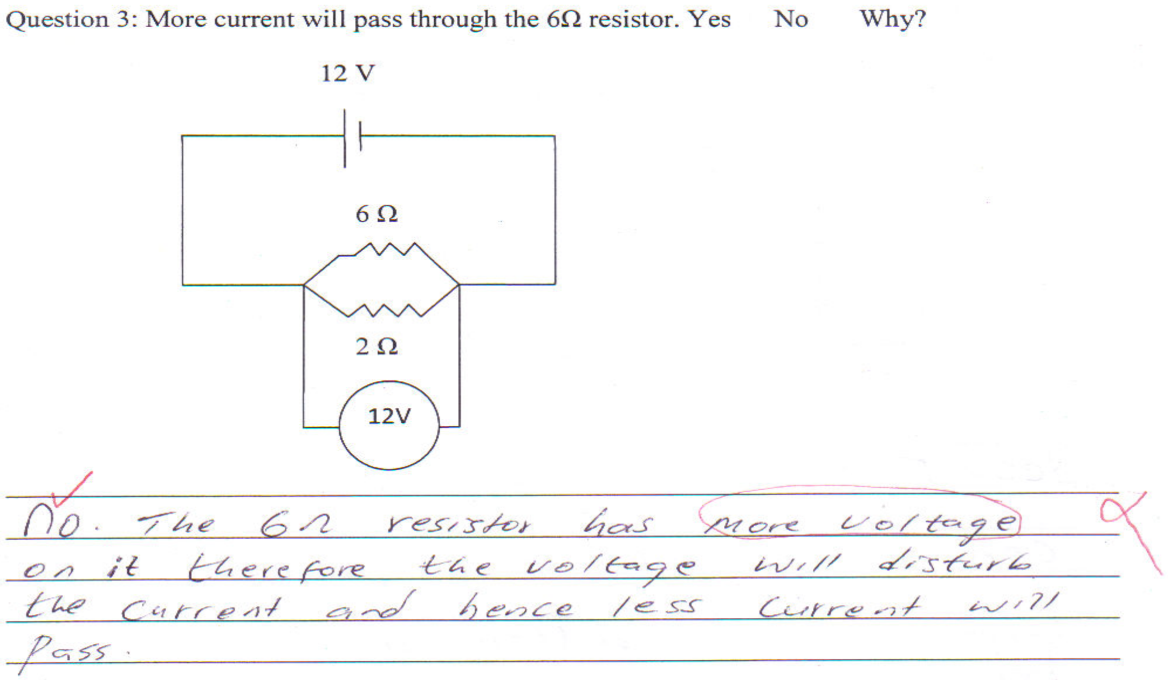
In question 3, two students from the experimental group and four students from the control group incorrectly thought that more current will pass through the 6Ω resistor because the 6Ω resistor is greater than 2Ω resistor; therefore more current will pass through it. Student Es was not sure why more current will not pass through a 6Ω resistor. Student Ed had an idea of what will happen to the current when it reaches the junction, but his reasoning was based on equal resistors. Student Ei answered correctly.



Question 3: More current will pass through the 6Ω resistor. Yes No Why?

No. The function of the resistor is to resist the flow of current. If you have two resistors more current will pass through the smaller resistor.

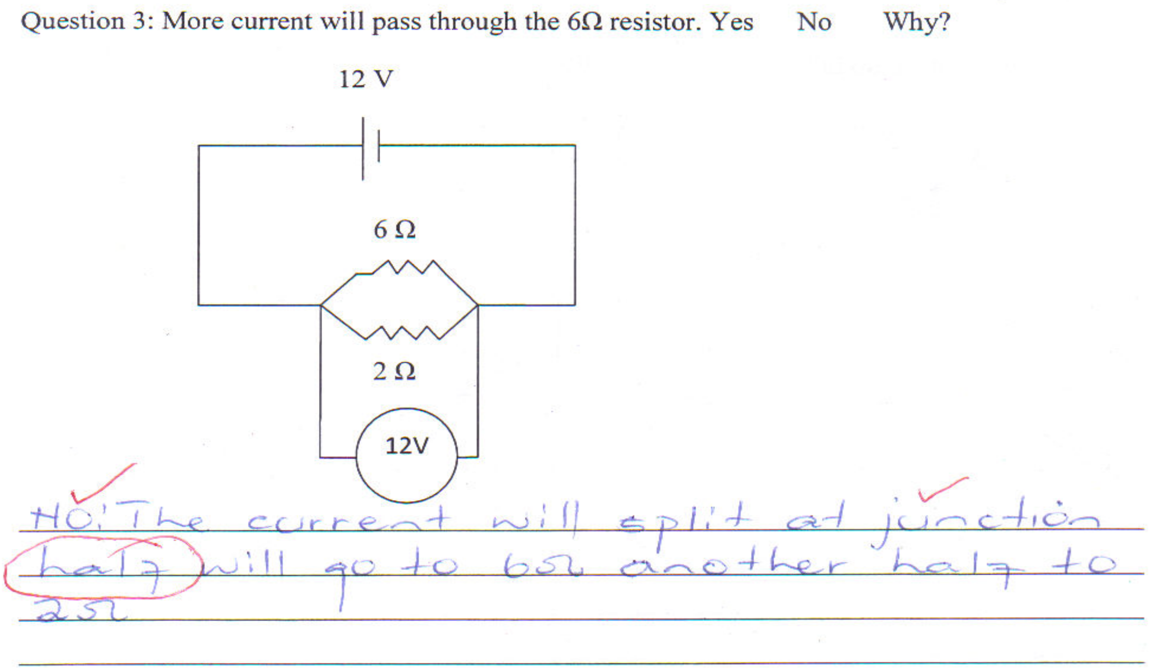
Example 4.26 Student Ei



Question 3: More current will pass through the 6Ω resistor. Yes No Why?

✓ No. The 6Ω resistor has more voltage on it therefore the voltage will disturb the current and hence less current will pass.

Example 4.27 Student Es

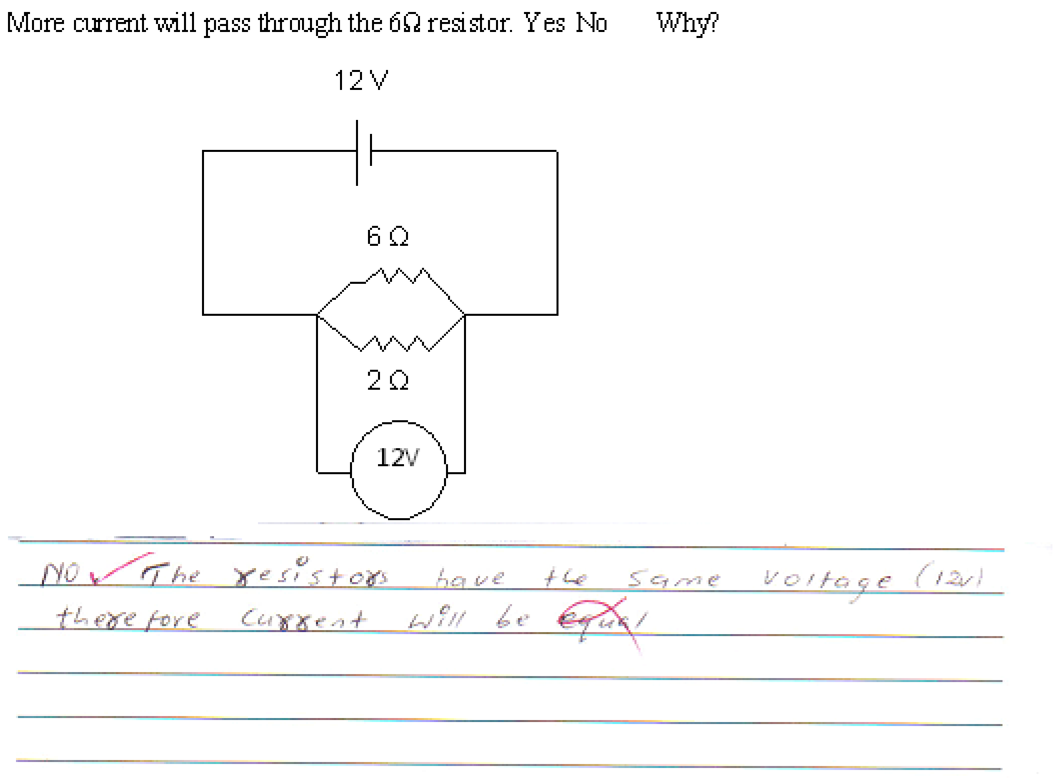


Question 3: More current will pass through the 6Ω resistor. Yes No Why?

✓ NO! The current will split at junction ✓ half will go to 6Ω another half to 2Ω

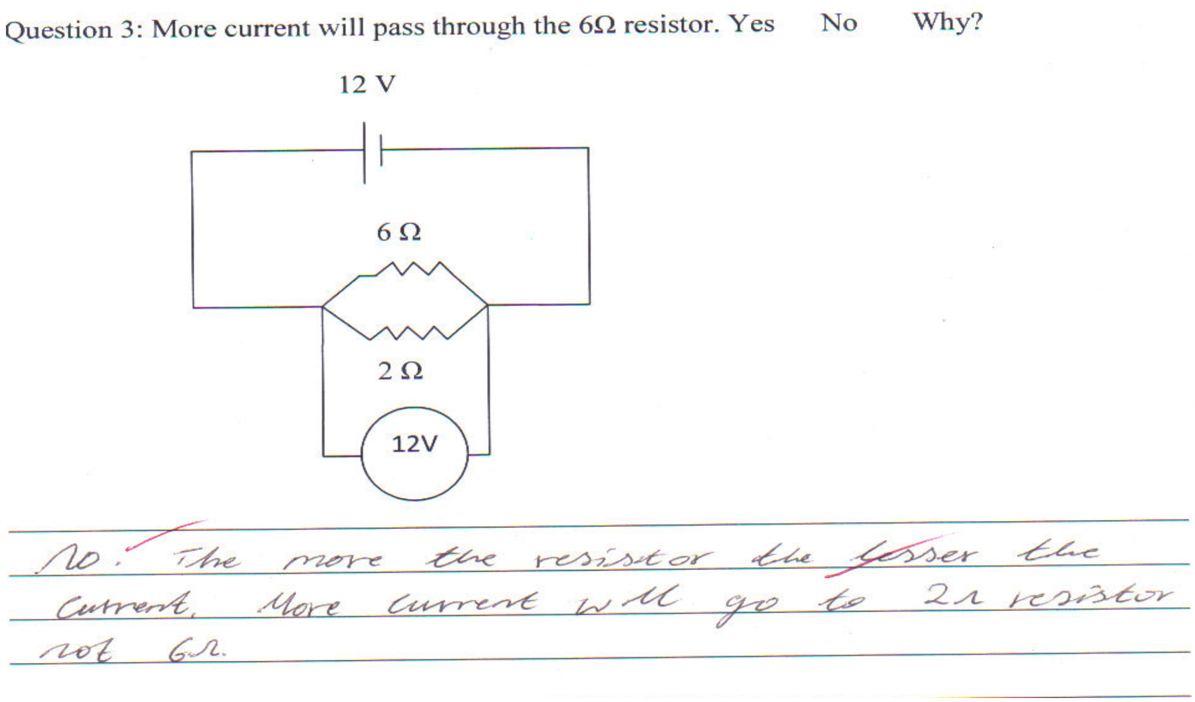
Example 4.28 Student Ed

From the control group, student Cs managed to get the correct answer whereas student Cd did not. Student Cd thought that the resistors attract current; if the resistor is big therefore it will attract more current. Student Ci knew that less current will pass through the 6Ω resistor but the problem was the reasoning part. The student was correct by saying the two resistors has equal potential difference across them.


More current will pass through the 6Ω resistor. Yes No Why?

NO ✓ The resistors have the same voltage (12V)
therefore current will be equal

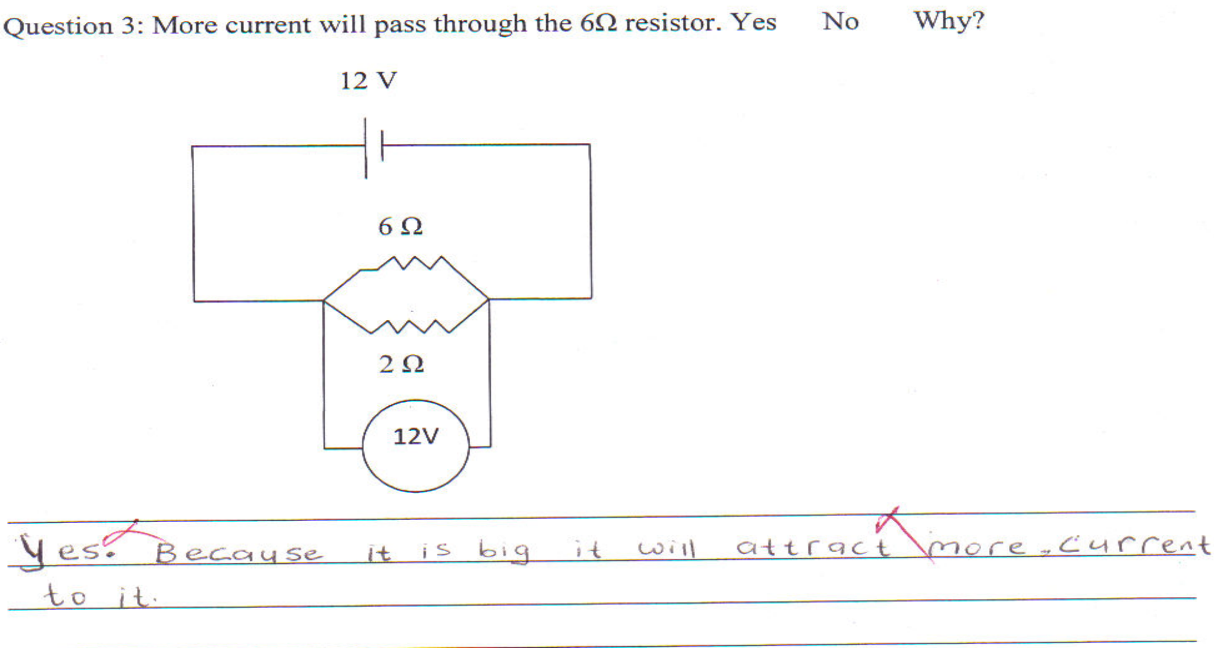
Example 4.29 Student Ci



Question 3: More current will pass through the 6Ω resistor. Yes No Why?

No. The more the resistor the lesser the current. More current will go to 2Ω resistor not 6Ω.

Example 4.30 Student Cs



Question 3: More current will pass through the 6Ω resistor. Yes No Why?

Yes. Because it is big it will attract more current to it.

Example 4.31 Student Cd

Question 4 was a calculation type of question. The students were asked the same question as in question 3 but in the form of a calculation. All the students managed to calculate the current that passes through the 6Ω resistor. It is easy to get the correct answer when you calculate as long as you know the correct equation to use. The problem mainly required substitution. Most students said that it is easy to apply the mathematical theorems or methods without understanding the physical phenomena and get correct answers. It implies that students are able to develop “a system” to solve problems with specific conditions. By just applying the right mathematical method it is possible to get the correct answer. But, when the conditions for the problem are changed “their system” will not work and some of them do not know how to handle the situation (McDermott, 1993). This is worrying in education because the students lose the principal aim (that is learn) and just work like machines, very skilful at using computers and calculators, producing good answers but without understanding the meaning of the calculations.

In question 5, seven students from the experimental group got the correct answer, the remaining three got the answer correct but they failed to give the correct explanation. The common explanation was that the 2Ω resistor will not have more potential difference because it has less resistance, therefore the 6Ω resistor will be the one having more potential difference. Considering the control group, the situation was the opposite, because seven of them got the wrong answer. They gave the same reasoning as the three from the experimental group.

In the last question the control group managed to score higher than the experimental group. Those who got the correct answer from both groups were able to state that the resistors will share the 12V. In this question the two groups were having a common understanding of the concepts.

The summary of the class test is given in table 4.7 below. It gives the number of students who got the correct and the wrong answers to all the questions in the class test.

Table 4.7 The number of students obtaining the correct answer (correct answer in bold and underlined) in the class test.

Class Test				
Question No	**Experimental group**		**Control group**	
	Yes	**No**	**Yes**	**No**
1	4	**6**	6	**4**
2	**7**	3	**5**	5
3	2	**8**	4	**6**
4	10		10	
5	3	**7**	7	**3**
6	2	**8**	1	**9**

4.9 Comparing the six students

The six students were compared based on their responses given in the examples. Their responses were graded as being good (G), moderate (M) and bad (B). The response was rated good if was correct, moderate if partly correct and bad if not correct. Their ratings are shown in table 4.8 below.

Table 4.8 Rating of the 6 students from both groups

	Graph (Ohm's law)			**Current (worksheets)**			**Bulb (class test)**			**Resistor/Current (class test)**		
	G	**M**	**B**	**G**	**M**	**B**	**G**	**M**	**B**	**G**	**M**	**B**
Ei	X			X			X			X		
Es	X				X				X		X	
Ed		X			X			X			X	
Ci		X			X		X				X	
Cs		X			X				X	X		
Cd			X		X			X				X

The 3 students from the experimental group responded good (G) 5 times, moderate (M) 6 times and bad (B) once whereas the 3 students from control group responded good (G) twice, moderate (M) 7 times and bad (B) three times. The students from the experimental group performed better than the control group.

4.10 Interviews and their analysis

The interviews were used for the verification of the data collected. The same students (Ei, Es, Ed, Ci, Cs, and Cd) were selected for the interviews. All the interviewees were relaxed and free to give their opinions. The researcher made it clear to the students that the interview will not contribute towards their marks because all their marks have been submitted to the head of department. The interview questions together with the students' responses are given below.

1. **When three unequal resistors are connected in series to a battery, which one will have more current passing through it and why?**

Student Ed responded to question 1 by saying "*I remember during the simulations, the resistors were not equal and more current passed through the less resistor, so more current will pass through the smallest resistor because the lesser the resistance the more the current*" Student Cd said "*Because the resistors are not equal, so everything will be unequal. According to Ohm's law R = V/I, resistance and current are inversely proportional, therefore less resistance more current*". Student Cs response was that if resistors are not equal, both current and voltage will not be the same and the one with less voltage will have less current. Student Ci stated that "*if the resistors are equal the current will be equal but also when the resistors are connected in series current is equal even if the resistors are not equal*". Students E_i and E_s were able to detect that the resistors are in series and their sizes does not matter because all of them will have the same current passing through them.

2. **When you have a circuit consisting of a battery, ammeter and a resistor in series, what will happen to the total current when you add another resistor in series and why?**

All 6 students answered this question correctly; they managed to explain that the total current will decrease because if you add another resistor, the resistance increases hence the current will decrease as compared to when there was only one resistor.

3. **Suppose you have three resistors connected in series to a battery and you measure their potential difference individually, what conclusion can you draw about their potential difference?**

In the third question, most of the students were a bit confused, but student E_i said "*I remember the slogan that I used to have when I was doing grade 11. Resistors in series are the potential divider and parallel are current divider. In series if you add the potential difference across all the resistors they will give you the potential difference you started with. I used to hear that but this year I managed to see the resistors being the current or potential dividers*". Ed, Ci, and Cs thought that all the resistors will have equal potential difference and it will be the same as that of the battery. Student Es said "*If you measure them individually you will get different voltage and at the end when you measure all of them, they will give you the voltage of the battery*". Student Cd was confused and claimed not to understand the question.

4. **When unequal resistors are connected in parallel to a battery, which one will have more current passing through it?**

All the students got the fourth question correct except student Cd. They were able to relate current correctly in this case. Less resistance, more current will pass through.

5. **What happens to the potential difference of resistors connected in parallel?**

Student Ei, Es and Ci mentioned that the potential difference of the resistors connected in parallel is constant; if the potential difference of the battery is 12V therefore the potential difference of all the resistors will be 12V. Student E_d responded that "*the potential difference will also depend on the value* *of the resistor and the number of resistors connected like if the resistors are many the potential difference will be lesser*.” Student Cd said “*I am confused because according to my knowledge nothing will happen, but the way you ask the question it seems as if something will happen. Nothing will happen*”. Student Cs did not know what to say, said “I don’t know”.

6. **What is the relationship between the current and the potential difference?**

All the students were able to relate the current and the voltage. They all quoted Ohm’s law.

Students Ei, Es and Ed were asked extra questions, because they were from the experimental group and they did the simulations:

7. Between the simulations and the laboratory work, which one (if any) do you think has helped you to understand the electric circuits’ concepts better and why do you say so?
8. If you were to choose between simulations and laboratory work, which one will you choose and why?

All students in the experimental group who did the simulations said they will choose simulations because they think that the simulations helped them to understand better.

4.11 Summary of the interviews

From the six students who were interviewed, one student was able to respond satisfactorily to all the questions and two responded well to five questions out of six. The other three students responded well to the three questions and not satisfactory to the other three. On average the three students from the experimental group were able to respond better than those from the control group. The correct responses from the experimental group were fourteen out of eighteen as compared to eleven for the control group. The ratings of the interviewees are shown in table 4.9 below. The students were rated good (G) if their response were correct and bad (B) if their response were not correct.

Table 4.9 Rating of six students from the interviews

	Q1		Q2		Q3		Q4		Q5		Q6	
	G	B	G	B	G	B	G	B	G	B	G	B
E_i	X		X		X		X		X		X	
E_s	X		X			X	X		X		X	
E_d		X	X			X	X			X	X	
C_i	X		X			X	X		X		X	
C_s		X	X			X	X			X	X	
C_d		X	X			X	X			X	X	

4.12 Summary of the chapter

The data collected indicated a positive contribution of the simulations to the practical work of Foundation Physics students at the University of Limpopo. Due to the fact that the sample was small, and the other group got an extra practice the results cannot be generalized and the difference in the scores might not be statistically significant. The eight percent increase in the DIRECT post test has shown that the experimental group performed better than the control group who only managed a four percent increase. This was also seen when their explanations on the DIRECT pre and post tests were compared. The reasoning of the experimental group has improved. The control group performed better than the experimental group in TISP (both the pre test and the post test). This shows that even if the simulations can contribute positively to the practical work, it does not mean it will develop the science process skills over such a short period of time. The observation schedule confirmed that the two groups did not show a significant difference in terms of the development of the 5 process skills tested. The class test has proved that the students are able to calculate values and get the correct answer, whereas they cannot give the correct answer by explaining. The students were able to link what they did in the laboratory with what they did in class. The creative feedback was positive. The responses from the interviews verified the data collected because students from the experimental group were able to respond well to the questions.

CHAPTER 5

SYNTHESIS, RECOMMENDATIONS AND CONCLUSIONS

5.1 Introduction

This chapter gives a brief account of what was carried out in the study as well as its limitations. The conclusions are presented as well as recommendations for the future.

5.2 Summary of the study

The purpose of this study was to investigate the contribution of simulations on students' practical work in Foundation Physics at the University of Limpopo (Medunsa campus). Data was collected from the students who agreed to take part in the study. The students were randomly divided into two groups, 10 were assigned to the experimental group and another 10 were assigned to the control group. The theoretical framework model was used as a guideline and the goals of Medunsa practical work were plotted using the theoretical framework model. The DIRECT and TISP tests were used as pre and post tests to determine their electric circuits understanding and their development in science process skills respectively. Observations, worksheets and the class test were also used to collect data. Finally interviews were conducted with 6 students (3 from the experimental and 3 from the control group) and the data was analyzed qualitatively. The reasons given in the DIRECT tests were analyzed with regards to conceptual understanding while the TISP tests were analyzed with regards to the 5 process skills namely: identifying variables, stating hypothesis, operational definitions, graphing and interpreting data and experimental design.

5.3 Discussions of findings

The research question in this study stated that: What is the contribution of simulations to the practical work of Foundation Physics students at the University of Limpopo? The question had the following sub questions:

- In what way could simulations contribute to students' understanding of electric circuits?
- In what way could simulations contribute to the development of science process skills?
- What contribution could simulations make with regards to the goals of practical work at Medunsa?
- Can simulations replace laboratory equipment to alleviate the problem of a large number of students and limited apparatus?

In order to answer the research questions, the following data instruments were used for data collection:

- DIRECT pre and post test and reasoning
- TISP pre and post test
- Worksheets
- Observation schedule
- Class test
- Interviews

In order to conclude that the simulations did contribute to the practical work, we should have a relook at the laboratory work at Medunsa before and after simulations were introduced. After the analysis of the data collected by the DIRECT pre and post tests together with the explanations, worksheets and class test, the findings showed that the simulations have contributed positively on the students' understanding of electric circuits. The experimental group has shown an improvement in the way they answered the questions. They have shown an understanding of concepts when answering conceptual questions.

Simulations can enhance the academic performance and learning achievement levels of students Michael (2001). The findings of this study confirmed the study conducted by Betz (1996), namely; that the students who supplemented their classes with the use of simulations performed better in their examinations.

After analysis of the data on the 5 process skills collected by TISP pre and post tests, the findings of the study showed that the students from the control group performed better than the students from the experimental group even though the difference is not actually significant (only 1% difference). The results showed that the experimental group did not perform better than the control group even after the simulations. This could indicate that the simulations did not have an effect on the development of science process skills. The observations confirmed the data collected by the TISP tests on the process skills tested. It showed that both groups were doing equally on the process skills; this means one group was doing well in one skill and the other group on another skill. During the laboratory work the two groups did not show any difference when handling the apparatus and recording the data.

Geban *et al.* (1992) found the impact of simulations on process skills such as, identifying variables, measuring, graphing and interpreting data and designing experiments, to be equally or more valuable than traditional methods. This is in agreement with the findings of this study, because simulations contributed equally to laboratory work with regards to the development of process skills. The simulations did not result in any change on the development of the process skills tested.

This study has shown that the simulations can be the solution to those institutions that experience a lack of experimental apparatus. This study was conducted on a small sample of students, but the simulations can be used with large groups to overcome the problem of lack of apparatus. The data collected from the interviews was used to supplement the data collected by other methods. The results from the interviews confirmed the results collected by DIRECT and other tests. The students from the experimental group were able to give valid explanations, indicating an understanding of the electric circuits' concepts.

This study has contributed to the practical work at Medunsa because as stated in chapter 1, the main goal of laboratory work at Medunsa was for students to gain experimental skills. After the intervention, the goal was no longer to gain experimental skills only, but also focused on conceptual understanding which led to creative feedback. The students were expected to understand the concepts done in the laboratory and be able to link them with what they did in class. A transfer of knowledge was expected and it was tested during a class test and interviews. Figure 2.4 showed the theoretical framework model (TF) of the practical work at Medunsa before the intervention. After the simulations, the fifth type (recall) was included in the TF model at Medunsa (see fig 5.1) and will be shown as the TF model at Medunsa in future. It was shown that simulations provide students with immediate and reliable feedback; hence simulations can be used as supplementary material.

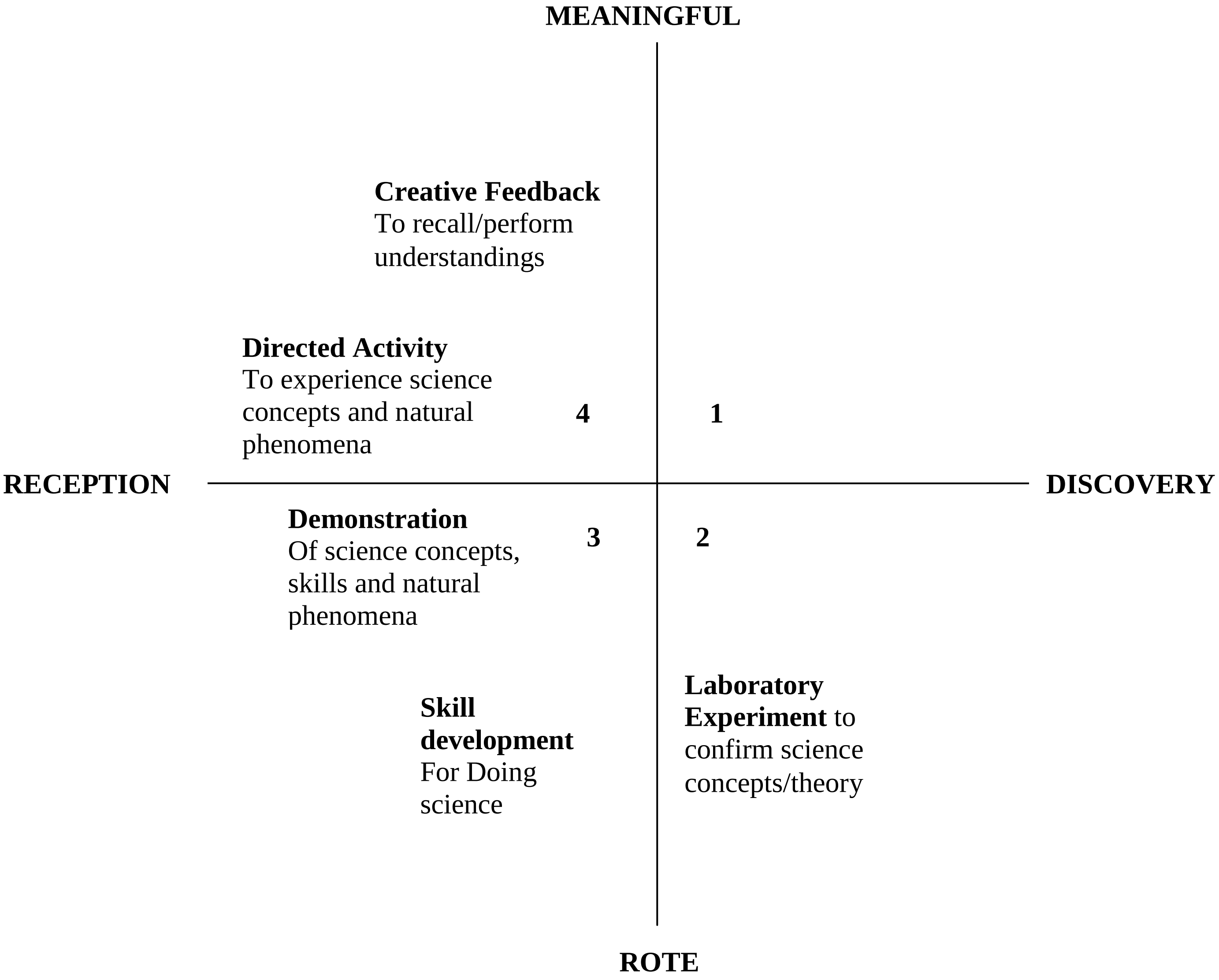


Figure 5.1. The Future Theoretical Model for Science Practicals at Medunsa

5.4 Limitations of the study

In every institution there are rules and regulations that govern practical work. There are certain procedures and protocols to be followed to use the allocated budget. To set up a good laboratory is very expensive. Factors such as the cost of equipment and safety issues have made the experimental laboratory a challenging component. At Medunsa we do not have enough apparatus and it becomes difficult for the students to understand all the concepts that the lecturer wants them to understand in the laboratory. It is also difficult for all the students to develop the science process skills if they are expected to work in large groups.

This study concentrated on improving the electricity section only. Other sections such as mechanics, optics, properties of matter & thermodynamics, modern physics and oscillations & waves will be taken into consideration at a later stage after evaluating the success of this intervention.

Another limitation of this study was that the sample was small and therefore quantitative data were not reliable.

5.5 Recommendations

Theory and laboratory work has been shown to supplement each other in this study. Practical work should not be seen as something different from what is taught in the lecture rooms. Students should be able to connect or relate the two. This study has shown that the simulations influence the understanding of students in electric circuits. Simulations should be used more often in laboratories and also in classes, but not be used as a substitute for laboratory work. Simulations should be considered especially in a situation where real equipment is expensive or not available.

5.5 Suggestions for future research

Future research on the contribution of simulations to the practical work of Foundation Physics students could include:

1. An expansion of the Theoretical framework model of science practical work (figure 2.4) to include all types of practical work in all 4 quadrants.

2. Research on the impact of simulations in the Foundation or first year level where institutions are faced with an increasing number of students every year.
3. Other experiments that can focus on process skills.

5.6 Conclusions

The present study which investigated the contribution of simulations to the practical work of Foundation Physics students at the University of Limpopo has not been carried out before. It was the first time that simulations were introduced in the laboratory at Medunsa. The present study reported that the simulations increased the conceptual understanding of students, and it agrees with McKee *et al.,* (2007). The experimental group showed that the simulations had a positive contribution on the understanding of electric circuits of students. Simulations added another dimension to the goals of practical work at Medunsa. Simulations can be used as a solution to alleviate the problem of the lack of enough apparatus in the lab. It can be concluded that the simulations did contribute positively to the practical work even though the results of this study cannot be generalized due to the small sample used.

Even though simulations increased conceptual understanding, they cannot be a substitute for the work done in the laboratory with real equipment; they should be used jointly because they did not contribute positively to the development of the tested process skills. Higher skills or integrated process skills may be developed using other types of practical work such as laboratory experiments, directed inquiry/problem solving or open inquiry/problem solving. Not all the skills will be developed by one laboratory experiment. The skill to be developed depends on which experiment is done (Bradley, 2005).

The findings of this study were in line with some of the advantages of simulations as described by Michael (2001) and listed in chapter 2 (2.7.1). Simulations did provide students with immediate and reliable feedback and saved the students’ time.

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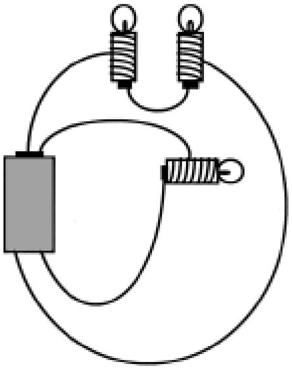
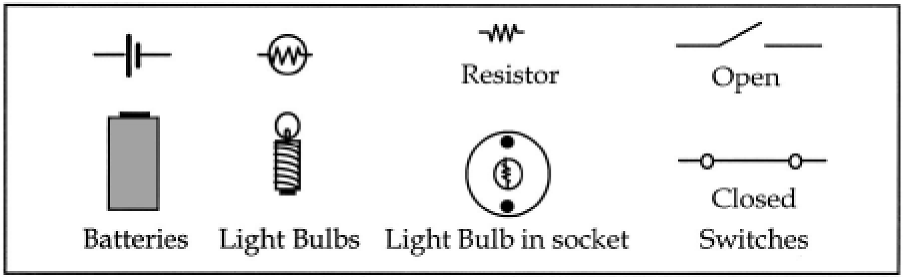
APPENDIX A



Determining and
Interpreting
Resistive
Electric Circuits
Concepts
Test Version 1.0

Additional comments about the test

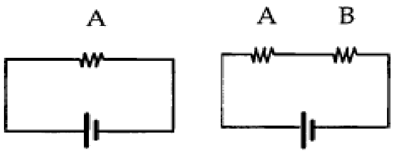
All light bulbs, resistors, and batteries should be considered identical unless you are told otherwise. The battery is to be assumed ideal, that is to say, the internal resistance of the battery is negligible. In addition, assume the wires have negligible resistance. Below is a key to the symbols used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



1. Are charges used up in the light bulb, being converted to light?

(A) Yes, charges moving through the filament produce “friction” which heats up the filament and produces light.
(B) Yes, charges are emitted
(C) No, charge is conserved. It is simply converted to another form such as heat and light.
(D) No, charge is conserved. Charges moving through the filament produce “friction” which heats up the filament and produces light.

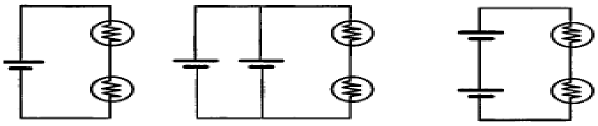
2. How does the power delivered to resistor A change when resistor B is added as shown in circuits 1 and 2 respectively?
(A) Increases
(B) Decreases
(C) Stays the same



Circuit 1 Circuit 2

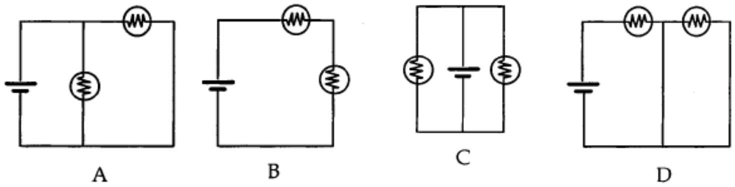
3. Consider the circuits shown below. Which circuit or circuits have the greatest energy delivered to it per second?

(A) Circuit 1
(B) Circuit 2
(C) Circuit 3’
(D) Circuit 1 = Circuit 2
(E) Circuit 2 = Circuit 3



Circuit 1 Circuit 2 Circuit 3

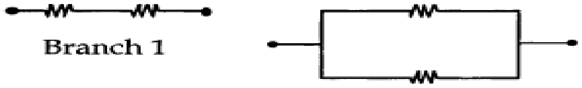
4. Consider the following circuits



Which circuit(s) above represent(s) a circuit consisting of two bulbs in parallel with a battery?
(A) A
(B) B
(C) C
(D) A and C
(E) A, C, and D

5. Compare the resistance of branch 1 with that of branch 2. A branch is a section of a circuit. Which has the least resistance?

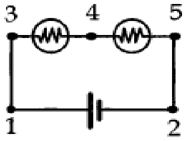
(A) Branch 1
(B) Branch 2
(C) Neither, they are the same



Branch 1 Branch 2

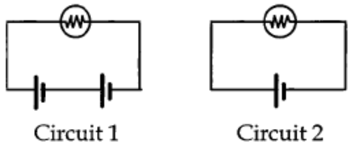
6. Rank the potential difference between points 1 and 2, point, points 3 and 4, and points 4 and 5 in the circuit shown below from highest to lowest.

(A) 1 and 2; 3 and 4; 4 and 5
(B) 1 and 2; 4 and 5; 3 and 4
(C) 3 and 4; 4 and 5; 1 and 2
(D) 3 and 4 = 4 and 5; 1 and 2
(E) 1 and 2; 3 and 4 = 4 and 5



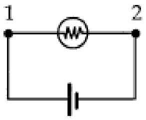
7. Compare the brightness of the bulb in circuit 1 with that in circuit 2. Which bulb is brighter?

(A) Bulb in circuit 1
(B) Bulb in circuit 2
(C) Neither, they are the same

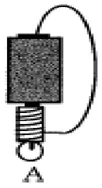


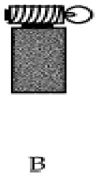
8. Compare the current at point 1 with the current at point 2. Which point has the larger current?

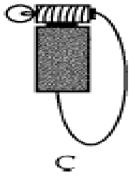
(A) Point 1
(B) Point 2
(C) Neither, they are the same

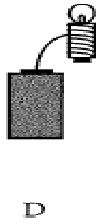


9. Which circuit(s) will light the bulb?
(A) A
(B) C
(C) D
(D) A and C
(E) B and D

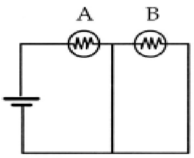




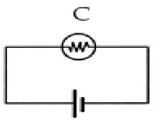




10. Compare the brightness of bulbs A and B in circuit 1 with the brightness of bulb C in circuit2. Which bulb or bulbs are the brightest?
(A) A
(B) B
(C) C
(D) A = B
(E) A = C



Circuit 1



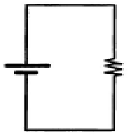
Circuit 2

11. Why do the lights in your home come on almost instantaneously?

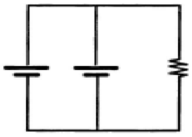
(A) Charges are already in the wire. When the circuit is completed, there is a rapid rearrangement of surface charges in the circuit.
(B) Charges store energy. When the circuit is completed, the energy is released.
(C) Charges in the wire travel very fast
(D) The circuits in a home are wired in parallel. Thus, a current is already flowing

12. Consider the power delivered to each of the resistors shown in the circuits below. Which circuit or circuits have the least power delivered to it?

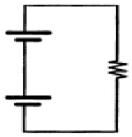
(A) Circuit 1
(B) Circuit 2
(C) Circuit 3
(D) Circuit 1 = Circuit 2
(E) Circuit 1 = Circuit 3



Circuit 1



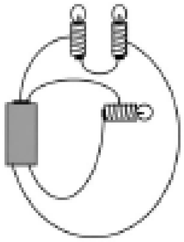
Circuit 2

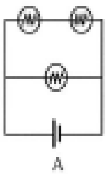


Circuit 3

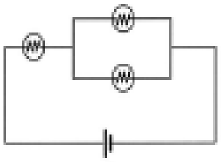
13. Which schematic diagram best represents the realistic circuit shown below?

(A) A
(B) B
(C) C
(D) D
(E) None of the above

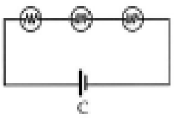




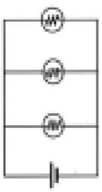
A



B



C

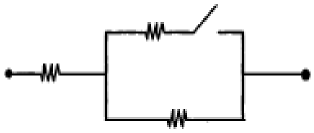


D

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

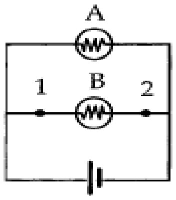
(A) Increases
(B) Decreases

(C) Stays the same



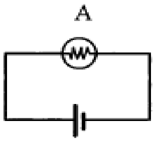
15. What happens to the potential difference between points 1 and 2 if bulb A is removed?

(A) Increases
(B) Decreases
(C) Stays the same

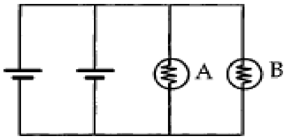


16. Compare the brightness of bulb A in circuit 1 with bulb A in circuit 2. Which bulb is dimmer?

(A) Bulb A in circuit 1
(B) Bulb A in circuit 2
(C) Neither, they are the same



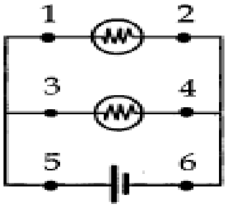
Circuit 1



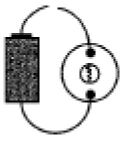
Circuit 2

17. Rank the currents at points 1, 2, 3, 4, 5, and 6 from highest to lowest.

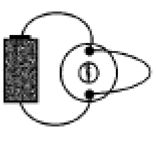
(A) 5, 1, 3, 2, 4, 6
(B) 5, 3, 1, 4, 2, 6
(C) 5 = 6, 3 = 4, 1 = 2
(D) 5 = 6, 1 = 2, 3 = 4
(E) 1 = 2, 3 = 4, 5 = 6



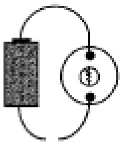
18. Which circuit(s) will light the bulb?



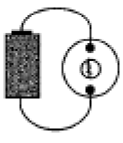
A



B



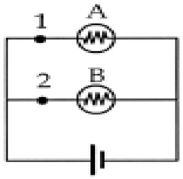
C



D

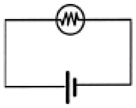
(A) A
(B) B
(C) D
(D) B and D
(E) A and C

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



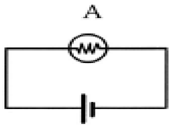
(A) Increases
(B) Decreases
(C) Stays the same
(D) A becomes brighter than B
(E) Neither bulb will light

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

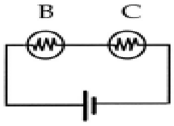


(A) Zero because the filament is a conductor
(B) Zero because there is a current flowing
(C) Non-zero because the circuit is complete and a current is flowing
(D) Non-zero because there are charges on the surface of the filament

21. Compare the energy delivered per second to the light bulb in circuit 1 with the energy delivered per second to the light bulb in circuit 2. Which bulb(s) have the least energy delivered to it per second?



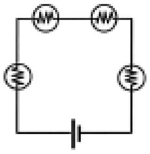
Circuit 1

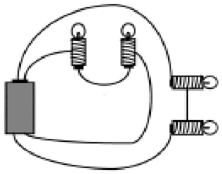


Circuit 2

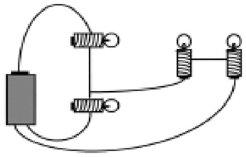
(A) A
(B) B
(C) C
(D) B = C
(E) A = B = C

22. Which realistic circuit(s) represents the schematic diagram shown below?

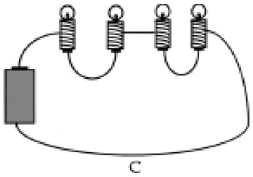


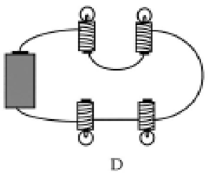


A



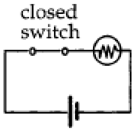
B





(A) A
(B) C
(C) D
(D) A and B
(E) C and D

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

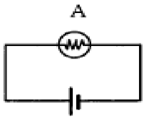


(A) The resistance increases
(B) The resistance decreases
(C) The resistance stays the same
(D) The resistance goes to zero

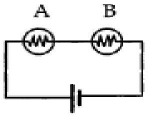
24. If you double the current through a battery, is the potential difference across the battery doubled?

(A) Yes, because Ohm's law says V = IR
(B) Yes, because as you increase the resistance, you increase the potential difference
(C) No, because as you double the current, you reduce the potential difference by half
(D) No, because the potential difference is a property of the battery
(E) No, because the potential difference is a property of everything in the circuit

25. Compare the brightness of bulb A in circuit 1 with bulb A in circuit 2. Which bulb is brighter?
(A) Bulb A in circuit 1
(B) Bulb A in circuit 2
(C) Neither, they are the same

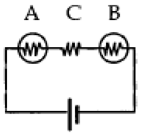


Circuit 1



Circuit 2

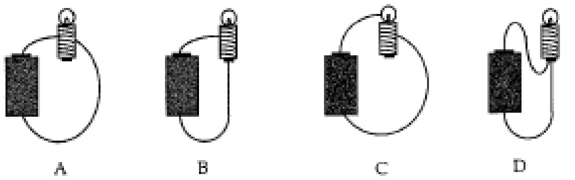
26. If you increase the resistance C, what happens to the brightness of bulbs A and B?



(A) A stays the same, B dims
(B) A dims, B stays the same
(C) A and B increase

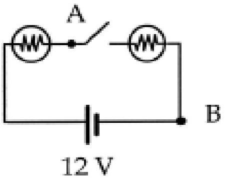
(D) A and B decrease
(E) A and B remain the same

27. Will all the bulbs be the same in brightness?



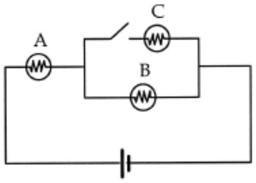
(A) Yes, because they all have the same type of circuit wiring.
(B) No, because only B will light. The connections to A, C, and D are no correct
(C) No, because only D will light. D is the only complete circuit
(D) No, C will not light but A, B, and D will.

28. What is the potential difference between points A and B?
(A)) V
(B) 3 V
(C) 6 V
(D) 12 V



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

(A) A stays the same, B dims
(B) A brighter, B dims
(C) A and B increase
(D) A and B decrease
(E) A and B remain the same



APPENDIX B

TISP

1. A learner wanted to know whether an increase in the amount of vitamins given to children results in increased growth. How can the learner measure how fast the children will grow?

   A. By counting the number of words the children can say at a given age.
   B. By weighing the amount of vitamins given to the children.
   C. By measuring the movements of the children
   D. By weighing the children every week.

2. Nomsa wanted to know which of the three types of soil (clay, sandy and loamy), would be best for growing beans. She planted bean seedlings in three pots of the same size, but having different soil types. The pots were placed near a sunny window after pouring the same amount of water in them. The bean plants were examined at the end of ten days. Differences in their growth were recorded. Which factor do you think made a difference in the growth rates of the bean seedlings?

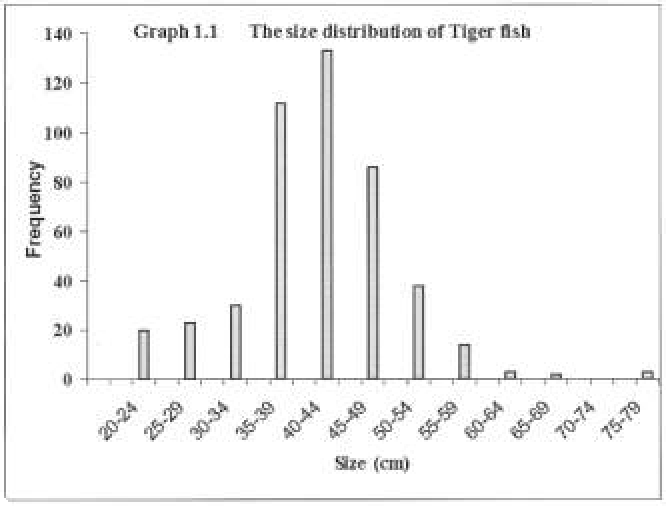
   A. The amount of sunlight available
   B. The type of soil used
   C. The temperature of the surroundings
   D. The amount of chlorophyll present

3. A lady grows roses as a hobby. She has six red rose plants and six white rose plants. A friend told her that rose plants produce more flowers when they receive morning sunlight. She reasoned that when rose plants instead of afternoon sunlight, they produce more flowers. Which plan should she choose to test her friend’s idea?

   A. Set all her rose plants in the morning sun. Count the number of roses produced by each plant. Do this for a period of four months. Then find the average number of roses produced by each kind of rose plant.
   B. Set all her rose plants in the morning sunlight for four months. Count the number of flowers produced during this time. Then set all the rose plants in the afternoon sunlight for four month. Count the number of flowers produced during this time.
   C. Set three white rose plants in the morning sunlight and the other three white rose plants in the afternoon sun. Count the number of flowers produced by each white rose plant for four months.
   D. Set three red and three white rose plants in the morning sunlight, and three red and three white rose plants in the afternoon sunlight. Count the number of rose flowers produced by each rose plant for four months.

Questions 4 and 5 refer to the graph below.

The fishery department wants to know the average size of fish in Tzaneen dam, so that they could prevent over-fishing. They carry out an investigation, and the results of the investigation are presented in the graph below.



4. What is the most common size range of Tiger fish found in Tzaneen dam

   A. 75 – 79 cm
   B. 40 – 44 cm
   C. 20 – 79 cm
   D. 45 – 49 cm

5. In which size range would you find the longest Tiger fish?

   A. 75 – 79 cm
   B. 40 – 44 cm
   C. 20 – 79 cm
   D. 35 – 49 cm

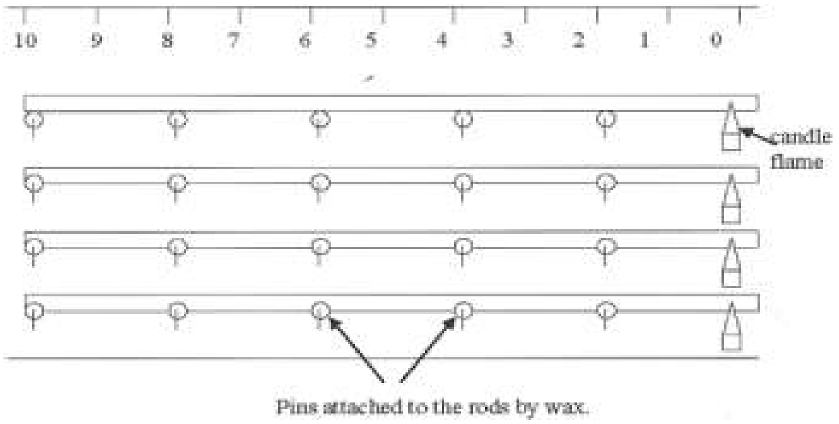
6. Mpho wants to know what determines the time it takes for water to boil. He pours the same amount of water into four containers of different sizes, made of clay, steel, aluminium and copper. He applies the same amount of heat to the containers and measure the time it takes the water in each container to boil.

   Which one of the following could affect the time it takes for water to boil in this investigation?

A. The shape of the container and the amount of water used
B. The amount of water in the container and the amount of heat used
C. The size and type of the container used
D. The type of container and the amount of heat used

7. A teacher wants to find out how quickly different types of material conduct heat. He uses four rods with the same length and diameter but made of different types of material. He attaches identical pins to the rods using wax, at regular intervals as shown in the diagram below. All the rods were heated on one end at the same time, using candle flames. After two minutes, the pins that fell from each rod were counted.

Diagram 1.1



How is the speed (rate) of heat conduction by various rods measured in this study?

A. By determining the rod, which conducted heat faster when heated.
B. By counting the number of pins that fall from each rod after 2 minutes.
C. By counting the number of minutes taken for each pin to fall from the rod.
D. By using wax to measure the rate of heat conduction.

8. A farmer wants to increase the amount of mealies he produces. He decides to study the factors that affect the amount of mealies produced.

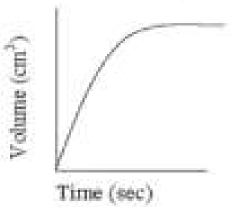
A. The greater the amount of mealies produced, the greater the profit for the year.
B. The greater the amount of fertilizer used, the more the amount of mealies produced
C. The greater the amount of rainfall, the more effective the fertilizer used will be
D. The greater the amount of mealies produced, the cheaper the cost of mealies.

9. Sandile carried out an investigation in which she reacted magnesium with dilute hydrochloric acid. She recorded the volume of the hydrogen produced from the reaction, every second. The results are shown below.

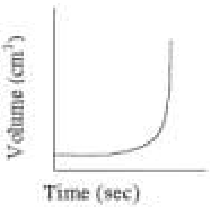
Time (seconds)	0	1	2	3	4	5	6	7
Volume (cm^3)	0	14	23	31	38	40	40	40

Table 1.1 Shows the volume of hydrogen produced per second.

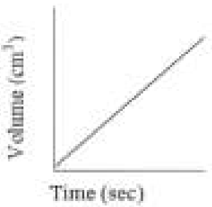
Which of the following graphs show these results correctly?



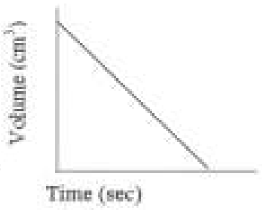
A.



B.



C.



D.

10. A Science teacher wanted to find out the effect of exercise on pulse rate. She asked each of three groups of learners to do some push-ups over a given period of time, and then measure their pulse rates: one group did the push-ups for one minute; the second group for two minutes, the third group for three minutes and then a fourth group did not do any push-ups at all.

How is pulse rate measured in this investigation?

A. By counting the number of push-ups in one minute
B. By counting the number of pulses in one minute
C. By counting the number of push-ups done by each group.
D. By counting the number of pulses per group

11. Five different hosepipes are used to pump diesel from a tank. The same pump is used for each hosepipe. The following table shows the results of an investigation that was done on the amount of diesel pumped from each hosepipe.

Size (diameter) of hosepipe (mm)	Amount of diesel pumped per minute (liters)
8	1
13	2
20	4
26	7
31	12

Table 1.2 Shows the amount of diesel pumped per minute.

Which of the following statements describes the effect of the size of the hosepipe on the amount of diesel pumped per minute?

A. The larger the diameter of the hosepipe, the more the amount of diesel pumped
B. The more the amount of diesel pumped, the more the time used to pump it
C. The smaller the diameter of the hosepipe, the higher the speed at which the diesel is pumped
D. The diameter of the hosepipe has an effect on the amount of diesel pumped.

12. Doctors noticed that if certain bacteria were injected into a mouse, it developed certain symptoms and died. When the cells of the mouse were examined under the microscope, it was seen that the bacteria did not spread through the body of the mouse, but remained at the area of infection. It was therefore thought that the death is not caused by the bacteria but by certain toxic chemicals produced by them.

    Which of the statements below provides a possible explanation for the cause of death of the mouse?

    A. The mouse was killed by the cells that were removed from it to be examined under the microscope.
    B. Bacteria did not spread through the body of the mouse but remained at the site of infection
    C. The toxic chemical produced by the bacteria killed the mouse
    D. The mouse was killed by developing certain symptoms

13. Thembi thinks that the more the air pressure in a soccer ball, the further it moves when kicked. To investigate this idea, he uses several soccer balls and an air pump with a pressure gauge. How should Thembi test his idea?

A. Kick the soccer balls with different amounts of force from the same point
B. Kick the soccer balls having different air pressure from the same point.
C. Kick the soccer balls having the same air pressure at different angles on the ground
D. Kick the soccer balls having different air pressure from different points on the ground

14. A science class wanted to investigate the effect of pressure on volume, using balloons. They performed an experiment in which they changed the pressure on a balloon and measured its volume. The results of the experiment are given in the table below.

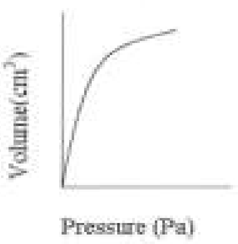
Pressure on balloon (Pa)	Volume of the balloon (cm^3)
0.35	980
0.70	400
1.03	320
1.40	220
1.72	180

Table 1.3. Shows the relationship between the pressure on a balloon and its volume.

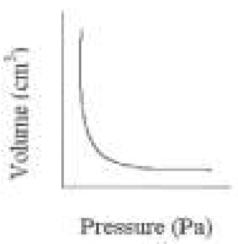
Which of the following graphs represents the above data correctly?

A.

B.



C.



D.

15. A Motorist wants to find out if a car uses more fuel when it is driven at high speed. What is the best way of doing this investigation?

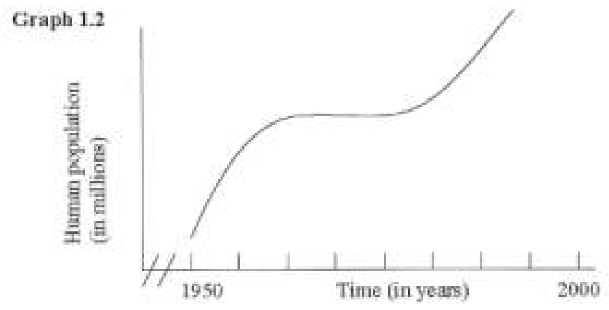
A. Ask several drivers how much fuel they use in one hour, when drive fast, and find the average amount of fuel used per hour.
B. Use his own car to drive several times at different speeds, and he should record the amount of fuel used each time.
C. He must drive his car at high speed, for a week, and then drive it at low speed for another week, and record the amount of fuel used in each case
D. Ask several drivers to drive different cars covering the same distance many times, at different speeds, and record the amount of fuel used for each trip.

16. A learner observed that anthills (termite moulds) in a certain nature reserve tend to lean towards the west, instead of being straight. In this area, the wind blows towards the direction in which the anthills lean.

    Which of the following statements can be tested to determine what causes the anthills to lean towards the west, in this nature reserve?

    A. Anthills are made by termites
    B. Anthills lean in the direction in which the wind blows
    C. Anthills leans towards the west to avoid the sun and the rain
    D. The distribution of anthills depends on the direction of the wind.

17. The graph below shows the changes in human population from the year 1950 to 2000



    Which of the following statements best describes the graph?

    A. The human population increases as the number of years increase
    B. The human population first increases, then it reduces and increases again as the number of years increase
    C. The human population first increases, then it remains the same and increases again as the number of years increase
    D. The human population first increases, then it remains the same as the number of years increase

18. Mulai wants to find out the amount of water contained in meat, cucumber, cabbage and maize grains. She finely chopped each of the foods and carefully measured 10 grams of each. She then put each food in a dish and left all the dishes in an oven set at 100 ^{o}C. After every 30 minutes interval, she measured the mass of each food, until the mass of the food did not change in two consecutive measurements. She then determined the amount of water contained in each of the foods.

How is the amount of water contained in each food measured in this experiment?

A. By heating the samples at a temperature of 100 ^oC and evaporating the water
B. By measuring the mass of the foods every 30 minutes and determining the final mass
C. By finely chopping each food and measuring 10 grams of it, at the beginning of the investigation
D. By finding the difference between the original and the final mass of each food

19. In a radio advertisement, it is claimed that Surf produces more foam than other types of powdered soap. Chudwa wanted to confirm this claim. He put the same amount of water in four basins, and added 1 cup of a different type of powdered soap (including surf) to each basin. He vigorously stirred the water in each basin, and observed the one that produced more foam.

Which of the factors below is **NOT** likely to affect the production of foam by powdered soap?

A. The amount of time used to stir the water
B. The amount of stirring done
C. The type of basin used
D. The type of powdered soap used.

20. Monde noticed that the steel wool that she uses to clean her pots rusts quickly if exposed to air after using it. She also noticed that it takes a longer time for it to rust if it is left in water. She wondered whether it is the water or the air that causes the wet exposed steel wool to rust.

Which of the following statements could be tested to answer Monde's concern?

A. Steel wool cleans pots better if exposed to air
B. Steel wool takes a longer time to rust if it is left in water
C. Water is necessary for steel wool to rust
D. Oxygen can react with steel wool

21. A science teacher wants to demonstrate the lifting ability of magnets to his learners. He uses many magnets of different sizes and shapes. He weighs the amount of iron filings picked by each magnet.

How is the lifting ability of magnets defined in this investigation?

A. The weight of the iron filings picked up by the magnets
B. The size of the magnet used.
C. The weight of the magnet used to pick up the iron filings
D. The shape of the magnet used

22. Thabo wanted to show his friend that the size of a container affects the rate of water loss, when water is boiled. He poured the same amount of water in containers of different sizes but made of the same material. He applied the same amount of heat to all containers. After 30 minutes, he measured the amount of water remaining in each container

    How was the rate of water loss measured in this investigation?

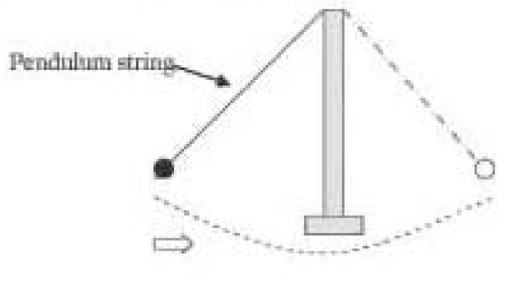
    A. By measuring the amount of water in each container after heating it.
    B. By using different sizes of the containers to boil the water for 30 minutes
    C. By determining the time taken for the water to boil in each of the containers
    D. By determining the difference between the initial and the final amounts of water, in a given time.

23. A school gardener cuts grass from 7 different football fields. Each week, he cuts a different field. The grass is usually taller in some fields than others. He makes some guesses about why the height of the grass is different. Which of the following is a suitable testable explanation for the difference in the height of grass?

    A. The fields that receive more water have longer grass
    B. Fields that have shorter grass are more suitable for playing football
    C. The more stones there are in the field, the more difficult it is to cut the grass
    D. The fields that absorb more carbon dioxide have longer grass

24. James wanted to know the relationship between the length of a pendulum string and the time it takes for a pendulum to make a complete swing. He adjusted the pendulum string to different lengths and recorded the time it took the pendulum to make a complete swing.

Diagram 1.2 A pendulum.

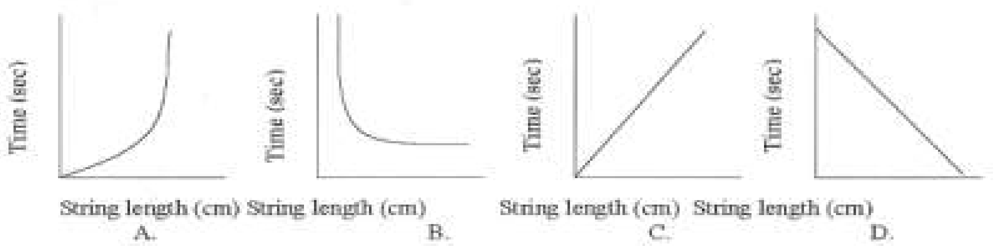


He obtained the following results from an investigation.

Length of string (cm)	80.0	100.0	120.0	140.0	160.0	180.0
Time taken (seconds)	1.80	2.02	2.21	2.39	2.55	2.71

Table 1.4. The relationship between the lengths of a pendulum string and the time the pendulum takes to make a complete swing.

Which of the following graphs represent the above information correctly?



25. A farmer raises chickens in cages. He noticed that some chickens lay more eggs than others. Another farmer tells him that, the amount of food and water given to chicken, and the weight of chicken, affect the number of eggs they lay.

    Which of the following is **<u>NOT</u>** likely to be a factor that affects the number of eggs laid by the chickens?

    A. The size of the cage where the eggs are laid.
    B. The weight of the chickens
    C. The amount of food given to the chickens
    D. The amount of water given to the chickens

26. A science class wanted to test the factors that might affect height. They felt that the following is a list of factors that could be tested: the amount of light, amount of moisture, soil type, and change in temperature.

    Which of the statements below could be tested to determine the factor that might affect the plant height?

    A. An increase in temperature will cause an increase in plant height.
    B. An increase in sunlight will cause a decrease in plant moisture.
    C. A plant left in light will be greener than one left in the dark.
    D. A plant in sand soil loses more water than one in clay soil.

27. A Biology teacher wanted to show her class the relationship between light intensity and the rate of plant growth. She carried out an investigation and got the following results.

Light intensity (Candela)	Plant growth rate (cm)
250	2
800	5
1000	9
1200	11
1800	12
2000	15
2400	13
2800	10
3100	5

Table 1.5. Shows the relationship between light intensity and the growth rate of a plant.

Which of the following statements correctly, describes what these results show?

A. As light intensity increases, plant growth also increases.
B. As plant growth increases, light intensity decreases
C. As plant growth increases, light intensity increases then decreases.
D. As light intensity increases, plant growth increases then decreases.

Questions 28, 29 and 30 refer to the investigation below.

Thabiso is worried about how the cold winter will affect the growth of his tomatoes. He decided to investigate the effect of temperature on the growth rate of tomato plants. He planted tomato seedlings in four identical pots with the same type of soil and the same amount of water. The pots were put in different glass boxes with different temperatures: One at 0 ^{o}C, and another at room temperature and the fourth at 50 ^{o}C. The growth rates of the tomato plants were recorded at the end of 14 days.

28. What effect does the difference in temperature have in this investigation?

A. The difference in the seasons
B. The difference in the amount of water used.
C. The difference in growth rates of the tomato plants
D. The difference in the types of soil used in the different pots.

29. The factor(s) that were being investigated in the above experiment are:

A. Change I temperature and the type of soil used
B. Change in temperature and the growth rate of the tomato plants
C. The growth rate of tomato plants and the amount of water used
D. The type of soil used and the growth rate of the tomato plants.

30. Which of the following factors were kept constant in this investigation?

A. The time and growth rate of tomato plant.
B. The growth rate of tomato plants and the amount of water used.
C. The type of soil and the amount of water used.
D. The temperature and type of soil used.

APPENDIX C

EXPERIMENT 1
OHM'S LAW

Aim

The purpose of this experiment is to verify Ohm's Law, and prove that irrespective of the value of the resistance, the relationship between the voltage and the current will always be linear.

Apparatus

Power supply
Ammeter
Voltmeter
Connecting wires
Switch
Resistors (R_1, R_2 and R_3)

Background:

Ohm's Law deals with the relationship between voltage and current in an ideal conductor. This relationship states that the potential difference (voltage) across an ideal conductor is proportional to the current through it. The constant of proportionality is called the "resistance", R.
Mathematically this law is expressed as:

V = I R

Where:
V = The potential difference between two points which include a resistance.
I = Current flowing through the resistance.
R = Resistance.

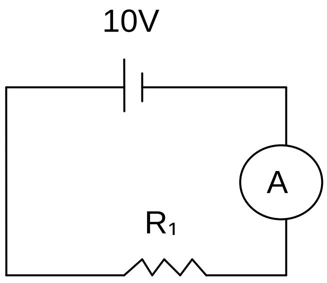


Figure 1

Procedure:

1. Set up the circuit as shown in fig 1, using resistor R_1.
2. Beginning with 0 volts, increase the input voltage to 10 V in steps of 2 volts. Measure the current I at each step. Record the results as in table 1.
3. Repeat steps 1 & 2 using resistor R_2 and R_3.

Table 1

R_1 (Ω)		**R_2 (Ω)**		**R_3 (Ω)**	
ΔV (V)	**I (A)**	**ΔV (V)**	**I (A)**	**ΔV (V)**	**I (A)**
0		0		0	
2		2		2	
4		4		4	
6		6		6	
8		8		8	
10		10		10	

Graphs

1. On the same axes plot graphs of I (A) against ΔV (V) for the three resistors.

Analyses

1. Determine the value of each resistor from the graphs

2. What relationship can be seen between current and voltage?

3. What conclusion can be drawn from the three graphs?

EXPERIMENT 2

Parallel and Series Connection

Aim:

The purpose of this experiment is to understand the behavior of current and the potential difference in resistors connected in series and in parallel.

Apparatus

Power supply	Connecting wires
Ammeter	Switch
Voltmeter	Resistors (R_1, R_2 and R_3)

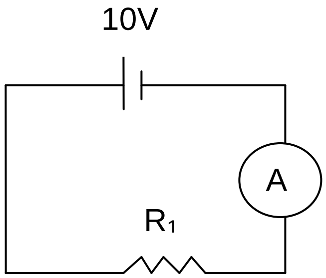


Figure 1

Series Connection

Procedure

1. Set up a circuit as in fig 1.
2. Measure the current I_1 and record it in table 1.
3. Measure the voltage across the resistor R_1
4. Include another resistor R_2 in series with R_1
5. Measure the current I_2 and the voltage across R_2
6. Include another resistor R_3 in series with R_1 & R_2.
7. Measure the current I_3 and the voltage across R_3
8. Measure the voltage across all three resistors and the total current.

Table 1

Resistors	**ΔV (V)**	**I (A)**
R_1 (Ω)		
R_2 (Ω)		
R_3 (Ω)		
Total		

Calculations

1. Calculate the resistance of each resistor.

2. What happens to the current when you add more resistors and why?

3. What conclusion can you draw about the potential difference across all the resistors?

4. What conclusion can you draw about the potential difference across each resistor?

5. What conclusion can you draw about the current?

Parallel Connection

1. Set up a circuit as in fig 1.
2. Measure the current I_1 and record it in table 2.
3. Measure the voltage across the resistor R_1
4. Include another resistor R_2 in parallel with R_1
5. Measure the current I_2 through R_2 and the voltage across R_2
6. Include another resistor R_3 in parallel with R_1 & R_2.
7. Measure the current I_3 through R_3 and the voltage across R_3
8. Measure the voltage across all three resistors and the total current.

Table 2

Resistors	**ΔV (V)**	**I (A) through each R**	**I_T (A)**
R_1 (Ω)			
R_2 (Ω)			
R_3 (Ω)			
Total			

Calculations

1. Calculate the resistance of each resistor.

2. What happens to the current when you add more resistors and what causes that?

3. What conclusion can you draw about the potential difference across all the resistors?

4. What conclusion can you draw about the potential difference across each resistor?

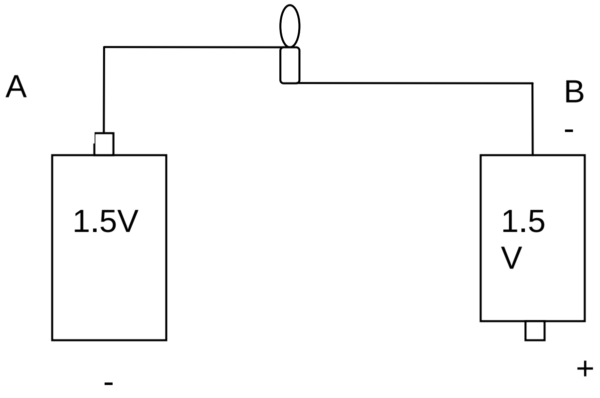
5. What conclusion can you draw about the total current?

6. What conclusion can you draw between series connection and parallel connection?

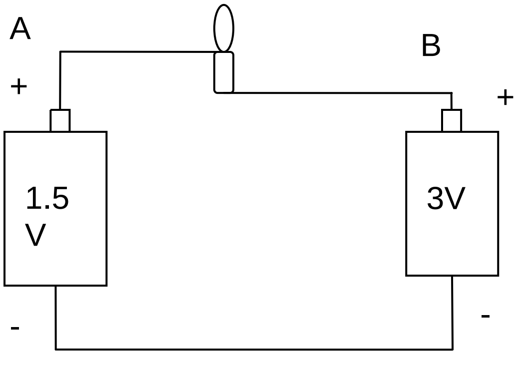
APPENDIX D

CLASS TEST

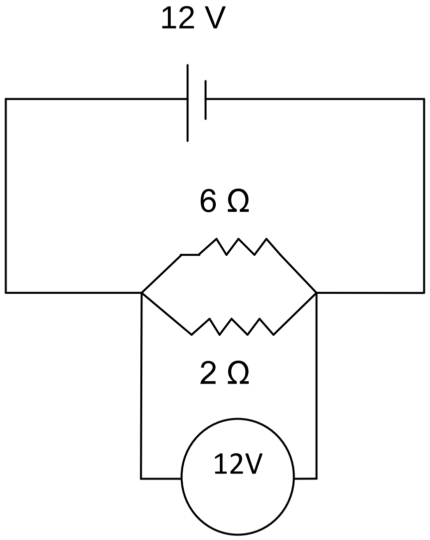
Question 1: Is the bulb lit? Yes No Why?



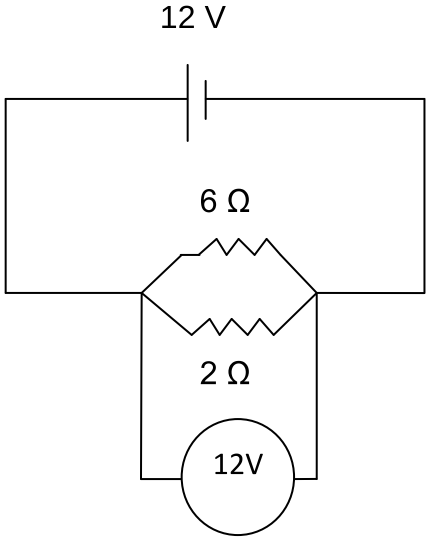
Question 2: Is the bulb lit? Yes No Why?



Question 3: More current will pass through the 6Ω resistor. Yes No Why?



Question 4: Calculate the current that will pass through the 6Ω resistor.



Question 5: The 2Ω resistor from the diagram in questions 3 and 4 will have more voltage across it. Yes No Why?

Question 6: If the two resistors in the question above were connected in series, the potential difference across the 2Ω will be 12V. Yes No Why?

APPENDIX E

OBSERVATION SCHEDULE

Student name ________________

Experimental group

	Process Skill					
		1	**2**	**3**	**4**	**5**
1	Identifying Variables					
2	Stating Hypothesis					
3	Operational Definitions					
4	Graphing and interpreting data					
5	Experimental design					

Student name ______________________

Control group

	Process Skill					
		1	**2**	**3**	**4**	**5**
1	Identifying Variables					
2	Stating Hypothesis					
3	Operational Definitions					
4	Graphing and interpreting data					
5	Experimental design					

APPENDIX F

INTERVIEWS QUESTIONS

Group_________________

Student _________

1. When three unequal resistors are connected in series to a battery, which one will have more current passing through it and why?

2. When you have a circuit consisting of a battery, ammeter and a resistor in series, what will happen to the total current when you add another resistor in series and why?

3. Suppose you have three resistors connected in series to a battery and you measure their potential difference individually, what conclusion can you draw about their potential difference?

4. When unequal resistors are connected in parallel to a battery, which one will have more current passing through it?

5. What happens to the potential difference of resistors connected in parallel?

6. What is the relationship between the current and the potential difference?

Students Ei, Es and Ed were asked extra questions, because they were from the experimental group and they did the simulations:

7. Between the simulations and the laboratory work, which one (if any) do you think has helped you to understand the electric circuits' concepts better and why do you say so?

8. If you were to choose between simulations and laboratory work, which one will you choose and why?