JRIIE Journal of Research Innovation and Implications in Education
ISSN: 2520-7504
Center for Research Implications & Practice

**Website:** www.jriiejournal.com SSN 2520-7504 (Online) Vol.5, Iss.3, 2021 (pp. 136 - 152)

# Examining the Effect of Solve Elec Simulation on Student's Understanding of Electric Current in High School Physics in Lilongwe, Malawi

[*1]Kondwani Chafulumira Chumachiyenda Mwale, & [2]Bernard Bahati

[1]African Centre of Excellence in Innovative Teaching and Learning Mathematics and Science, University of Rwanda-College of Education

[2]Center for Teaching and Learning Enhancement, University of Rwanda-College of Education.

Corresponding Author: **mwale477@gmail.com**

***Abstract**: Physics is often regarded as a daunting subject for both teachers and pupils. This is because some topics are abstract, loaded with symbolic representations, lack concrete examples, and require a high level of mathematical manipulations and visualization. Quasi-experimental study involving 181 students and 6 teachers was conducted to determine the effect of Solve Elec simulation on students understanding of electric current. Two research questions guided this study (i) what teaching resources do teachers use when teaching electric current in the secondary schools of Lilongwe, Malawi? (ii) How different is the academic performance in Electric current between the students' who are exposed to the use of Solve Elec and those taught using chalk-talk method (traditional method)? The goal of this study was to potentially gain more awareness to the use of Solve Elec on learning electric current and its impact on students' academic performance. Pre-test and Post-test results on electric current were collected and analyzed using Statistical Package for Social Science (SPSS v23). The independent samples t-test results showed that students who were exposed to the use of Solve Elec instruction performed significantly higher than those who were taught through the use of traditional "talk-and-chalk" instruction. These findings recommends the use of Solve Elec as a supplementary instructional resource in the teaching/learning of electric current in high school physics classrooms.*

**Keywords**: *Solve Elec, Academic performance, Information Communication Technology (ICT), Electric current, Physics education, physics educational technology.*

**How to cite this work (APA):**

Mwale, K. C. C. & Bahati, B. (2021). Examining the effects solve Elec simulation on students' understanding of electric current in high school physics in Lilongwe Malawi. *Journal of Research Innovation and Implications in Education, 5*(3), 136 – 152.

# 1. Introduction

Physics is often regarded as a difficult subject for both teachers and students in secondary school (Moodley & Gaigher, 2019; Uwizeyimana et al., 2018; Yuliati et al., 2018). Jimoyiannis & Komis ( 2001), argued that physics is perceived to be abstract, it is loaded with symbolic representations, lack concrete examples, requires a high level of mathematical manipulations and visualization. Very often, physics teachers deal with concepts that are microscopic in nature, students can't directly perceive and understand them. Teaching students to construct these concepts is often a difficult task. However, this is the task of a physics teacher to look around on how best he/she can make his/her students understand these complex physics concepts.

Several research studies have been done over the last four decades to develop science teaching methods (Hestenes, 1992; Jimoyiannis & Komis, 2001; Mulhall et al., 2001; Smetana & Bell, 2012; Uwizeyimana et al., 2018). Nonetheless, current research studies suggest that students still have a lot of misconceptions and lack of understanding of physics electricity in particular, which leads to their poor academic performance (Ramnarain & Moosa, 2017; Yuliati et al., 2018) . In Malawi, the student academic performance in Physics has been poor ( Kalambo, 2020; Cahya, 2016; Dzama, 2006; Lionetto et al., 2020; Mlangeni, 2015; Mutanu & Machoka, 2019; et al., 2018).

Poor academic performance is not a Malawian problem only. As it was observed by Okoth et al (2018) in South Africa, students' knowledge in physics is weak which results in low grades. Dzana (2012) found out that the lack of science laboratories, enough and good textbooks, student's perceptions of science subjects as difficult, student's laziness and insufficient time allocated to practical lessons were all factors that led to the drop in student academic performance in physics. Table 1 shows the students' academic performance of all subjects including physics in Malawi School Certificate of Education (MSCE) results from 2015 to 2019.

**Table 1: Students' performance in MSCE in Malawi from 2015 to 2019**

| S/N | Year | % Pass |
|---|---|---|
| 1 | 2016 | 57 |
| 2 | 2017 | 56 |
| 3 | 2018 | 60 |
| 4 | 2019 | 63 |
| 5 | 2020 | 41 |

Table 1 shows students' performance in MSCE in the space of five years starting from 2016. Although the pass rates seems to have increased over the years, in physics students have been performing poorly (Dzama, 2006; Mlangeni, 2015; Okoth et al., 2018). The consequences of this poor academic performance are reflected in the number of students admitted into science-related courses at the University of Malawi. For instance in 2017 physics class there were only 8 students and out of 8 students, 6 graduated with a bachelor's of science degree. It's difficult to link MSCE pass rates to the general pass rates in all subjects. Only less than 30% of the students pursue science related courses at the University of Malawi(Ministry of Education, Science & Technology, 2019).

The causes of this poor academic performance can be attributed to many factors one of them being the insufficient teacher's knowledge and students interactions as stipulated above. Also according to Kola (2013) this poor academic performance is attributed to teacher's instructional pedagogy, teachers lack the necessary teaching strategies to teach physics. Changes in teacher's strategy or method of teaching are bound to improve the academic performance of secondary school pupils in physics.

There is considerable research evidence that an appropriate teaching strategy is central to the successful learning of Physics. Many of the present learner-centered strategies used in physics instruction such as lecturing with demonstration, and problem solving with teacher guidance as well as integrating Information and Communication Technology abbreviated as (ICT) in teaching/learning of science have proved to be successful over the years (Cox et al., 2004; Nguyen et al., 2012). In the current era, integrating ICT into physics education is an alternative solution for increasing students' academic performance.

The applications of ICTs in learning resources include educational software, portable document format (PDF) resources via the internet and video resources. Educational software is more than just learning tools for students; it is also a platform for educational learning organization (Nguyen et al., 2012). Physics education program examples include physics virtual lab, PhET, Solve Elec, Crocodile Physics and many more. Several Computer simulations exist such as Solve Elec, Physics Virtual lab, PhET, Maple, and many-more but for this study Solve Elec was used as it does not require a teacher to have expertise in programming, it only requires basic ICT skills such as ability to use Microsoft word, power point, ability to run software applications, presentation software and communication tools, to teach electric current. Secondly, it is completely a free software package which can be easily accessed ( Greg Fiumara, 2005).

# 2. Literature Review

A computer simulation, according to Smetana & Bell (2012) is a program that includes a model of a sysytem or a process ( natural or artificial). Their use in science classes has the potential to revolutionize science education (Astutik & Prahani, 2018; Ramnarain & Moosa, 2017). Computer models may be used in physics to teach or observe difficult concepts like electric current (Barakabitze, 2014; Baser, 2006; Nguyen et al., 2012; Smetana & Bell, 2012; Taub et al., 2015; Zacharia, 2003). Examples of computer simulations which can be used to teach electric current are circuit construction kit, physics virtual lab and Solve Elec just to mention a few. For example the movement of electrons in the wire will best be appreciated by a student when he/she sees it demonstrated by this Computer simulation. Many physics teachers can’t explain the movement of electrons because it’s microscopic and a Complex Phenomenon. The problem of complexity can be solved when proven in a computer using simulations, and student learning can be improved.

Researchers have studied the efficacy of computer simulations in promoting science teaching/learning over the past four decades; several studies, including a meta-analysis by (Kulik & Kulik, 1991) and a narrative study by Lee (1999), as well as (Bakaç et al., 2011; Bell, 2015; Jaakkola et al., 2011; Martínez Muñoz et al., 2013; Ramnarain & Moosa, 2017; Sarabando et al., 2014; Smetana & Bell, 2012; Spodniaková Pfefferová, 2015; Taub et al., 2015; Trundle & Bell, 2010; Vreman-de Olde & de Jong, 2004) have previously been written on this research, however, there are still gaps in the previous reviews' scope and time coverage, which limits their utility for addressing questions about the effectiveness of more recent computer simulations such as Solve Elec. There are no published research studies about the effectiveness of Solve Elec simulation in teaching electric current in Malawian context and beyond in the teaching and learning of physics.

Alloway (2006), Bell (2015), Rosenberg & Lawson (2019), Smetana & Bell (2012) and, Trundle & Bell (2010) meta-analysis study contained just six experiments concerning science computer simulations, and the majority of them are too old, mostly from the 1970s, making their usefulness in the twenty-first century doubtful. Although Bayraktar’s (2001) and Rosenberg & Lawson (2019) meta-analysis included only quantitative work on Biology and Chemistry simulations, it did not include Physics. Furthermore, the reviewers consider a variety of technologies without specifically discriminating between drill and rehearsal, tutorials, simulations, and a combination of computer-assisted teaching systems (Jaakkola et al., 2011; Martínez Muñoz et al., 2013).

Bell (2015), Smetana & Bell (2012) and, Lee’s (1999) meta-analysis of computer simulations, contains only nine articles about scientific computer simulations, while the others are about non-science computer simulations like political science and special education administration. While De Jong and Van Joolingen's (1998) review is widely cited, it is now more than twenty years old and must address computer simulations that are even older. There is little research about the use and effectiveness of Solve Elec in teaching/learning of electric current in Africa and Malawi inclusive. However, efforts are being made to improve the situation and there are some efforts made by the government to increase access to technologies such as computers in both public and private secondary schools. The use of technology to teach seems to be part of a big theoretical discussion, but its application is still minor in most secondary schools in Malawi (Gondwe, 2020; Isaacs, 2007; Mwambene & Luneta, 2015)

Since concepts in an electric current are abstract and mathematical, students develop a number of alternative concepts related to current, potential difference, a complete circuit, and power dissipated inside the circuit element. Many students assume that current travels in one direction across the circuit and is consumed, leaving less usable current for other components farther along in the circuit. Others assume that a single wire is adequate to bring current from the positive terminal of the battery to a bulb and that adding the negative terminal of the battery to the bulb is unnecessary (Baser, 2006; Marks, 2012). Students also struggle with analyzing electric circuits, understanding electric diagrams, and interpreting circuits (Vreman-de Olde & de Jong, 2004). Although nothing beats real-world laboratory experiments for learning about electric current, computer simulation is a great substitute.

Several experiments have been performed to explore the use of computer simulations in the teaching/learning of electric current, with the findings showing that computer simulations improve students' conceptual understanding of the electric circuit. De Olde and de Jong (2004) studied student evaluation and discovered that allowing students to develop assignments for other students about electric circuits in a computer simulation setting appeared to increase their domain awareness by retrieving and demonstrating problem-solving steps and relying on the complex properties of the simulated circuits.

According to the results of Zacharias' (2005) and, Ramnarain & Moosa (2017) research, both computer simulations and laboratory experiments improved students' conceptual understanding of electric circuits, but computer simulations tended to improve students' conceptual understanding more than actual laboratory experiments. Jaakkola et al (2011) used the Electricity Exploration Tool to model electric circuits and showed that computer simulation increased students' understanding of current electricity over experimental work.

Computer simulations have been successfully used in all levels of physics teaching, from high school (Gomile-Chidyaonga, 2003; Ramnarain & Moosa, 2017; Sarabando et al., 2014; Smetana & Bell, 2012; Spodniaková Pfefferová, 2015; Taub et al., 2015; Trundle & Bell, 2010) to university. Computer simulations may help in the planning, development, and assessment of complex systems (Rutten et al., 2012). They may use computational software to simulate a current or planned system and are helpful when modifications to the actual structure are impossible to execute, expensive, or unrealistic. As a result, they have been used to diagnose and correct alternative velocity conceptions (Azar & Şengüleç, 2011; Jacob Kola, 2013) as well as to include alternative mechanics student conceptions.

According to a recent study, simulations are almost as successful as microcomputer-based laboratories in helping students grasp concepts including object free fall (Zhang & Liu, 2016). Another study investigated how computer simulations influences students' practical perception of electricity (Astutik & Prahani, 2018; Taub et al., 2015; Yuliati et al., 2018). An intriguing study result is that, even after computer-assisted physics teaching, students maintain the plurality of difficulties and vacillate between alternate and scientific conceptions from one context to the next.

## 2.1. Simulating electric circuits through Solve Elec

Solve Elec is a free open-source dynamic program that can be used to teach electricity to students at all grade levels. Any educational institution can afford to download and install it in their own computers or lab computers. The simulation engine needs no scripting. Solve Elec's main advantage is the ability to compute literal formulas relevant to the user-drawn circuit. Solve Elec is an electrical circuit analysis and resolution utility.

Solve Elec can "test" the circuit to make sure it works. Solve Elec, for example, will "test" the circuit to ensure that it operates properly. Solve Elec can also obtain values and formulas for currents and voltages in the circuit, as well as produce diagrams. Solve Elec's graphing function is incredibly efficient and one-of-a-kind. The power of real simple shown in Solve Elec does not end with the program's key functions. After creating the optimal circuit, the user would want to print the diagram and probably a graph or two. Solve Elec simplifies this method for the user.

Solve Elec can complete a circuit that would usually take hours to construct in less than a minute. After executing the instruction, a solve Elec window appears with solutions. Figure 1 depicts Solve Elec with a circuit drawn (Left column), followed by a graph of current versus resistance (Right column).

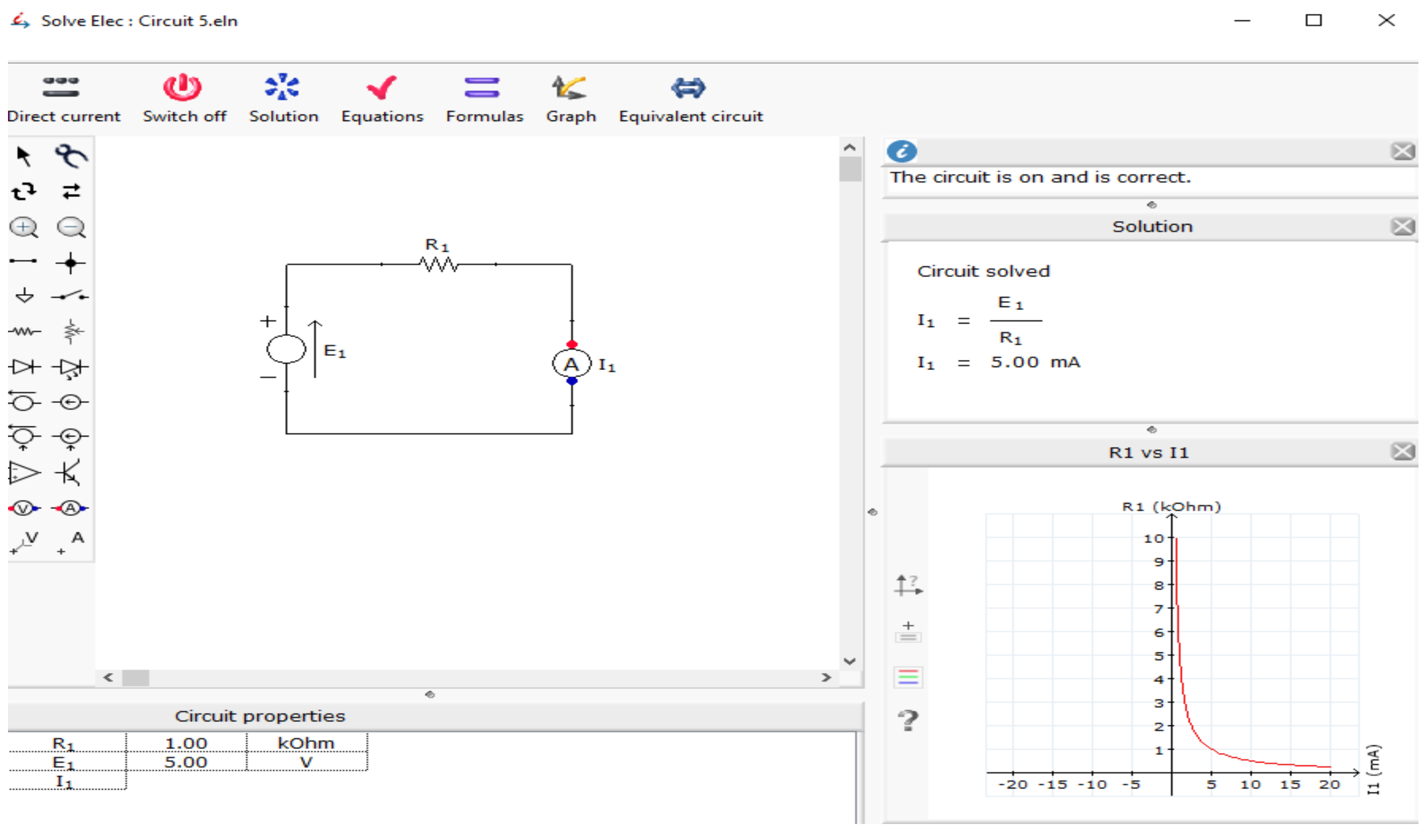


**Figure 1: The Solve Elec window**

The Solve Elec window portrays an electricity works station and is divided into three parts.

1. The upper section includes numerous buttons for turning on and off the circuit as well as opening various instruments as desired.
2. The left column often has two instruments for drawing the circuit and changing its properties.
3. The right column displays instruments that can be accessed by clicking a button on the main toolbar. Cover certain instruments by clicking on their close tab. When the circuit is switched on, the instrument displays are automatically changed if a circuit property changes.

The measurements of the instrument can be adjusted by dragging the separators between them or resizing the window.

## 2.2. Purpose of the study

This study seeks to analyze the effects of using Solve Elec Simulations on students' academic performance in electric current in form three. This research study purposes to report the results of the data analysis collected from teachers and students on a questionnaire and electric current test involving open ended questions which seeks to answer the following research questions.

1. What resources or materials teachers normally use when teaching electric current in secondary schools of Lilongwe?
2. How different is the academic performance in Electric current between the students' who are exposed to the use of Solve Elec and those taught using chalk-talk method (traditional method)?

These questions guided the research and were explored and analyzed based on questionnaires, pre-test and post-test analysis of electric current test.

# 3. Methodology

This study adopted a purposive non-probability sampling technique. Since it is affordable and participants are readily accessible, convenience sampling was used to select two schools from the available public schools in Lilongwe Malawi. Only the schools having required essential resources such as computers, uninterrupted power supply, and are easily accessible were considered in the sample. The researchers went to the nearby schools to ask their consent so as to be included in the sample. However, only schools having characteristics of interests were targeted. The participants' average age was 16 years, with high and minimum ages of 22 and 14, respectively. All students in the main sample sat for a pre-test and a post-test during the study. All the teachers in the main sample drawn from the participating schools completed the anonymous questionnaire.

This technique focuses only on identified participants believed to be knowledgeable and informative about the phenomena the researcher is investigating. It was in this line that the researchers sampled purposefully form three classes. Before the study, the researchers followed the proper procedures such as obtaining the written permission from the Ministry of education through the district education manager (EDM) and an ethical approval from the Research and Innovations unit of the College of Education, University of Rwanda. All the participants were also provided with a consent form formulated by the researchers. The experimental group consisted of 53 males and 32 females while the control group consisted of 50 males and 46 females.

This research study largely depended on quantitative data collection methods, it employed questionnaires, observations, pre-test and post-test for data collection. However, not all methods were done at once. The baseline study was done first to check the academic performance of students and the required tools teachers use to teach the topic of electric current. This was done by administering a questionnaire. This helped the researchers to have an overview of what was happening in schools so as to follow the proper structure and plan on the proposed topic. A survey questionnaire established the status quo of resources teachers use in teaching/learning of electric current in recent years.

The researchers solely used a quasi-experimental design-(non-equivalent comparison group design). This is because in practice it was impossible to assign the students into random groups in the same class, it is unethical in formal schools system. Secondly, the two groups involved used different timetables for their class lessons. Two groups of students from two different schools in Lilongwe, Malawi, who were in the same grade level were selected for the study. The experimental group learned by supplementing their lessons with a computer simulation (Solve Elec) in the school's computer lab, while the control group was taught in the traditional manner using the traditional method of instruction (chalk-and-talk) and conventional textbooks. The researchers administered a pre-test to both groups before the intervention thereafter, a post test was administered to both groups after the experimental group received the intervention.

The researchers administered a pre-test to both groups with the aim of checking prior knowledge on the topic, as it is a common knowledge that learners are not tabula Rasa. They know something whenever they come to class, this was done according to constructivism theory of learning(Alanazi, 2016; Cohen et al., 2007; Ndibalema, 2014; Treagust, 2001). This was also done to establish the comparability of scores for both groups before intervention. After that a post-test was given to evaluate the students' academic performance after the intervention and to see whether the therapy had any effect. The experimental group and the control groups were not constituted randomly. Instead intact classes were chosen and used in this study.

# 4. Results and Discussion

The purpose of this research study was to analyse the effects of using Solve Elec to teach electric current on students' academic performance in form three. Here are the research questions.

1. What resources or materials teachers normally use when teaching electric current?
2. How different is the academic performance in Electric current between the students who are exposed to the use of Solve Elec and those taught using chalk-talk method (traditional method)?

## 4.1. Resources or materials teachers normally use when teaching electric current in secondary schools of Lilongwe

While this study’s key research concern was about student academic performance, it also looked at the resources teachers use to teach electric current in secondary schools of Lilongwe, Malawi. To answer this question, a survey questionnaire was administered to a sample of physics teachers in the selected secondary schools and the results are summarized in the following tables.

**Table 2: Materials used by teachers in teaching/learning of electric current**

| | | Responses | | |
|---|---|---|---|---|
| | | N | Percent | Percent of Cases |
| Yes[a] | Textbooks | 6 | 14.6% | 100.0% |
| | Experiences | 6 | 14.6% | 100.0% |
| | Charts | 6 | 14.6% | 100.0% |
| | Cells | 4 | 9.8% | 66.7% |
| | Voltmeters | 4 | 9.8% | 66.7% |
| | Ammeters | 1 | 2.4% | 16.7% |
| | Wires | 6 | 14.6% | 100.0% |
| | Switch | 6 | 14.6% | 100.0% |
| | Resistors | 1 | 2.4% | 16.7% |
| | Other | 1 | 2.4% | 16.7% |
| Total | | 41 | 100.0% | 683.3% |

Teachers were requested to indicate the teaching esources they use to teach Electric current in their classrooms as it is illustrated in Table 2. Teachers indicated the teaching resources they use when teaching/learning of electric current. Teacher's response on the use of textbooks, charts and other materials by in both the experimental and control groups in their teaching and learning of electric current is presented in Table 2.

**Table 3:** ***Other materials used by teachers in teaching/learning of electric current***

| | | Responses | | |
|---|---|---|---|---|
| | | N | Percent | Percent of Cases |
| No[a] | Cells | 2 | 8.0% | 33.3% |
| | Voltmeters | 2 | 8.0% | 33.3% |
| | Ammeters | 5 | 20.0% | 83.3% |
| | Resistors | 5 | 20.0% | 83.3% |
| | Solve Elec | 6 | 24.0% | 100.0% |
| | Other | 5 | 20.0% | 83.3% |
| Total | | 25 | 100.0% | 416.7% |

Teacher's response on the use of other teaching resources is presented in Table 3.

In practice, teachers in Malawi secondary schools use ICTs for administrative purposes. Computers are used for setting examinations, writing official letters, schemes, and records of work but not for teaching and learning Physics, from Table 3, all teachers responded negatively to the use of Solve Elec in their teaching of Physics. However, computer studies are part of the school curriculum, which was introduced in 2005, aiming at preparing students for ICT literacy and self-employment (Malawi Government, 2006). But not all schools use ICT or learn computer studies as a subject because of inevitable challenges such as limited infrastructure and, lack of qualified personnel. A qualified teacher is key to how teacher education addresses ICT (computer simulation) integration in teaching and learning as previous research also shows low usage of computer simulation among teacher educators.

## 4.2. Difference in academic performance in Electric current between the students who are exposed to the use of Solve Elec and those taught using chalk-talk method (traditional method)

The experimental group consisted of 85 students from the same class and 3 teachers from Public Secondary school in Lilongwe urban. The mean age of the students was 16.1 years hence a written consent was signed by the students above 16years and those below 16 years parents/guardians were the ones to sign the consent forms . Before the intervention, all the students took a Pre-test, to assess learners' prior knowledge about electric current. This is in line with constructivism theory of learning which says that a learner is not a tabula rasa but has some knowledge before coming to a class.

The Control group consisted of 96 students from the same class and 3 teachers from public secondary school of Lilongwe urban. The mean age of the students was 16.2 years similarly the consent forms were also provided to this group. This group did not receive any treatment during the study. Before the study this group also took a pre-test, this was also to assess what they knew about electric current. Before presenting the data the researcher had to make sure that the data was normally distributed.

### 4.2.1. Pre-test results.

Two weeks prior to the interventions, all groups (control and experimental) were given a pre-test to ensure that they had the necessary knowledge of the subject. Results of the Pre-test for the Experimental and Control group are presented in Table 4.

**Table 4: Measures of dispersion and central tendency of the Pretest results**

| Group | N | Minimum | Maximum | Range | Mean | Std. Deviation | Std. Error of Mean |
|---|---|---|---|---|---|---|---|
| Experimental | 85 | .00 | 24.00 | 24.00 | 14.0941 | 6.27471 | .68059 |
| Control | 96 | .00 | 25.00 | 25.00 | 13.9271 | 6.98456 | .71286 |
| Total | 181 | .00 | 25.00 | 25.00 | 14.0055 | 6.64287 | .49376 |

The Pre-test results for both groups (Experimental and Control) are presented in Table 4. The mean score for the experimental was 14.0941 while that of control group was 13.9063. The students from both groups had prior knowledge of the electric current topic before the intervention and the similarity of both the experimental and control group was established based on their mean scores. The aim of the pre-test was to check whether the groups to be involved in the intervention (both the experimental and control) were at the same level. The distribution of scores is also displayed in figure 2 and 3 below

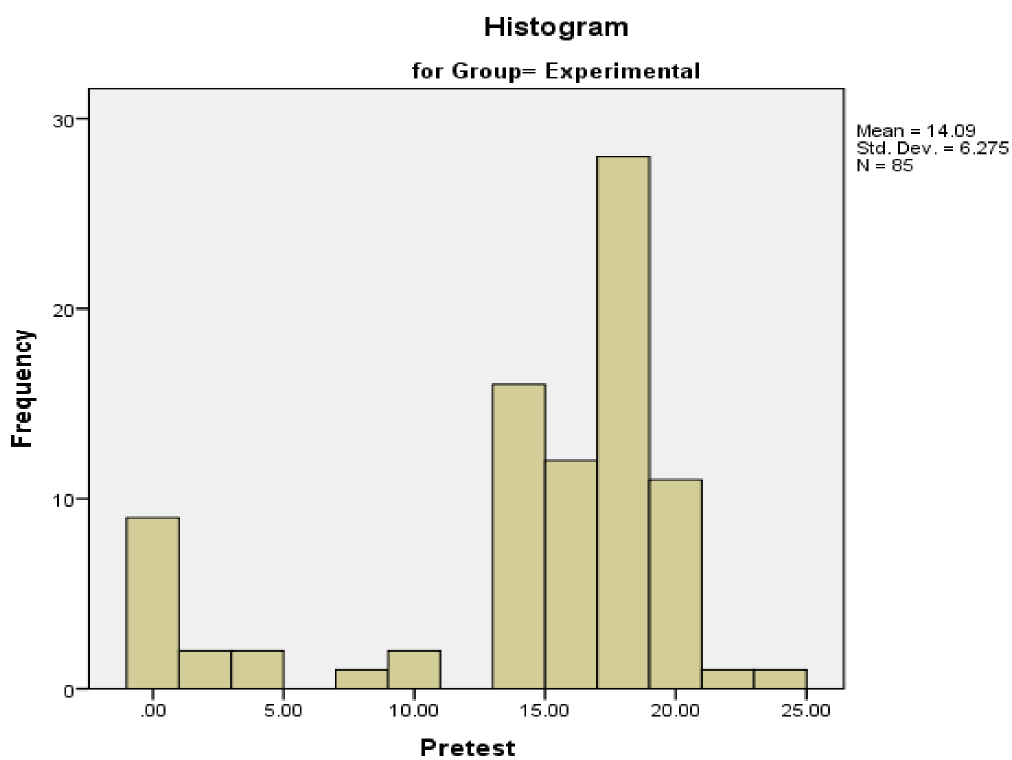

**Figure 2: Control group-pre-test**

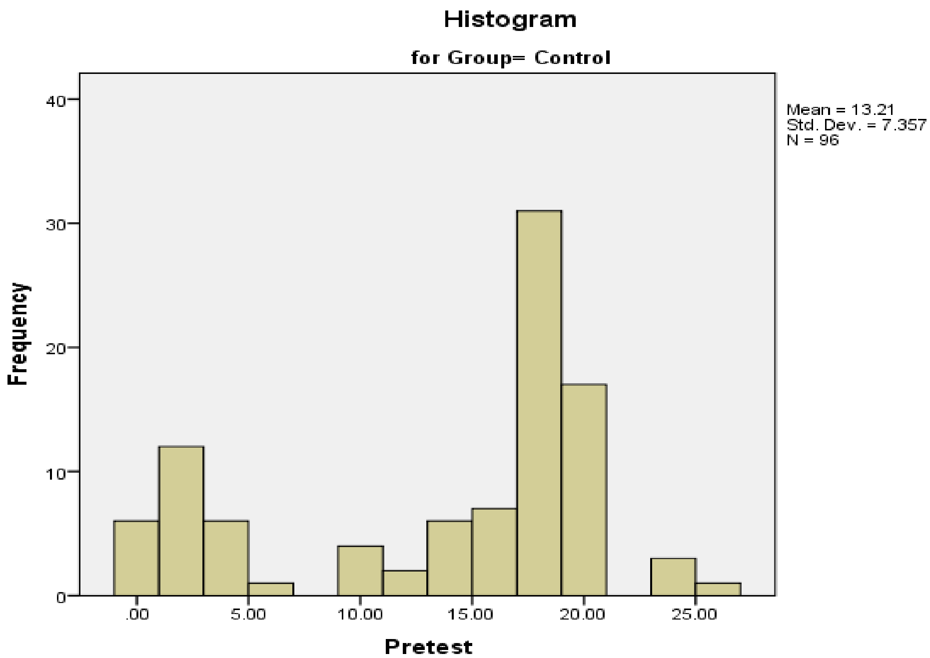


**Figure 3: Experimental Group Pretest**

As shown in figure 2 and 3 the distribution of the test scores ranges from 0-25 in the Experimental group while it ranges from 0-30 in the control group, the scores distribution varies slightly in both groups, this shows that the two groups were of a comparable abilities in electric current. Inferential statistics was also run to determine whether the two group's academic performance was statistically significant. The independent samples t-test was used to investigate whether the gaps between the groups' academic performance were statistically significant. With a 95% confidence interval. The independent sample t-test results are presented in Table 5.

**Table 5 : Independent Samples Test for both the experimental and control groups**

| | | Levene's Test for Equality of Variances | | t-test for Equality of Means | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | 95% Confidence Interval of the Difference | |
| | | F | Sig. | t | df | Sig. (2-tailed) | Mean Difference | Std. Error Difference | Lower | Upper |
| Pretest | Equal variances assumed | 3.729 | .055 | .168 | 179 | .866 | .16703 | .99203 | -1.79055 | 2.12462 |
| | Equal variances not assumed | | | .169 | 178.959 | .866 | .16703 | .98558 | -1.77782 | 2.11189 |

An independent T-test for each group before intervention was run in SPSS v**23.0** at a confidence interval of **95%** and a P-value of **0.05**. A T value was calculated for each group **t (179) =0.168**) and a P-value of **0.866**. The results presented in Table 5 shows that there was no statistical significant difference in the scores between the experimental and control group. There test results confirms that the two groups were of similar abilities in electric current before the intervention hence any differences after the intervention is attributed to the intervention.

The results of the Post-intervention test (Post-test), which was performed after the intervention, are discussed in this segment and used to answer the research questions. In the control group, students performed better at lower levels than at higher levels, while in the experimental group, students performed better at higher levels than lower levels as outlined in Table 6 below.

Table 6 displays the Post-test results for both the experimental and the control groups after a successful completion of the topic of electric current. This was done to assess whether the intervention had an impact in the experimental group. What follows are the results of the post-test for both groups.

### 4.2.2. Post-test results

**Table 6: Measures of central tendency of Posttest results**

| Group | N | Minimum | Maximum | Range | Mean | Std. Deviation | Std. Error of Mean |
|---|---|---|---|---|---|---|---|
| Experimental | 85 | 8.00 | 100.00 | 92.00 | 65.5294 | 22.40195 | 2.42983 |
| Control | 96 | 20.00 | 91.00 | 71.00 | 47.5937 | 12.71599 | 1.29782 |
| Total | 181 | 8.00 | 100.00 | 92.00 | 56.0166 | 20.00263 | 1.48678 |

After the intervention the results of Post-tests, are presented in Table 6 for both groups (Experimental and Control). The mean score for the experimental was **65.5294** while the control was **47.5938.** The two groups scored different marks at the end of the intervention.

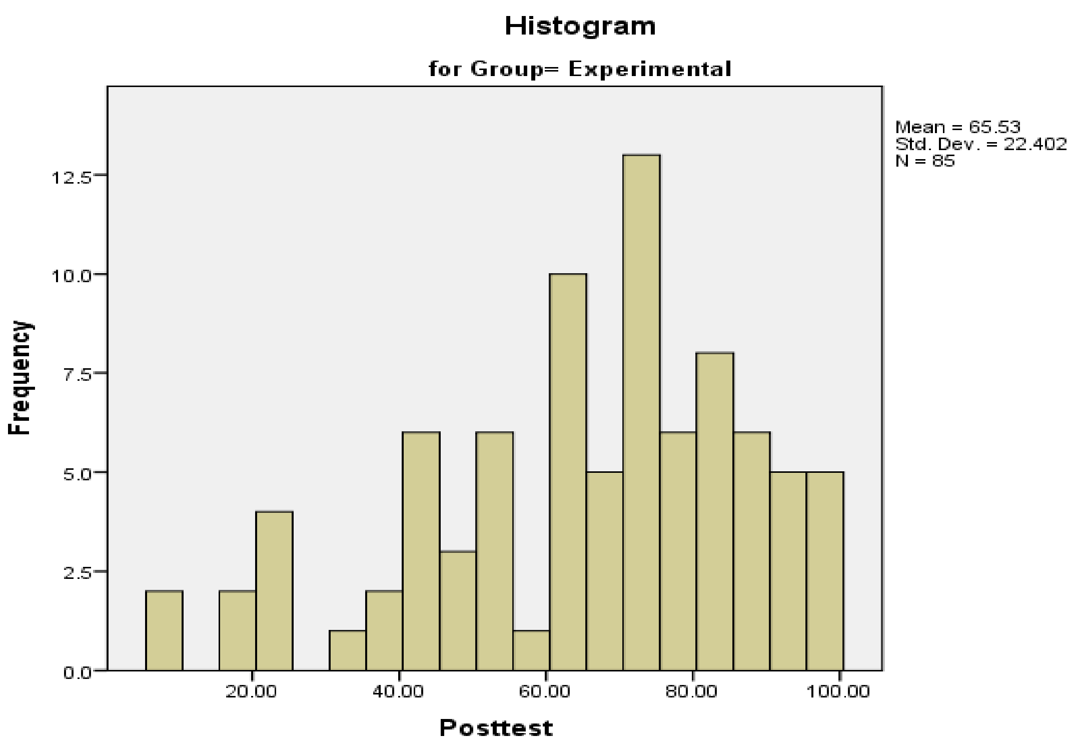


**Figure 4: Control group-post-test**

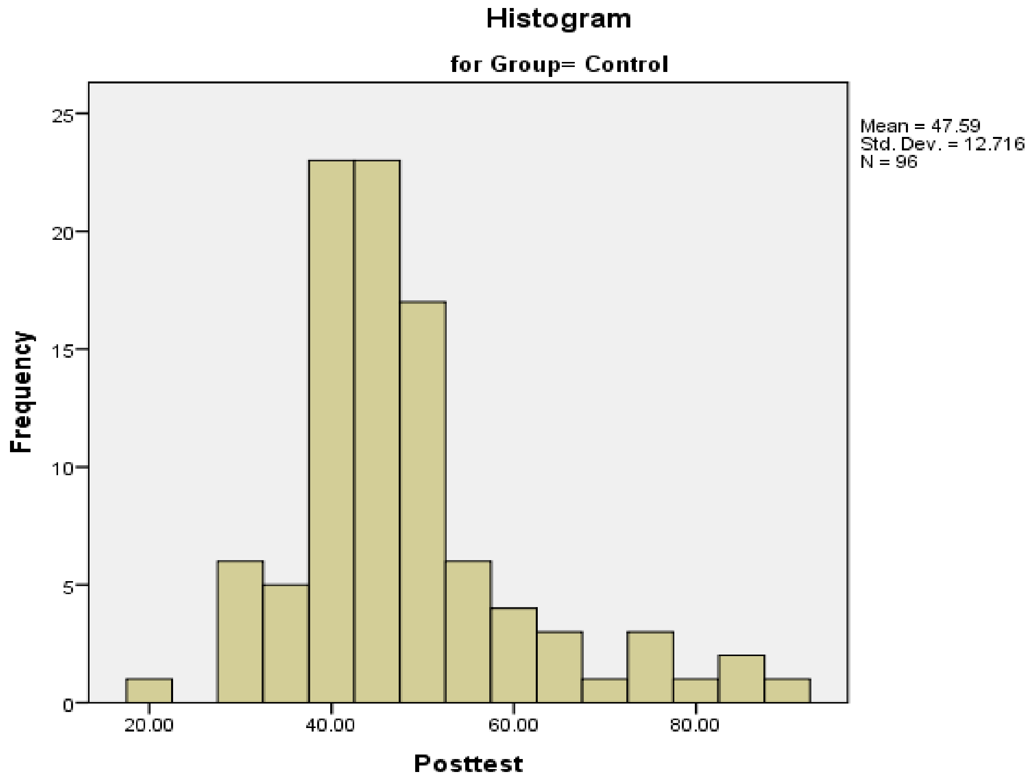


**Figure 5: Experimental group-post-test**

As seen in Figure 4 the mean has shifted more to the right for the Experimental group than the control group with the mean of 65.53 and 47.59 respectively. To substantiate this evidence Independent T-test was run and the results are presented in Table 7 below. First of all Independent T-test was run between the two groups and the results are as follows.

**Table 7:** *Independent Samples t-Test for both the experimental and control groups*

| | | Levene's Test for Equality of Variances | | t-test for Equality of Means | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | 95% Confidence Interval of the Difference | |
| | | F | Sig. | t | df | Sig. (2-tailed) | Mean Difference | Std. Error Difference | Lower | Upper |
| Posttest | Equal variances assumed | 28.413 | .000 | 6.718 | 179 | .000 | 17.93566 | 2.66971 | 12.66752 | 23.20381 |
| | Equal variances not assumed | | | 6.511 | 129.449 | .000 | 17.93566 | 2.75471 | 12.48558 | 23.38574 |

After the Experimental group received intervention a Posttest was administered for both groups and an Independent T-test was run at a confidence level of 95% and a P value was calculated which **0.00** and is below **(P<0.05).** This means that the intervention had a significant difference in the Post-test scores at the end of the study. The results presented in Table 5 shows that there was no statistical significant difference in the scores between the experimental and control group. The test results confirms that the two groups were of similar abilities in electric current before the intervention hence any differences after the intervention is attributed to the intervention.

An independent t-test was used to see whether the differences in physics achievement between the experimental and control groups was substantial. The independent t-test findings show that there was a substantial difference between the groups' post-test scores on the Physics Achievement Test. **$t(179) = 6.718$, $p<0.05$)** between the experimental and the control group.

## 4.3 Discussion of the results

This segment addresses the study's key findings, including the effect of Solve Elec on students' academic performance in form three.

### 4.3.1 Instructional resources and materials frequently used by teachers when teaching electric current

Based on the results presented in Table 2 and 3, most of the participating teachers indicated that they have never used Solve Elec or any computer simulation in the teaching of electric current. This was because the use of computer simulation in teaching/learning of science is new to them besides most teachers lack basic ICT skills hence they need proper training on how they can use computer simulations in their mode of instruction. Besides the altitudes and perception of teachers towards the use of computer simulations needs to change otherwise the use of computer simulations is more theoretical than practical in most secondary schools in Malawi.

To substantiate this research finding (Gondwe, 2020) also found similar results that teachers use ICT for setting examinations, writing an official letter, schemes, and records of work but not teaching and learning of physics. There is under usage of technological materials, which in turn leads to poor performance. Besides, even where technological resources are available such as computers, class interactive teaching is under-developed as it is dominated by a traditional approach i.e. talk and chalk (Ghavifekr & Rosdy, 2015), it is often underused and hindered by a set of practical constraints and teachers' negative attitudes towards the use of ICT in teaching/learning. Some of the learner centered strategies include problem solving with teacher guidance, lecturing with demonstration, direct instruction, and question and answer.

### 4.3.2 Academic performance in electric current between the students who are exposed to the use of Solve Elec and those taught using chalk-talk method (traditional method)

The results of an independent t-test on the academic performance of students exposed to the use of Solve Elec significantly achieved higher scores than those taught with traditional methods (talk-chalk). The possible reasons behind the experimental groups success is attributed to the integration of Solve Elec in their mode of learning electric current. The students in the experimental group checked the accuracy and correctness of their work by examining the circuit solution, which included literal formulas for entities defined by measurement devices. Students in the experimental group were able to draw and analyse complicated circuit problems unlike students in the control group who used talk-chalk method.

Students in the experimental group could make a circuit and also change properties of the circuit components and create new related entities based on their formulas, while in the control group teaching was more limited to the teacher talk-chalk method. Traditional method of teaching resulted in low academic performance in the control group.

The use of Solve Elec in teaching/learning of electric current enabled teachers to draw a circuit which is more complicated to draw on the chalkboard, explain difficult concepts, and allowed students in the experimental group to explore problems in real-time. As a result, the learning process changed in terms of speed and consistency. Students used Solve Elec to explore complex problems, they used less time drawing circuit diagrams and calculation, giving them more time to investigate the properties of various circuit theorems. All of these variables have aided the experimental group's success.

Moodley & Gaigher (2019) and Taub et al., (2015) argued that in situations and circumstances that computer technologies make abstract concepts tangible, teachers can easily, build upon students' prior knowledge and skills; emphasize connections among physics concepts; address common misunderstandings and introduce more advanced ideas. Computer simulations such as Solve Elec allows interactive learning hence it is virtually impossible to have passive learners in the teaching and learning process. Solve Elec can change passive students to independent thinkers and the teacher's role is less like a facilitator and monitoring students' work. Physics concepts and procedures learned using Solve Elec are better incorporated into students' cognitive structure, which makes them easier to apply (Nguyen et al., 2012; Ramankulov et al., 2020).

# 5. Conclusion and Recommendations

The present study aimed at analyzing the effect of Solve Elec on learning electric current. This was achieved by conducting an experimental study on high Physics students in form three. The study compared achievement scores by students taught using Solve Elec and those taught using the conventional method. The findings show that Solve Elec can result in significant differences in student achievement in teaching/learning of electric current. The findings of the study show that teachers do not use Solve Elec in their instruction of electric current representing a 100% absence of integration of ICT in the teaching/learning of Physics. The independent t-test was used to determine if there was a significant gap in physics academic achievement between the experimental and the control group. The independent t-test results show that there was a substantial difference between the groups' post-test scores on the Physics Achievement Test **t (179) =6.718, p<0.05)**.

The findings indicate that there is a statistically significant difference in the experimental group's Post-test scores. (Mean=65.5294; SD = 22.40195) and control group (Mean = 47.5937.; SD = 12.7159); t (181) = 6.718, p = 0.000).Based on these findings, it was determined that there was a statistically substantial difference in academic performance between students who were exposed to Solve Elec and those who were not. The results showed that students who were exposed to the use of Solve Elec outperformed those that were exposed to the traditional method. Therefore it is concluded that Solve Elec made an impact on the teaching/learning of electric current.

To better understand the implications of these results, future studies into the impact of Solve Elec on learning electric current on student performance could address the necessity of longer-term studies of much broader samples at various schools with diverse ethnic compositions and socioeconomic statuses that represent the entire Malawian economy, not only in urban areas. As the findings of this study demonstrate, a technology-enhanced instructional program will greatly increase academic performance.

According to the research findings, physics teachers in Malawian secondary schools and beyond should be allowed to use this program in their classrooms. Teachers should get training in how to use the program so that they can instruct their pupils better. This research further proposes that teachers use a hybrid teaching/learning system of instruction, in which computer tools (such as Solve Elec) are used in combination with the conventional talk-and-chalk teaching technique. The hybrid teaching and learning process is a system that combines face-to-face instruction with computer-mediated instruction.

# References


Agyei, D. D., & Voogt, J. M. (2011). Computers & Education Exploring the potential of the will, skill, tool model in Ghana : Predicting prospective and practicing teachers ' use of technology. *Computers & Education*, *56*(1), 91–100.

Aina, J. K. (2014). Effect of socioeconomic and socio-cultural barrier on female education: implications for students‟ enrolment and learning in Physics. *International Journal of Modern Education Research*, *1*(4), 73-77.

Alper, A., & Gulbahar, Y. (2009). Trends and issues in educational technologies: A review of recent research in TOJET. *Online Submission*, *8*(2).

Andaloro, G., Bellomonte, L., & Sperandeo-Mineo, R. M. (1997). A computer-based learning environment in the field of Newtonian mechanics. *International Journal of Science Education*, *19*(6), 661-680.

Ariyo, A. O., & Jonathan-Ibeagha, E. (2008). A path analytical study of Nigerian senior secondary school students' characteristics and their academic performance in physics/Estudio analítico sobre el rendimiento académico en física en una escuela secundaria nigeriana. *Journal of Science Education*, *9*(1), 44.

Astutik, S., & Prahani, B. K. (2018). The Practicality and Effectiveness of Collaborative Creativity Learning (CCL) Model by Using PhET Simulation to Increase Students' Scientific Creativity. *International Journal of Instruction*, *11*(4), 409-424.

Bangert-Drowns, R. L., Kulik, J. A., & Kulik, C. L. C. (1991). Effects of frequent classroom testing. *The journal of educational research*, *85*(2), 89-99.

Barakabitze, A. A. (2014). The Context of Education Initiatives, Importance and Inhibitors of ICTs towards improving teaching and learning in Tanzania: A Critical Literature review. *Context*, *4*(10).

Barakabitze, A. A., Kitindi, E. J., Sanga, C., Kibirige, G., & Makwinya, N. (2015). Exploring students' skills and attitudes on effective use of ICTs: Case study of selected Tanzanian public secondary schools. *Universal Journal of Educational Research*, *3*(6), 407-425.

Baser, M. (2006). Effects of conceptual change and traditional confirmatory simulations on pre-service teachers' understanding of direct current circuits. *Journal of Science Education and Technology*, *15*(5-6), 367-381.

Bayraktar, S. (2001). A meta-analysis of the effectiveness of computer-assisted instruction in science education. *Journal of research on technology in education*, *34*(2), 173-188.

Bliss, J. (1996). Externalizing thinking through modeling:

ESRC tools for exploratory learning research program. In S. Vosniadou, E. de Corte, R. Glaser, & H. Mandl, International perspectives on the design of technology-supported learning environments (pp.25±40). New Jersey: Lawrence Erlbaum Associates.

Chamba, M. M. (2009). An investigation of the availability and value of in-service education and training for secondary school physical science teachers in Malawi: a case of Blantyre city (Master's thesis, University of Cape Town).

Chimuka, A. (2017). The effect of integration of geogebra software in the teaching of circle geometry on grade 11 students ' (issue may). university of south africa.

Chirwa, G., & Naidoo, D. (2014). Curriculum change and development in Malawi: a historical overview. *Mediterranean Journal of Social Sciences*, *5*(16), 336-336.

Choong, K. W. P. What English Language Teachers Need to Know Volume II: Facilitating Learning. *Teachers College Record*.

Cohen, L., Manion, L., & Morrison, K. (2017). *Research methods in education*. Routledge.

Collins, C. S., & Stockton, C. M. (2010). The central role of theory in qualitative research. *International Journal of Qualitative Methods*, *17*(1), 1609406918797475.

Collis, B., & Moonen, J. (2001). *Flexible learning in a digital world: Experiences and expectations*. Psychology press.

Cook, T. D., Campbell, D. T., & Shadish, W. (2002). *Experimental and quasi-experimental designs for generalized causal inference*. Boston, MA: Houghton Mifflin.

Cox, M., Webb, M., Beauchamp, T., & Rhodes, V. (2004). A review of the research literature relating to ICT and attainment. *A Review of the Research Literature Relating to ICT and Attainment*, *1*(January), 1–58.

Cresswell, J. W. (2013). John W. Creswell-Research Design_ Qualitative, Quantitative, and Mixed Method Approaches-SAGE Publications (2013).pdf (p. 273). p. 273.

De Jong, T., & Van Joolingen, W. R. (1998). Scientific discovery learning with computer simulations of conceptual domains. *Review of Educational Research*, *68*(2), 179–201.

Denzin, N. K., Lincoln, Y. S., & ...[et al]. (2013). *Collecting and Interpreting Qualitative Materials-SAGE Publications*, (p. 710). p. 710.

Dinardo,J.(2013).Natural experiments and quasi-natural experiments. In *Micro econometrics* (pp. 139-153). Palgrave Macmillan, London.

Docktor, J. L., & Mestre, J. P. (2014). Synthesis of discipline-based education research in physics. *Physical Review Special Topics-Physics Education Research*, *10*(2), 020119.

Dzama, E. (2006). Malawian Secondary School Students' Learning of Sciences: Historical Background, Performance and Beliefs, Unpublished thesis submitted in partial fulfillment of the requirements of the degree of Doctor of Philosophy, Department of Mathematics and Science Education, University of Western Cape, South Africa.

Dzana E.N, (2012). Poor performance in science subjects in Malawi, University of Malawi. Education sector Development Program (ESDP), 2011, education sector performance report.

Elisha, M. (2008). The application of Information and Communication Technology (I.C.T.) in Nigerian academic libraries prospects and problems. *Information Manager (The)*, *6*(1), 35–39.

Erinosho, S. Y. (2013). How do students perceive the difficulty of physics in secondary school? An exploratory study in Nigeria. *International Journal for cross-disciplinary Subjects in Education (IJCDSE)*, *3*(3), 1510-1515.

Ghavifekr, S., & Rosdy, W. A. W. (2015). Teaching and learning with technology: Effectiveness of ICT integration in schools. *International Journal of Research in Education and Science*, *1*(2), 175-191.

Gondwe, F. (2020). ICT Integration into Teacher Education: Teacher Educators' Experiences of Policy at Two Teacher Education Institutions in Malawi. *Journal of International Development Studies*, *29*(1), 117-128.

Greg Fiumara. (2005). Solve Elec, physicsbox

Gribbons, B., & Herman, J. (1997). True and quasi-experimental designs. *Practical assessment, research, and evaluation*, *5*(1), 14.

Gunstone, R., Mulhall, P., & McKittrick, B. (2009). Physics teachers' perceptions of the difficulty of teaching electricity. *Research in Science education*, *39*(4), 515-538.

Hestenes, D., Wells, M., & Swackhamer, G. (1992). Force concept inventory. *The physics teacher*, *30*(3), 141-158.

Huffman, D., Goldberg, f., Michlin, M. (2003). Using computers to create constructivist learning environments: impact on pedagogy and achievement. Journal of Computers in Mathematics and Science Teaching, 22(2), 151–168.

Jaakkola, T., Nurmi, S., & Veermans, K. (2011). A comparison of students' conceptual understanding of electric circuits in simulation only and simulation-laboratory contexts. *Journal of research in science teaching*, *48*(1), 71-93.

Jimoyiannis, A., & Komis, V. (2001). Computer simulations in physics teaching and learning: a case study on students' understanding of trajectory motion. *Computers & education*, *36*(2), 183-204.

Konyango, O. B., Ogeta, N. O., Otieno, M., & Orodho, J. A. (2018). Influence of Resources on Students' Academic Performance in Physics at Secondary Schools in Ugenya Sub-County, Siaya County, Kenya.

Kauts, A., & Gupta, S. (2013). Efficacy of ICT as a transactional pedagogical strategy in teaching of science at secondary stage. *Educational Quest*, *4*(1), 49.

Kazima, M., & Winter, M. (2013). ICT and the teaching and learning of mathematics in Malawi: experience and prospects.

Kearney, M., & Treagust, D. F. (2001). Constructivism as a referent in the design and development of a computer program using interactive digital video to enhance learning in physics. *Australasian Journal of Educational Technology*, *17*(1).

Kearney, M., Treagust, D. F., Yeo, S., & Zadnik, M. G. (2001). Student and teacher perceptions of the use of multimedia supported predict–observe–explain tasks to probe understanding. *Research in Science Education*, *31*(4), 589-615.

Lacambra, W. T. (2016). Students' academic performance in physics 1: basis for teaching and learning enhancement. *Research on Humanities and Social Sciences*, *6*(4), 78-84.

Lawshe, C. H. (1975). A quantitative approach to content validity. *Personnel psychology*, *28*(4), 563-575.

Lloyd-Smith, L. (2010). Exploring the advantages of blended instruction at community colleges and technical schools. *Journal of Online Learning and Teaching*, *6*(2), 508-515.

Loughran, J., Milroy, P., Berry, A., Gunstone, R., & Mulhall, P. (2001). Documenting science teachers' pedagogical content knowledge through PaP-eRs. *Research in Science Education*, *31*(2), 289-307.

Lungu, F. C. S. (2009). *Investigating Malawian Physical Science Teachers' Teaching Startegies: A Case Study in Nuclear Physics* (Doctoral dissertation, University of the Witwatersrand).

Maganga, J. H. (2016). Factors Affecting Students" Academic Performance: A Case Study of Public Secondary Schools in Ilala District, Dar es Salaam, Tanzania. *Master of Education Thesis, University of Tanzania*.

McMillan, J. H., & Schumacher, S. (2001). Research in Education. New York: Addison Welsey Longman.

Meleisea, E. L. L. I. E. (2007). The UNESCO ICT in education programme. Bangkok, Thailand: United Nations Educational, Scientific and Cultural Organization.

Mellar, H. G., & Bliss, J. (1993). Expressing the Student's Concepts versus Exploring the Teacher's: Issues in the Design of Microworlds for Teaching. *Journal of Educational Computing Research*, *9*(1), 89-113.

Merriam, S. B., & Tisdell, E. J. (2016). *Qualitative research: A guide to design and implementation*. John Wiley & Sons.

Ministry of Education (2006). 2006 Education Statistics, Department of Education Planning, Lilongwe: Unpublished.

Mlangeni, A. N. J. T., & Chiotha, S. S. (2015). Why Rural Community Day Secondary Schools students' performance in Physical Science examinations is poor in Lilongwe Rural West Education District in

Malawi. *Educational Research and Reviews*, *10*(3), 290-299.

Moodley, K., & Gaigher, E. (2019). Teaching electric circuits: Teachers' perceptions and learners' misconceptions. *Research in Science Education*, *49*(1), 73-89.

Msila, V. (2015). Teacher readiness and information and communications technology (ICT) use in classrooms: A South African case study. *Creative Education*, *6*(18), 1973.

Muñoz, M. M., Rodríguez, M. L. J., & De Mesa, J. A. G. (2013). Electrical Storm Simulation to Improve the Learning Physics Process. *Informatics in Education*, *12*(2), 191-206.

Mutanu, L., & Machoka, P. (2019, July). Enhancing computer students' academic performance through explanatory modeling. In *Annual Conference of the Southern African Computer Lecturers' Association* (pp. 227-243). Springer, Cham.

Nastiti, D., Rahardjo, S. B., VH, E. S., & Perdana, R. (2018). The need analysis of module development based on search, solve, create, and share to increase generic science skills in chemistry. *Jurnal Pendidikan IPA Indonesia*, *7*(4), 428-434.

Ng, B. L. L. (2012, December). The application of community service learning in science education. In *Asia-Pacific forum on science learning & teaching* (Vol. 13, No. 2).

Nguyen, N., Williams, J., & Nguyen, T. (2012, December). The use of ICT in teaching tertiary physics: Technology and pedagogy. In *Asia-Pacific Forum on Science Learning and Teaching* (Vol. 13, No. 2, pp. 1-19). The Education University of Hong Kong, Department of Science and Environmental Studies.

Nguyen, N., Williams, J., & Nguyen, T. (2012, December). The use of ICT in teaching tertiary physics: Technology and pedagogy. In *Asia-Pacific Forum on Science Learning and Teaching* (Vol. 13, No. 2, pp. 1-19). The Education University of Hong Kong, Department of Science and Environmental Studies.

Nuamah, E. (2020). The approach to teaching integrated science and its effect on students'academic performance: a case study of bisease senior high school in the ajumako eyan essiam district.

Okoth, B. K., Ogeta, N. O., Otieno, M., & Orodho, J. A. (2018). Influence of Resources on Students' Academic Performance in Physics at Secondary Schools in Ugenya Sub-County, Siaya County, Kenya. *Greener Journal of Educational Research*, *8*(5), 111–118.

Olde, C. V. D., & Jong, T. D. (2004). Student-generated assignments about electrical circuits in a computer simulation. *International Journal of Science Education*, *26*(7), 859-873.

Ramankulov, S., Dosymov, E., Turmambekov, T., Azizkhanov, D., Kurbanbekov, S., & Bekbayev, S. (2020). Integration of case study and digital technologies in physics teaching through the medium of a foreign language. *International Journal of Emerging Technologies in Learning (iJET)*, *15*(4), 142-157.

Ramnarain, U., & Moosa, S. (2017). The use of simulations in correcting electricity misconceptions of grade 10 South African physical sciences learners. *International Journal of Innovation in Science and Mathematics Education*, *25*(5).

Scaife, T. M., & Heckler, A. F. (2011). Interference between electric and magnetic concepts in introductory physics. *Physical Review Special Topics-Physics Education Research*, *7*(1), 010104.

Smetana, L. K., & Bell, R. L. (2012). Computer simulations to support science instruction and learning: A critical review of the literature. *International Journal of Science Education*, *34*(9), 1337-1370.

Solomonidou, C. (2009). Constructivist design and evaluation of interactive educational software: a research-based approach and examples. *Ανοικτή Εκπαίδευση: το περιοδικό για την Ανοικτή και εξ Αποστάσεως Εκπαίδευση και την Εκπαιδευτική Τεχνολογία*, *5*(1), 6-24.

Stangor, C. (2011). Research Methods for Behavioral Sciences. In *Wadsworth*, *Cengage Learning* (4thed, Vol. 1). Jon-David Hague.

Taub, R., Armoni, M., Bagno, E., & Ben-Ari, M. M. (2015). The effect of computer science on physics learning in a computational science environment. *Computers & Education*, *87*, 10-23.

UNESCO (2007). Sensitization workshop on the use of the science kit planned for Malawi, Malawi National Commission for UNESCO, 2, 48-49.

Uwizeyimana, D., Yadav, L., Musengimana, T., & Uwamahoro, J. (2018). The impact of teaching approaches on effective physics learning: an investigation conducted in five Secondary Schools in Rusizi District, Rwanda. *Rwandan Journal of Education*, *4*(2), 4-14.

Ware, S. A., & Mundial, B. (1992). The education of secondary science teachers in developing countries.

Yuliati, L., Riantoni, C., & Mufti, N. (2018). Problem Solving Skills on Direct Current Electricity through Inquiry-Based Learning with PhET Simulations. *International Journal of Instruction*, *11*(4), 123-138.

Zacharia, Z. (2003). Beliefs, attitudes, and intentions of science teachers regarding the educational use of computer simulations and inquiry-based experiments in physics. *Journal of Research in Science Teaching*, *40*(8), 792–823.

Zacharia, Z. C. (2007). Comparing and combining real and virtual experimentation: an effort to enhance students' conceptual understanding of electric circuits. *Journal of Computer Assisted Learning*, *23*(2), 120-132.

Zavala, B. M. (2008). Teaching electricity in elementary, middle and high school: Some real life examples.

Zeman, M., Willemen, J. A., Vosteen, L. L. A., Tao, G., & Metselaar, J. W. (1997). Computer modelling of current matching in a-Si: H/a-Si: H tandem solar cells on textured TCO substrates. *Solar Energy Materials and Solar Cells*, *46*(2), 81-99.

Zhang, D., & Liu, L. (2016). How does ICT useinfluences students’ achievements in math and science over time? Evidence from PISA 2000 to 2012. *Eurasia Journal of Mathematics, Science and Technology Education*, *12*(9), 2431–2449.