The Use of Computer Simulations for Cognitive Load Change and Acquisition of Knowledge and Skills in Geometrical Optics

by

Sam James Murungi Kaheru

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Supervisor: Professor Jeanne Kriek

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Student number:456 55 456

I declare that **The Use of Computer Simulations for Cognitive Load Change and Acquisition of Knowledge and Skills in Geometrical Optics** 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.

Kaheru SJM

Digitally signed by Kaheru SJM
DN: cn=Kaheru SJM, o=Univen, ou=School of Education, email=samkaheru@univen.ac.za, c=ZA
Date: 2015.04.02 21:30:59 +02'00'

SIGNATURE
(Mr)

DATE

Abstract

The aim of the study was to compare the effects of the use of interactive computer simulations for cognitive load change of grade 11 learners in the acquisition of knowledge and a science process skill in geometrical optics. Both the use of computer simulations and traditional teaching was teacher centred. The study was done in a rural area in South Africa, in the Limpopo Province in the district of Vhembe. The theoretical framework was based on the information processing model. Within the non-equivalent quasi experimental design a switching replications design study was used whereby 105 learners in four schools took part. This study found that in terms of the acquisition of knowledge, female learners gained more by the use of simulations than their male counterparts. No significant effect was found in the acquisition of the skill when computer simulations were used. Initial reduction of cognitive load was found when simulations were used and with time this increased. Experienced educators reduced the cognitive load through use of their knowledge and expertise and their role needs to be highlighted. Further studies are suggested to study the effect of a learner centred approach on decreasing the cognitive load and its effect on the acquisition of knowledge and skills.

Key words:

Computer simulations; cognitive load; role of physical science teachers; geometrical optics; information processing.

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My children Peace, Kezia, Patience, Talemwa and Grace who as curious people in their growth and as beneficiaries in the education scenario, gave me insight into the complexity of human kind – thank you so much.

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Summary of the study

This study was about using computer simulations to reduce cognitive load with regard to knowledge and skills in geometrical optics in the grade 11 high school physics. The study was based on four schools where a switching replications design was used. It was an intact group quasi-experiment with the schools selected using a sampling and the schools to start as treatment or control being randomly assigned. The rational for the switching replications design was that each of the schools had to be in the treatment as well as control at the different stages of the study. The theoretical framework was based on the information processing model.

Data analysis involved the use mixed methods where parametric and non-parametric analysis was done with within and between groups using student t tests and the Mann-Whitney U and Wilcoxon tests done for the quantitative analysis. The qualitative analysis used the Focus group discussion as a point of collecting data which was then analysed by consideration of the various categories.

The unit of analysis was the learner and gender was an important aspect of the study to determine if there were differences in the acquisition of the knowledge and skills.

The major findings of this study include:

- The greater improvement of the female learners with regard to knowledge and skills. The improvement was from a lower point of performance compared to male learners.
- Computer simulations decreased the cognitive load but also interestingly the teacher use of the traditional teaching also reduced the cognitive load.
- An improvement in both categories of learners male and female.
- The computer simulations indicated that the knowledge items were easily grasped whereas the skills items did not improve as much.

The study premised the use of a teacher centred approach due to the majority of educators being comfortable with it, however for further work, it was necessary to study the effect of learner centred on decreasing the cognitive load and its effect on the acquisition of knowledge and skills.

Table of Contents

List of Tables

List of Figures

List of Appendices

List of Abbreviations and Glossary of Terms

Basic skills or basic science process skills that are simple and cannot be broken down to lower skills.

CAPS Curriculum and Assessment Policy

Cognitive load where what is learned in used in the sensory, working memory and ending up in the long term memory.

CS Computer simulations

Extraneous load comes from the instruction material itself, what the educator uses to teach or deliver what is to be learnt.

FET Further Education and Training

Geometrical optics is the study of light rays where light rays are taken to be an approximation to wave theory when the wavelength is taken to be very small compared to other lengths involved in the problem for example the size of the openings

Germane load is the one to do with the deeper processing of content into existing representations and involves also organising what is learnt into what is known.

Integrated science process skill a skilla that is comprised of more than one basic science process skills and is more complicated than the basic skill.

Intrinsic load what is being learnt determines the intrinsic load. The unit or subject is what is being referred to.

Long term memory Provides long term repository for different types of knowledge

Matriculation a term used for the grade 12 final year group in South Africa. This could be in connection with examinations taken in grade 12.

NCS National Curriculum Statement

Pacesetters content and work to be done which was given to District, circuit offices and schools to enable schools to be teaching and learning the same things.

Physlets small computer applications that are simulations.

Short term memory sensory register with information from the sensory parts of the eyes, ears, nose tongue and skin

Switching replications design where each group has the tretment and control conditions in an alternating way.

TDRV-GO Test of describing relationships between variables in geometrical optics

Working memory short term memory

Chapter 1

Introduction

1.1 Background of the Study

South Africa was successful in its bid for an award for an international telescope project to construct and host the largest radio telescope in the world for space exploration. This project is referred to as Square Kilometre Array (SKA) project (SKA Africa, 2012). SKA resulted from efforts from an earlier project to build a large telescope called SALT (Southern African Large Telescope) in order to give a chance to South Africa to win the right to host the larger international project (Southern African Large Telescope, 2011). The last two countries left in the bid were South Africa and Australia, and they shared the bid. The implications are a lot of resources being poured into expertise to develop scholars in physics, astronomy and the servicing and development of radio telescopes. This has also led to recruitment of many students for advanced degrees in the study of stellar and interstellar bodies as well as renewed interest in geometrical optics and physics in general.

Geometrical optics is a topic that deals with lenses needed in telescopes, a section prescribed in the South African National Curriculum Statement (NCS) in physical sciences for Grade 10 -12 (Department of Education, 2008). The subject -physical science consists of physics and chemistry at the upper high school level. The topic is normally dealt with in Grade 11 where the knowledge and skills of geometrical optics are emphasised. In this study, knowledge is referred to as the content area which has to be covered as prescribed by the Department of Education (Department of Education, 2006). The skills can be cognitive as well as practical (Singer, Hilton, & Scheiwngruber, 2005). Cognitive skills are described as when information is manipulated in the head rather than a practical task. A practical task involves the need to manipulate equipment and normally a site for these to take place like laboratories. However, South Africa and specifically the Limpopo Province is confronted with a lack of laboratories (NEIMS, 2009). Therefore, there is a need to explore a way to address the lack of resources and a way could possibly be an alternative technology, for example computer simulations to develop knowledge and skills in a chosen topic geometrical optics.

In a study in the past decade (2001 – 2010) on the learning effects of computer simulations in science education, vigorous evidence is provided that computer simulations can enhance traditional instruction especially as far as laboratory activities are concerned (Rutten, van Joolingen, & van der Veen, 2012)). They found that computer simulations could be used for better understanding, more knowledge expansion, improved attitude toward the subject and better performance on retention and problem-solving tests (Rutten, van Joolingen, & van der Veen, 2012), It can also provide many opportunities for practice without the "chemicals" running out (Zacharia & Olympiou, 2011). This study will enhance the mentioned research in the fact that it is done in a rural part of South Africa and that the Cognitive load theory is used.

Cognitive load theory is based on the Information processing model, and it deals with how what is learned ends up in the long term memory. It can also be referred to as Sweller's Cognitive Load theory (Deschri, Jones, & Hekkinen, 1997; Plass, Hommer, & Hayward, 2009; Zheng, Yang, Garcia, & McCadden, 2008). The information processing model, uses cognitive theories of learning (Mayer, 2002; Paas, Renkl, & Sweller, 2003) as its tenets. The theories which handle how knowledge can end up in long term memory through appropriate instructional strategies are called cognitive theories of learning (Paas, Renkl, & Sweller, 2003; Paivio, 1991). With the cognitive theories, comes the importance of how different memory functions can easily handle new information, which we will call cognitive load. Any teaching strategy that will be able to reduce the cognitive load would lead to gains in learning or ending up in the long term memory (Paas, Renkl, & Sweller, 2003). This study will explore ways to reduce the cognitive load by using computer simulations in the acquisition of knowledge and skills in geometrical optics.

There are three interfaces in the brain: the sensory, working and the long term memory. The first two can keep information for very short time intervals (see section 2.6.2.) The long term memory has unlimited capacity. There are several outcomes for the knowledge and skills learnt ending up in long term memory. One of the outcomes for long term memory is "automation" (Paas & Sweller, 2012, p. 25; van Merrienboer, Kirschner, & Kester, 2003). The moment something ends up in the long term memory, it is performed with ease. There is limited or no effort at all needed to perform a task, meaning the speed of performance is increased. This study focussed on how computer simulations affect the speed of answering questions in the test used as instrument.

1.2 Context of the Study

This study was done in South Africa, in one of the nine provinces, namely Limpopo Province and is located in the north of the country. The province borders three countries, to the west of the province is Botswana, to the north, Zimbabwe and to the east is Mozambique. Having so many international borders, it is thus a gateway province to the rest of Africa (SAinfo reporter, 2012).

Limpopo Province consists of five districts; namely, Mopani, Sekhukhune, Waterberg, Capricorn and Vhembe (see *Figure 1*).

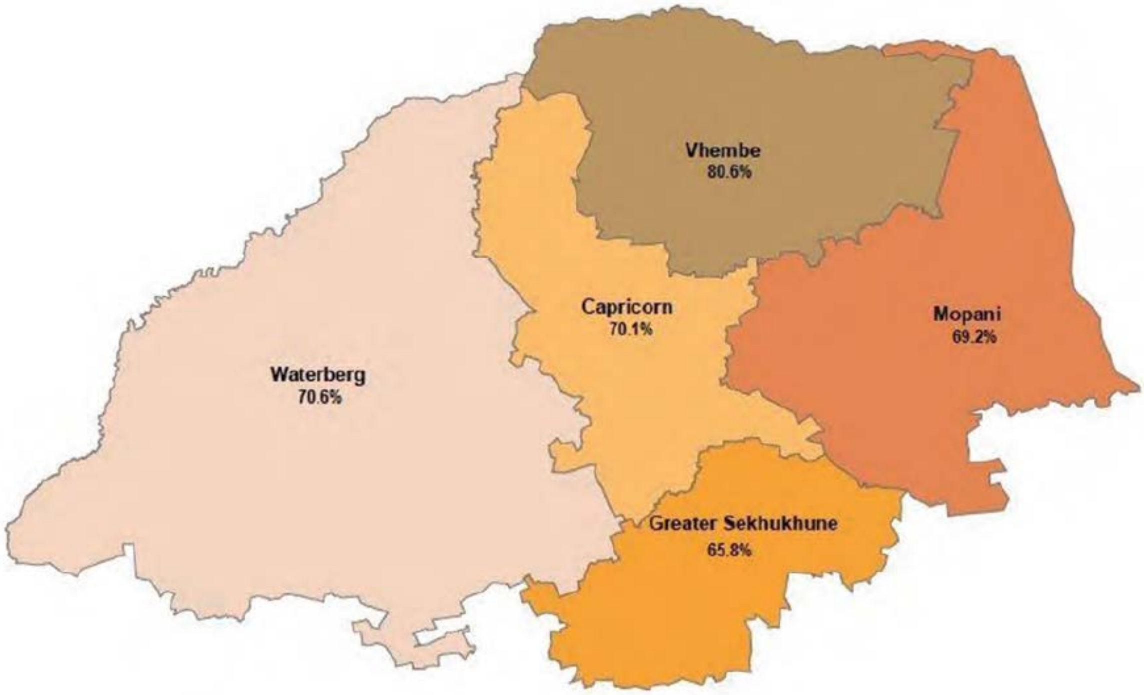

Figure 1. Map of Limpopo showing the districts and the 2013 Grade 12 final pass rates

The study was done in the Vhembe district located in the northern part of the province. In the 2013 Grade 12 results, Vhembe was the best in Limpopo (Department of Basic Education, 2013). For a comparison of the provincial pass rates for 2013, see Appendix A.

The minimum pass mark in South Africa for physical science is 30% based on the National Curriculum Statement (Department of Basic Education, 2010). Despite this low pass mark, the percentage of learners passing Grade 12 physical sciences is lower than other subjects. When the percentage is compared for those passing at 40% and above, it is much lower (Department of Basic Education, 2014). Many schools in South Africa have large classes and considerable resource limitations (Taylor & Vinjevold, 1999). The state of the laboratories for science and computer showed a lot of disparities as seen in the infrastructural report (NEIMS, 2011, pp. 24-25). From this report, the Limpopo province's laboratory statistics is presented (see *Figure 2*). Out of the 3923 schools in this province only 235 (6%)

had science laboratories and of these only 59 (2%) were stocked with the necessary equipment. The situation with regards to computer laboratories was slightly better. There were 426 (11%) schools with computer labs while 167 (4%) were supplied with the necessary equipment (NEIMS, 2011, p. 25). Since laboratories are very useful (Makgato & Mji, 2006; Hofstein & Mamlok-Naaman, 2007) in improving the learning of physical science, lack of them and their under resourced state would make the acquisition of process skills problematic. Lack of experiments and possibly not obtaining the accompanying skills to enable conceptual understanding adversely affect the acquisition of process skills.

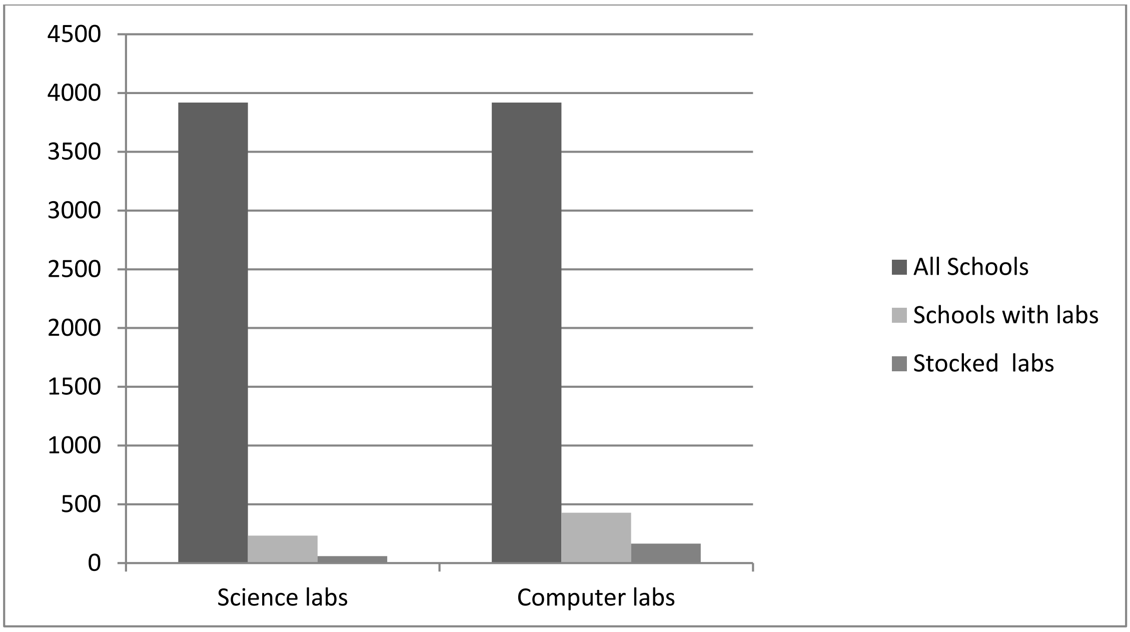

Figure 2. Computer and Science laboratory statistics for Limpopo province.

Source: (NEIMS) May 2011

1.3 Aim of the Study

The aim of the study was to determine the effect of the use of computer simulations for cognitive load change on the acquisition of knowledge and skills in the context of geometrical optics in rural schools.

1.4 Statement of the Problem

There is a low performance in physical science by learners in South Africa. International surveys and assessments like Trends in Mathematics and Science Studies (TIMSS) rank South Africa at the lowest of all participating countries (HSRC, 2012). In other assessment like the Annual National Assessments (ANA) where proficiency in English and mathematics literacy is tested as well as in the Programme for International Student Assessment (PISA) low attainments by the learners have been pointed out (Aydin, Uysal, & Sarier, 2010). PISA considers mathematics, science and reading.

The Department of Education has put several strategies in place to address these shortcomings. For example, repeated changes in the National curriculum beginning, in 1997 when inclusive democracy was ushered in the Outcomes Based Education (OBE) was introduced, called then Curriculum 2005; the new terminologies were many and it was difficult for the educators to implement and we had the National Curriculum Statement, shortly after that we had the Revised National Curriculum Statement (Mouton, Louw, & Strydom, 2012). When this study was done, a "new" curriculum had been introduced in 2013 which placed prominence in the science skills among the revised content. They introduced pace setters wherein the content to be done is set out in such a way that the learners are doing the same things at the same time. The "new" curriculum, is the Curriculum and Assessment Policy (CAPS) (Department of Basic Education, 2010). This curriculum was not considered because data was already been captured before implementation. Another strategy in place was to provide bursaries to address the shortages of educators of physical science and improve their knowledge and skills levels, a concern highlighted by Gaigher (2004) and Kriek and Grayson (2009).

One of the challenges the department of education has to deal with is the lack of infrastructure to ensure the proper teaching of knowledge and skills. Low cost equipment could be used instead of the expensive laboratory equipment, but even if this is the case it is important to note that educators also have to be trained to handle this equipment. The development of skills in physical science is important as it encourages growth in science, technology engineering and mathematics (STEM). The progress in these subjects is essential for the advancement of a nation (Bayrak, 2008).

The teacher centred approach is prevalent and used throughout South Africa. This approach is able to give stability and growth in the expected direction and with the challenge of big class sizes it creates stability and learners can be guided (Chukhlomin, 2011). It is easier to reach the objectives (van Merrienboer, Kirschner, & Kester, 2003; Klahr & Nigam, 2004) set out for the lesson and the curriculum unit. Since the teacher is central in guiding the learners it was decided to use the Information processing model. The information processing model, uses cognitive theories of learning advocates for scaffolding, or guidance for learners to perform well (van Merrienboer, Kirschner, & Kester, 2003), desperately needed in specifically the rural areas of South Africa.

In order for information to go the long term memory, it is important that it passes through the working memory; the working memory is limited with regard to how much information units it can process. It is important to determine the appropriate load and that is, the cognitive load. The cognitive load (Paas, Renkl, & Sweller, 2003; Mayer, 2002) is what will be researched in terms of what and how computer simulations can change the cognitive load especially the load that leads to taking the information to the long term memory.

South Africa is a country that is working hard to decrease the historical imbalances and this research looks at one area of that imbalance- gender. Historically and culturally males were more advantaged. Only since 1984 did female teacher earn the same salaries than their male counterparts. An analysis of how gender influenced the performance of learners when using computer simulations were considered.

It was not easy to find comparable schools for this research. The schools had many differences and to determine how they would perform under the same constraints determined the research strategy which was a quasi-experimental approach with intact non-equivalent groups with a switching replications design. The permission from the District Manager (see Appendix E) was not to interrupt the school. The timetable, the schedule and what was being taught was kept as is and the class memberships were static.

In order to possibly address the lack of teachers' content knowledge, low performance of learners in physical science, computer simulations were introduced. Teachers were trained to use the computer simulations to possibly support their own understanding but in a teacher-centred environment because this was the status quo. Therefore to possibly address the problem of lack of resources, overcrowded classrooms, teaching poor content knowledge, low performance of learners and gender this study determined if the use of computer simulations for cognitive load change were effective for the teaching of knowledge and skills in a topic on geometrical optics.

1.5 Rationale of the Study

My experience as a teacher of physical science for over 18 years and as a lecturer for 16 years where part of my work is to train pre-service teachers in physical science has led to this study. Many of the educators I interacted with had problems with performing experiments, and this was one of my main concerns. Teachers are very good in motivating learners to do homework and practice the physical science problems in the classroom. They do their best to teach in such a way they think the learners will understand but without doing any experiments to support concept understanding.

The ratio of girls to boys in the physical science classes is another concern, being skewed in favour of the girls. In many of the classes observed, one finds keen boys and girls.

The study looked at how the different interventions affected the male and female learners respectively.

A way around the problem was the use of computer simulations (a recent technology) as a convenient way of being more practical, hands-on in the teaching of the knowledge and skills in physical science in general.

1.6 Research Questions

The following research questions underpin the study:

What is the effect on Grade 11 learners (male/female) when the topic Geometrical Optics is taught using a teacher centred approach? The questions also posit to identify the effect in the acquisition of:

a. knowledge *with* the use of computer simulations?
b. knowledge *without* the use of computer simulations?
c. a skill with the use of computer simulations?
d. a skill without the use of computer simulations?
e. knowledge and a skill with the use of computer simulations on the cognitive load?
f. knowledge and a skill without the use of computer simulations on the cognitive load?
g. knowledge and a skill with the use of computer simulations on the speed of writing a test?
h. knowledge and a skill without the use of computer simulations on the speed of writing a test?

1.7 Significance of the Study

The importance of the study would be addressing the lack of laboratories by using one computer with a data projector in the physical science classroom. The computer simulations used were the PhET simulations which are accessible and freely available from the web (http://phet.colorado.edu/en/simulations/category/new). This exploratory study would possibly give insight to determine what the effect of these computer simulations are on one chosen topic in terms of acquisition of knowledge and a skill would be on learners (male and female) in rural South Africa by using a teacher centred approach (Klahr & Nigam, 2004) that teachers are accustomed to. The significance of the cognitive load in this study, would increase understanding with regard to what factors contribute to an increase or a decrease in the cognitive load. The subsequent effect of cognitive load on learning would also be looked at. When a skill is acquired the speed of using it would increase, would this be the case for the skill of identifying relationships among variables. This would be indicated by the research, especially with regard to the cognitive skills

1.8 Limitations

The study was limited to four schools with 105 physical science learners in Grade 11. For this reason, generalisations cannot be made because of the small sample size and the fact that only one topic of the Grade 11 physical science curriculum was considered, namely geometrical optics. Knowledge was restricted to what was prescribed in the NCS and only one process skill was considered namely, the skill of describing relationships between variables in geometrical optics since the section of geometrical optics deals a lot with variables such as the focal length, image distance, object distance, real image, virtual image, real object and virtual object. Schools in the Limpopo provinces were following Pacesetters (see Appendix C for example). The teachers had to teach specific content at a prescribed time and were not allowed to deviate. A teacher centred approach was used in this study because this was the most prevalent method among teachers and also the information processing model advocated it. Computer simulations were not used by the learners individually. It was used as demonstration tool by teachers in a teacher centred environment because this was the status quo in the Vhembe district.

1.9 Definition of Key Terms/Phrases

See List of abbreviations and glossary of terms on page 21.

1.10 Structure of the Thesis

In order to place this study in the operational, regional context of existing research and situations, the researcher for this project conducted an in-depth literature review and presented it in Chapter Two of this thesis. This is followed in Chapter Three by a description of the contextual, logistical, and prevailing conditions. A discussion of the methodological norms, rationale, and data analysis is also included. In Chapter Four, the researcher presented the analysis and results of the data for research questions 1 through 4. In Chapter Five, the researcher presented the analysis and results of data for research questions 5 through 8. Finally, in Chapter Six, the researcher summarized the findings and their significance, and offered recommendations for future research.

Chapter 2

Literature Review

2.1 Introduction

This study aims to investigate the effects of the use of computer simulations for cognitive load change in the acquisition of knowledge and skills of learners in the high school on the topic geometrical optics. To investigate what is done in the unit of geometrical optics, background is presented on what is learned and how it is taught in South African high schools and other schools in different countries. The use of computer simulations has advantages and disadvantages and is introduced in the ambit of the information processing model which guided the theoretical framework of the study. The cognitive load theory and the cognitive theory of multimedia learning is discussed and the research in the study is built on the premise of reducing the cognitive load to enable learning to take place. The study also looks at the possibilities of differential learning with regard to gender, and literature to support this is discussed.

2.2 Knowledge and Skills

A committee of universities (whose decisions are called Bloom's taxonomy) was tasked in 1956 (Krathwohl, 2002) to categorise all learning to enable consistency in assessment and evaluation in the different universities in the USA. They agreed on three general categories (domains) namely, cognitive (knowledge), psycho-motor (skills) and affective (attitudes) (Mayer, 2002; Krathwohl, 2002). They further divided these categories into hierarchies in terms of how learning increases from the basic to the most complicated. Each hierarchy builds on the foundation that precedes it and that we learn the lower hierarchies before we can effectively use the skills in the higher ones. This study considered only two of these categories namely; knowledge and skills.

Bloom's taxonomy shows the different hierarchies of thinking when learning. In Figure 3, what is indicated is the revised Bloom's Taxonomy which is not very different from the original one except for a few defining terms. The revised Bloom's taxonomy uses action verbs. Another distinct difference is the *Evaluation* hierarchy in the old taxonomy is downgraded while and *Synthesis* is upgraded and it becomes *Creating* (Krathwohl, 2002). In this thesis, the Revised Bloom's taxonomy is used with the end point of creating being the outcome of skills.

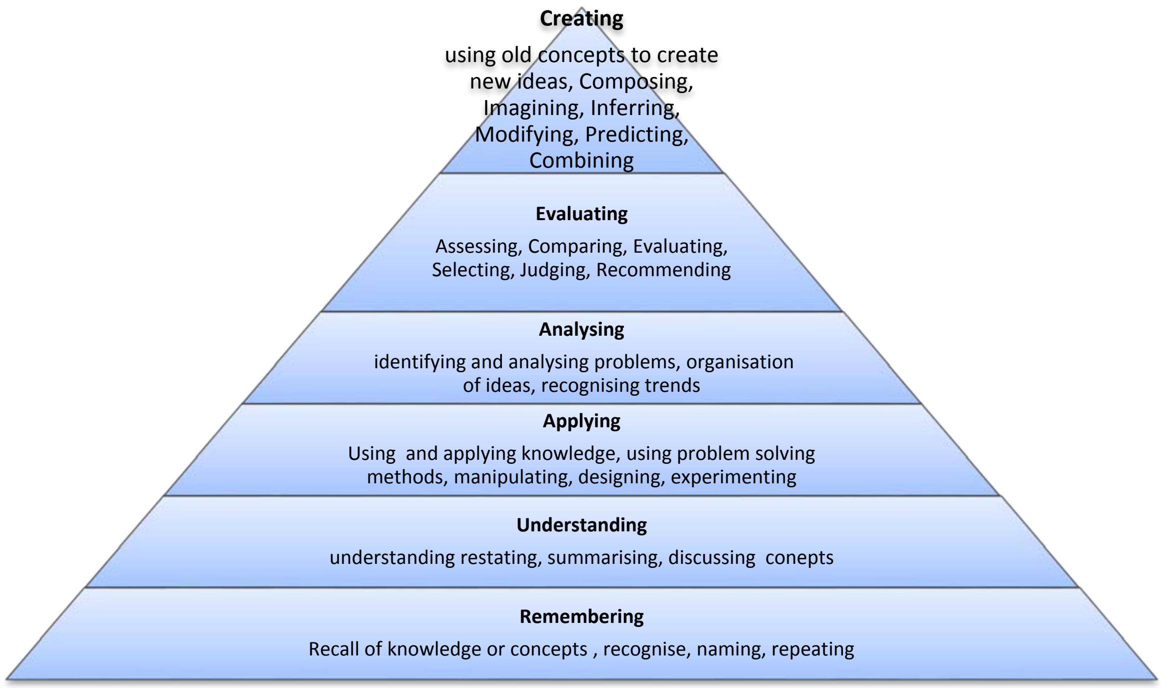

Figure 3. Revised Bloom's taxonomy Pyramid

(Adapted from (Pillai, 2013))

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2.2.1 Knowledge.

Recall of knowledge is considered to be the lowest hierarchy (or taxonomy) of the "Remember" category in the revised Bloom's taxonomy (see *Figure 3*). The different categories are understanding, applying, analysing, evaluating, and creating. The acronym

RUAAEC for the revised Bloom's taxonomy can be used. The categorisation used in the diagram is like a single step from the old to the revised Bloom's taxonomy. One can relate which parts are closely associated with what for the old and revised Bloom's taxonomy. Furthermore, in the revised Bloom's taxonomy (Krathwohl, 2002) the knowledge level is divided into several categories namely, (a) Factual (b) Conceptual (c) Procedural and (d) Metacognitive knowledge. These constitute the cognitive process dimension where they range from the lowest (remember) through to the highest (create). The procedural knowledge is closely related to the knowledge of what to use, which links very well to the process skills.

2.2.2 Skills

Science process skills, can be categorised into two broad categories namely: basic and integrated science process skills (Rambuda, 2002; Kazeni, 2005). In this section and the study, science process skills will be considered as cognitive skills and not for the physical manipulation as indicated in the revised Bloom's taxonomy (Pillai, 2013) and in the Singer et al definition (Singer, Hilton, & Scheiwngruber, 2005). Basic process skills are observing, classifying, predicting, measuring, inferring and communicating. Integrated science process skills are: identifying variables, constructing tables of data and graphs, describing relationships between variables, acquiring and processing data, analysing investigations, constructing hypotheses, operationally defining variables, designing investigations and experimenting (Rambuda, 2002; Kazeni, 2005).

There are however several other categorisations of skills. An example is Wilke and Straits' general skills "Observing, classifying, designing, drawing, writing, measuring, predicting, inferring, analysing, applying, summarising, communicating, evaluating, synthesising, creating, problem-solving etc." and scientific method skills as "Asking questions, proposing hypotheses, making predictions, designing experiments, collecting and analysing data, drawing conclusions interpreting evidence, building models, making judgments, etc.**”** (Wilke & Straits, 2005, p. 535)**.**

The science process skills by Wilke and Straits and the ones as quoted in Rambuda (2002) share commonalities. The differences lie in the general categorisations, basic and integrated as opposed to general process skills and scientific method skills. The basic and integrated termed so based on their complexity where the integrated are made up of the basic and are more complicated while Wilke and Straits categorise them in functional forms of general and scientific method and what is being done with these skills.

For this study it was decided to focus only on one of the integrated skills i.e. that of describing relationships between variables and was used in the context of geometrical optics.

2.3 Geometrical Optics

2.3.1 Definition of geometrical optics.

Geometrical optics is the study of light rays where light rays are taken to be an approximation to waves (Popescu, 2010) when the wavelength is taken to be very small compared to other lengths involved in the problem for example the size of the openings. When the opening is relatively very small then light rays are represented by straight lines. Straight lines or rays are then used in determining the types and sizes of images or objects from the light. The geometrical optics for this study was restrained to describing light as rays represented by straight lines which could bend due to different objects, like concave and convex lens being in the way. The skills side of the study was the ability to describe the relationship between variables of the type of lens, object distance and image distance as indicated in section 1.8.

2.3.2 Prescribed knowledge and skills for grade 11.

The data for this study was collected in 2011. During that time the then curriculum namely the National Curriculum Statement (NCS) prescribed the content for each subject and level. The levels are categorised into Gr R –Grade 3 as foundation; Grade 4 –6 as Intermediate; Grade 7 – 9 as Senior and Grade 10 – 12 as Further Education and Training which is abbreviated as FET. A new curriculum called Curriculum and Assessment Policy Statement (CAPS) which made its debut in 2012 for Grade 10 has been progressively implemented up the different grades, that is in 2013 it was in Grade 11 and will be examined in 2014 for the first time in Grade 12. The content of geometrical optics for CAPS which is taught in Grade 11 is limited to presenting light moving from an optical denser to optical less dense mediums and vice versa. The characteristics of different lenses and the application have been removed. This should be an oversight, since the part regarding South Africa Large Telescope (SALT) and the Sutherland Telescope programme referred to earlier made South Africa a world leader with regard to being able to peer into outer space which is synonymous with peering into history have been removed. The content knowledge for geometrical optics (GO) is prescribed in the NCS (Department of Education, 2006, p. 58) and an extract is in Appendix B. Below is a summary:

- Describe 2 types of lenses namely converging and diverging lenses
- Define optic axis, focal point and focal length
- Draw ray diagrams for both types of lenses
- Draw different ray diagrams for the different types of lenses and locate the positions of images when objects are at f, 2f, and in between the distances f and 2f.
- The eye and correcting short sightedness and long sightedness.
- Drawing ray diagrams for the formation of images in refracting and reflecting astronomical telescopes.
- Knowledge of telescopes used at Sutherland in the Western Cape.

It is emphasised that learners have to understand how converging takes place and that they should not just memorise the concept. The NCS also requires the learners to relate the properties of phenomena like gravitational "lens" as a result of gravitational fields and how they also lead to convergence and divergence of light or objects as they move in and out of our earth's atmosphere.

In general, the scope of the geometrical optics in the NCS ranges from knowing the definitions of lenses to their use in the various instruments as in telescopes, microscopes and also the human eye. It is also expected to be able to correct defects of poor eyesight using appropriate lenses. The NCS did not only apply, but also included the value of geometrical optics to the country wherein learners were expected to know the importance of the South African Large Telescope project (see section 1.3).

The skills prescribed in the National Curriculum Statement (NCS) for physical sciences are indicated in such a way that they can be used in any of the content areas. They are not restricted to specific content areas. The expected skills for the practical work are indicated and one skill "Identify and describe variables" is highlighted for the purposes of the study (see Figure 4). The general skills required are indicated and it should be noted they appear in general and details are not indicated (see Figure 5). Worth noting is the inclusion of the process skills.

Practical work	Carry out instructions to conduct an experiment. This will involve some or all of the following skills: • Collect appropriate apparatus • Assemble apparatus • Use apparatus • Identify and describe variables • Write an investigative question or hypothesis • Take measurements • Make observations • Record observations • Analyse data using graphs, calculations, etc. • Interpret results • Formulate hypotheses • Test hypotheses • Synthesise • Evaluate • Give conclusions

Figure 4. Expected skills for practical work in the NCS for grade 10.

Reprinted from (Department of Education, 2008, p. 8).

Assessment tasks should focus on the following in an integrated manner:

- **The learner's ability to use process skills, critical thinking, scientific reasoning and strategies to investigate and solve problems in a variety of scientific, technological, environmental and everyday contexts (Learning Outcome 1)**
- **The learner's demonstration of inquiry skills, like planning, observing, collecting data, comprehending, synthesising, generalising, hypothesising and communicating results and conclusions**

Figure 5. General skills suggested in the NCS.

Reprinted from (Department of Education, 2008, p. 7)

Teachers should address both knowledge and skills in their classroom using appropriate teaching approaches. The teaching approach used by the majority of teachers in South Africa is the teacher centred approach which will be considered next.

2.3.3 Studies in geometrical optics.

Studies using based on geometrical studies are considered. The first is one where practical work was considered ranging from the group performing and groups watching. Use of practical work could be where there are many watching one person doing it. It could be a learner doing the work while the rest are watching (Winkelmann & Erb, 2013). It was this type that considered its effectiveness.

In the study of the effectiveness of the small group or demonstration experiments in geometrical optics it was found that "girls are supported best by step-by-step instruction" (Winkelmann & Erb, 2013, p. 8). Where each step is explained without leaving gaps.

Another study investigated how instruction in a project changed learners' views and answers based on explanations by teachers and also how teachers taught (Leonard, Hannahoe, Nollmeyer, & Shaw, 2013). The study was in geometric optics and it used technology to determine how the answers of the learners depending on the teachers who taught them.

The above cited studies in general, indicate that working with geometric optics it can be seen that the amount of work learners perform in an interactive mode makes them understand more than when they were just demonstrated to. It was also evident that the less the interruptions with regard to what was not working created a lot of difference in their performance (Leonard, Hannahoe, Nollmeyer, & Shaw, 2013). When things proceeded smoothly the learners' understood much faster and the attitudes were better.

It would be worthy of note that geometrical optics development can be traced to Fermat and Newton. From elliptical curves to the straight lines as used in today's classes. As indicated earlier using the Popescu's (Popescu, 2010) use of rays of light to determine the paths taken. It may be a theoretical juxtaposition, but when it comes to the learning of geometrical optics, as knowledge or a skill it is important that the intended users are able to understand. This learning scenario was explored further by (Maurício, 2011) using a constructivist stance. Issues raised by Maurício include the difficult of understanding some of the concepts. The acquisition of knowledge and skills was undertaken so that insights into the hindrances could be considered.

2.4 The Teacher-Centred Approach

2.4.1 Definition of teacher-centred approach.

There is no simple definition of a teacher-centred approach as it depends on the context as well as country. In Turkey for example we have teachers giving explanations with a great reliance on textbooks and a common feature of questioning and discussion Learners are considered to be passive participants during these lessons. When experiments are performed in the teacher-centred approach they are presented by demonstration (Taşoğlu &

Bakaç, 2010). In Germany, they refer to teacher centred approach as a “talk-and-chalk type” as where learners are sitting silently and just take notes (Gürbüz & Birgin, 2012, p. 934). In the Nigerian situation, Owusu, Monney, Appiah and Wilmont (2010, p. 908) used “conventional” rather than teacher-centred, and described the characteristics as classroom lecture, discussion, and “intermittent questions and answers” (Owusu, Monney, Appiah, & Wilmont, 2010, p. 908), where the questions were from the educator and the answers from the learners.

In trying to get a common understanding of a teacher-centred approach, one could agree with the view of Lee and Tsai from Taiwan as “any face-to-face meetings or lectures without support of any computerised or internet-based learning environments” (Lee & Tsai, 2011, p. 907). The case of Lee and Tsai shows a relative advance in the use of materials and the moment the computers are included it stops being teacher-centred. It is important to note in our case, it was teacher-centred where the teacher demonstrated with a computer connected to a data projector by manipulating the computer simulations and not the learners individually. In an extension of teacher-centred, Sweller (2006) indicated that in order for the cognitive load to be decreased it was important to have direct teaching where direct instructions would be given to the learners (Kalyuga, 2010). At the heart of the teacher-centred, this narrative brings in the importance of a teacher (or instructor) to give direct instruction which would not be in the long term memory of the learners so that the learners are able to use it for what they are learning. The information directly provided reduces the cognitive load (see section 2.6.2) by readily providing the learners what they should learn, it is not about interacting or being learner centred but the information is given to and used by the learners as it is needed.

The above terms about teacher-centred approach have been considered from different authors in different countries. The common thread seems to be questions and answers mainly led by the teacher.

Close to teacher-centred is also the transmission approach to teaching and learning. Here transmission is looked as it unfolds in the research.

The transmission model is based on the belief that “knowledge is a fixed quantity that can be acquired by listening to someone more knowledgeable” (Haydey, Zakaluk, & Straw, 2010, p. 2). In this model, the learners are passive and the most active agent is the teacher. The learners listen as the knowledgeable teacher gives them the useful information. This model was used because of the characteristics of what goes on in the actual classes. The difference when it is considered in transmission is we still have the teacher centred approach but in two conditions, where in one the teacher is using computer simulations and the other there are no computer simulations.

2.4.2 Advantages of teacher-centred approach.

In many USA schools in the 1970s, learning was implied when practical work was used. The Intermediate Science Curriculum Study (ISCS programmes) was an epitome of the practical approach. Atash and Dawson, did a meta-analysis where they compared the practical approach to the teacher-centred one (Atash & Dawson, 1986). Their findings indicated that in the achievement tests, the teacher-centred group outperformed the ISCS group.

The effect of student centred and teacher centred approaches using technology mediated instruction on the different aspects of “engagement” was investigated. Wu and Huang decided to differentiate between emotional, cognitive and behavioural engagement (Wu & Huang, 2007). In other research (Rutten, van Joolingen, & van der Veen, 2012; Riess & Mischo, 2010; Duran, Gallardo, Toral, Martinez-Torres, & Barrero, 2007) it was found that in many instances teachers use technology to extend their existing practices. However, research to determine what encouraged achievement with regard to teacher-directed or student-centred computer applications instruction, it was found that the learners in the teacher directed one performed much better than those in the student centred one Chang (2003). In their study data was captured from various sources: they videotaped the whole teaching scenario, and also chose to observe 6 students from each of the two groups. They placed audio recorders on the tables they were working on so that they would capture the discussion of the learners in the course of the activity. They also used a software package called Camtasia Studio which records the screen as the students are working. The capturing of the screen enabled researchers to synchronise what the students were doing with what they were talking about as they watched or worked with simulations in this case physlets. They then used the NVivo software to analyse the expressions on the faces of the students frame by frame comparing with what they were saying and doing. The research was on the engagement of, cognitive, behavioural and emotional dimensions. Six categories were identified which they used to analyse student engagement: manipulating simulations, solving problems, making reflections, asking for help, filling out work sheets and off-task. The degree of analysis they used was based on the following categories: interacting with subject matter, the cognitive level, cognitive engagement and behavioural engagement. The analysis also looked at how the two groups performed with regard to the two teaching methods. The six students identified in the groups were from three performance levels, the high, medium and low achievers. The research also wanted to establish the performance of the different levels. The overall results show that the teacher centred group which used a data projector to work on the different simulations performed better than where the students were left to work on the simulations (student centred). When the various analyses were made, they found that the medium and high achievers greatly improved on the pre and delayed post test scores in the student centred group, however, the low achievers did not improve as much. The medium and high achievers improved by as much as 15 and 19 points in the teacher centred approach whereas the low achievers only with 7. This category interpreted as the low achievers would benefit most from the teacher's guidance other than being left on their own. Structured instruction would seem to be beneficial to the low achievers. The researchers also found out that the effect of the two instructional methods did not last long, when there was a delayed post-test they found that the gains had more or less gone down. This means that there appears to be no long term effect from their findings.

One of the strengths of teacher-centred approach, is the reliance on scaffolding. When the learner learns new information, a teacher can guide the learner by starting with what the learner already knows (Paas, Renkl, & Sweller, 2003; Paas & Sweller, 2012; van Merrienboer, Kirschner, & Kester, 2003; Vygotsky, 1986). Initially the teacher is very supportive as the learner interacts with what is to be learnt for the first time. The teacher fades out gradually and the learner is left to work on his or her own with little or no assistance at all. This is initiated and implemented by the teacher because he is more knowledgeable than the learner (van Merrienboer, Kirschner, & Kester, 2003). Linked with what has been said, the teacher is able to assess how much the learner knows and as a result operate in the zone of proximal development to increase his knowledge (Vygotsky, 1986). Where the learner is able to work in an incremental area so as to grasp what he has to learn.

The final advantage could be that the teacher-centred approach could work well within the tenets of the Information Processing Model of learning. Paas and Sweller (2012) in their paper differentiated the type of offerings to be learnt or subject or unit, they used the terms primary biological information and secondary biological information. The primary biological information is where the organism has evolved to make learning effortless and what is learnt is accommodated in the long term easily. Examples of primary biological information include face recognition, mother tongue learning. The secondary biological information is where it has to be taught. School subjects or sections thereof, for example, geometrical optics with its knowledge and skills falls in the secondary biological information category. It needs someone who knows and is able to determine at what stage information should be taught and linked. This shows that it would need guidance and it is this guidance we have referred to as teacher-centred. The learner is not simply left on her own to grapple with the new knowledge in self-discovery. The case for the teacher-centred comes in with regard to a need where someone takes charge and determines what has to be learnt and also taught.

2.4.3 Disadvantages of teacher-centred approach.

The disadvantages of teacher-centred approach stem from learners being passive while the active person is the teacher in a learning situation. Depending on the type of questions asked by the teacher, the learners can stay passive. Another disadvantage could be that the same approach is followed for each learner. No distinction is made between high and low achievers. They give the same exercise, the same work and the work is not geared to the stage of learning an individual learner is at. The learner who is ahead may then be bored with what is being taught.

One of the criticisms of teacher centred, is that it does not address the importance of open inquiry (Barrows, 1992). It does not facilitate or lead to learner's autonomous study skills, where the learners could search out for information (Trilling & Fadel, 2009). In other words the teacher is concerned with the large scale "manufacture" of the finished products that come out of the teaching process.

It is also criticised because it does not easily lead to Global workforce competencies (Farrell & Fenwick, 2007). These are competencies that are needed in the current situation in the world.

2.4.4 Challenges experienced in Vhembe district in the teaching of physical science.

In the Vhembe district, in the Limpopo Province, the supply of equipment and the provisions of laboratories are very low (NEIMS, 2009) (see section 1.2). Of the 100 schools in the province, only 2 have laboratories with equipment (NEIMS, 2009; Kaheru & Kriek, 2010). The lack of equipment for the whole class, the large enrolments in the science classes in some schools render the use of teacher led demonstration a feasible option. Sadly, this does not mean the educators are doing it. The option that is used is the talk and chalk (Gaigher, 2004).

The use of teacher centred approach is prevalent in Vhembe district. This could be for historical reasons. Educators were taught like that when they were learners and they continue doing so. It could also be due to lack of equipment as indicated in section 1.2 There are some classes that have many learners and as such it is difficult to have a learner centred approach. Though laboratories may not be available, it is possible to have a small number of equipment for demonstration.

Another limitation of teacher-centred approach in the Vhembe context is that learners do not have the opportunity to use equipment individually. Exacerbating the problem is that there are limited resources and therefore not even the teachers demonstrate the experiments.

The few institutions that would have to cultivate the habits of using of laboratory would be the tertiary training institutions. Many of these have only three years to do this, which is the time allotted to a BSc. The UNIFY programme at Limpopo University shows the effect of a catch up programme for the students who failed Mathematics and Science subjects (Mabila, Malatje, Addo-Bediako, Kazeni, & Mathabatha, 2006). The drive to perform experiments is at the tertiary level not at the high school level. This is despite the curriculum documents indicating practical work to be done (Department of Basic Education, 2010).

2.5 Computer Simulations

2.5.1 Description of computer simulations.

Computer simulations are normally used on a computer terminal as a single unit or connected to a network (Balamuralithara & Woods, 2009; Barron, Doody, Cassucio, & Henderson, 2004; Nedic, Machotka, & Nafalski, 2003). The word simulation stands for something that is supposed to be, or that is not real or actual (Carolus, 2009). The computer simulations used were interactive and could be manipulated which meant the images were not static but were able to move and also respond to the mouse or the key board movements (Aravind & Heard, 2010).

The term, animations (Carolus, 2009), is used to represent an object taking on animal-like attributes of movement and communication has been used for this study. The two terms of animations and simulations were used and applied interchangeably. An example is where an animation of the eye, telescopes was used for teaching. The animation included the application of geometrical optics in instances of the eye, telescopes and magnifying glasses. The working definition for computer simulations used in this study is use of a lap top computer with a data projector with interactive objects that could be manipulated in geometric optics. The specific package used was PhET.

2.5.2 Physics Education Technology (PhET) Project.

The PhET project based at the University of Colorado at Boulder was the simulation package used. The simulations created are in the areas of Physics, Chemistry, Biology, Earth Science and Mathematics. The simulations are freely available on the internet at the PhET website (http://phet.colorado.edu). In developing the PhET simulations (Adams et al., 2008b) 52 of the 60 simulation interviews are video-taped as a means to ensure that the on-going research ensures better simulations. Engaging students in an exploration of a simulation is possible when the students are comfortable with the simulation, leading to simulations appealing to them. The major aim of the simulations is to increase learner's engagement with the materials (Adams, et al., 2008b). Engagement may be looked at as not just manipulating but also cognitive functioning (Wu & Huang, 2007).

The PhET simulations are developed using small groups of learners where it is possible to use data from six learners to develop a simulation (Adams et al., 2008a) and this would be sufficient to make it relevant for all the others. In the development of simulations, Adams et al (2008a) pointed out the dangers of what Dweck (1987) had called *performance mode*, the feeling of a person. There is a tendency to move over simulations very fast with little or no learning taking place. This attitude makes the learners not to concentrate on the task since they think that they know it all when they do not.

2.5.3 Using computer simulations for acquisition of knowledge.

The way learners use technology can be placed into 5 different categories. They are (a) tools for the acquisition and manipulation of data, where packages like spread sheets and micro-computer based laboratories (MBL) are used (b) multimedia software (c) micro worlds and simulations which at a lower level, we have physlets, which are java-based simulations which can easily be adjusted or changed by the educators; (d) modelling tools, these are tools where the students are able to make their own simulations; and finally (e) telematics and internet tools, where the whole world is linked by communication and internet and many resources are available in real time (Esquembre, 2002).

These network resources could also link up the professionals with the novices in real space and time. Learners or novices can get world class data from the actual scientists who are producing it. Institutions of higher learning are involved in this where their lectures, academic activities are disseminated in real time to a global audience where there is a network.

The available ways people learn, the interconnectedness and the available technological interface that shape how people learn (Dunleavy, Dede, & Mitchell, 2009) are described as (a) world to the screen interface (b) multi-user virtual environment (c) augmented reality. These environments may foster learning as the learners are used to the games and screens in front of them as in (a) and also being involved in playing games of several players as in (b).

As an example of seeing what is happening in the real world, the introduction to their paper Nicholas & Ng (2009, p. 305) point out that "we live in a society where an enormous amount of information is readily and cheaply available on the Web". Nicholas and Ng quote Cavanaugh et al. (2004) wherein it is said that in 2004 there was an estimated 40 000 to 50 000 learners in the 2 400 public funded cyber-based charter schools in the USA. They continue to say that some of the programmes were text based or fully technology-mediated. The successful schools were identified as having the following qualities: (a) able to scaffold the learners, or support them as to lead to being fully autonomous to work on their own (b) awareness and following Piaget's stages of cognitive development and constructivist learning, and to build on what the learners have learnt so as to get better and finally (c) a requirement of teachers being present so as to give instructions.

It was decided that the focus would be on only two qualities namely, scaffolding and educator being present in the class. The educators' role would be to encourage participation of the learners to acquire knowledge as being active would be helpful to learning (Cavanaugh, Gillan, Kromrey, Hess, & Blomeyer, 2004). Central to learning would be scaffolding. This is when the new knowledge or skills would be presented, the educator would gradually fade and leave the learners to themselves to do the work. . It would be difficult in the conditions of the school not to have educators. In this way the disruption in the classroom was minimal.

2.5.4 Using computer simulations for skills.

Research to determine the effect of Computer simulated Experiments (CSE) and the problem solving approach on the student's chemistry achievement, science process skills, and attitudes towards chemistry at the high school level, found that CSE produced significantly greater performance in achievement and science process skills than the conventional approach Zacharia (2003) quoting Geban et al. (1992). When simulations were combined with the problem solving approach there was a significant increase in the performance. The students' attitude becoming positive after experiencing a computer simulation is quoted as researched by Chou (1998). The study of the use of Interactive Computer-based Simulations (ICBS) and Laboratory Inquiry-based Experiments (LIBE) and a combination of ICBS and LIBE was done in a natural setting of the teaching-learning environment not in an experimental research setting and Zacharia argues this adds to the validity of their findings. In Zacharia (2003), in which teachers' attitudes were important, the results indicated that the attitudes towards the use of computer simulations were low at the beginning of the study. The pre-test attitudinal score was very low, there were very few teachers who had positive attitudes towards the use of the computer simulations but the post test scores show many actually were going for the use of the combination of both computer simulations and laboratory equipment. It is important to emphasise that Zacharia was using ICBS and LIBE to refer to the computer simulations and the laboratory equipment respectively. Zacharias' findings show that after using the ICBS and LIBE in the natural classroom conditions the students or teachers' attitudes towards simulations changed so much that it indicated that the teachers would be able to use the simulations in their practice. The use of ICBS or LIBE or both as a combination improved their attitudes positively. Those who were in the group that were using ICBS were negative but after using them the teachers had a positive attitude of using them and also to use them in the teaching and learning environment.

2.5.5 Advantages of computer simulations.

The following advantages of simulations are discussed.

2.5.5.1 Visualisation.

Computer simulations are a virtual representation. It has been indicated that simulations are being developed with the feel, touch, haptic elements but in this research it is the visual that is emphasised. Learners are able to see what is happening at the level needed at both the microscopic and the macroscopic levels. The strength of visualisation is further discussed in Trundle and Bell's (2010) study where the student teachers were able to learn the moon phases much more through use of simulations as compared with the actual data.

2.5.5.2 Use of real time data in computer simulations.

Hands on teaching of science activities is emphasised (Escalada & Zollman, 1997). This is seen in the work of Brasell (1987), in which Brasell where he says "a delay of only 20 – 30 seconds in displaying the graphed data inhibited nearly all of the learning". The real-time laboratory graphing microcomputer device shows the importance of faster display of results from what had been done. This is used to show like for the simulations the graphs, visualisations are seen in almost the same time and hence the learning benefits could be the same.

2.5.5.3 Virtual laboratories.

Virtual laboratories are laboratories in the digital space which can be manipulated in real time by users either as stand-alone on a computer or on the web and are accessible 24/7. What the virtual laboratories do is to enable the learners to perform experiments on a PC or the internet. In this research computer simulations were downloaded from the web on a cd and transferred to the laptop and connected to the data projector. The educator was able to work with the learners and the class could observe the images of the simulations on the wall where it was projected.

Closely related is exemplified in a remote microscope (Barron, Doody, Cassucio, & Henderson, 2004) and a remote laboratory (Balamuralithara & Woods, 2009) . A person accesses the remote laboratory using a computer screen and is able to manipulate the chemicals or equipment, the results will also be available on the screen. Despite being far could also lead to students manipulating the equipment. As seen in the preceding paragraphs the importance of hands on would be felt. The justification for this is when learning is digitized, as in this case for computer simulations, it is difficult to differentiate simulations and the remote laboratory.

2.5.5.4 Increased conceptual understanding.

Simulations were used to guide students in a high school, aged 15 – 16 from the alternative conceptions to the real concepts in Newton’s laws (Jimoyiannis & Komis, 2001). The control group consisted of 60 students while 30 students were in the experimental group. The control group was subjected to a teacher-centred approach. The data collected through a questionnaire indicated that the experimental group had less alternative conceptions in Newton’s laws as compared to the control group.

In the use of a computer to promote conceptual change Trundle and Bell (2009) were able to show how different treatment improved conceptual understanding. They had three treatment groups which they worked on. The group consisted of 157 Early Childhood pre-service teachers who were divided into three treatment groups, one used a planetarium software the second: the software and natural observations and the third natural observations only. They found out that the Simulation group, using a software package called Starry Night™ was the most effective compared to the other two treatments in sequencing the moon phases. It must be emphasised that all the three treatment approaches led to gains in conceptual understanding.

2.5.5.5 Engagement and interaction.

Computer simulations are used in the training of deaf students and have been found to be very useful (Lang & Steely (2003). Empirical studies were done in this area and they indicated that the lack of "visual text alternatives" when viewing video or television and "the use of certain sentence constructions" (Lang & Steely, 2003, p. 278) which have been proved to be difficult especially for the deaf needs to be attended to.

2.5.5.6 Enabling quick skills development.

Computer simulations are used when there is a need to develop skills rapidly. An example is the use of a simulation for glass pressing (Shin, Guojun, & Shao, 2008). In this way it can be avoided to stop the industrial processes by using simulations to help the students to master the skills of glass pressing issues. This could be adopted for the study where what is to be learnt is put in a computer simulation then worked on practically later (Zacharia, Olympiou, & Papaevripidou, 2008; Zacharia & Olympiou, 2011).

2.5.6 Disadvantages of computer simulations.

In a criticism of computer simulations Chen (2010) points out the hypothetical-deductive model of the simulations, where simulations represent the ideal conditions. The ideal conditions are in reality conditions that do not exist at all. He gives examples of a frictionless world, where there is no oxygen on earth. He argues in order to reduce the cognitive load we may be pushing science out and make it too easy for the learners to lose sight of the actual science. He posits that simulations should have a measure of reality, a messy sort of world where the actual frustrations, non-perfect conditions are included, where it may take time to collect data. The aim being that learners get to understand the way science works other than being deceived. As we would like everyone to be scientifically literate, it is important that people appreciate what is done and how easy or difficult it is to get it or to get to it (Chen S. , 2010).

Other limitations are that whereas immersive technology may be good for visualisation (Trindade, Fiolhais, & Almeida, 2002) it is not all students who benefit. In their study it was those with high spatial aptitude that benefited. The use of technology may be helpful to some and not helpful to others.

Adolescent learners may not change their views when computer simulations are not well designed and the effect may be the opposite of what is expected (Renken & Nunez, 2013).

2.6 Information Processing Model

The Information processing Model is one of the models for use in teaching and learning and was developed in the early 1950s (Schraw & McCrudden, 2006).

2.6.1 Description of the Information Processing Model.

The Information processing model of the human learning posits that memory is made of three components namely; the sensory memory, working memory (short term memory) and the long term memory (see *Figure 6*). In the Information Processing Model, human cognition works in more or less the same way as the computer, where there is input, a central processor, a storage unit and an output unit. People have a sensory register with information from the sensory parts of the eyes, ears, nose, tongue and skin (touch) to the working memory (or short-term memory) and finally the long term memory if it is retained.

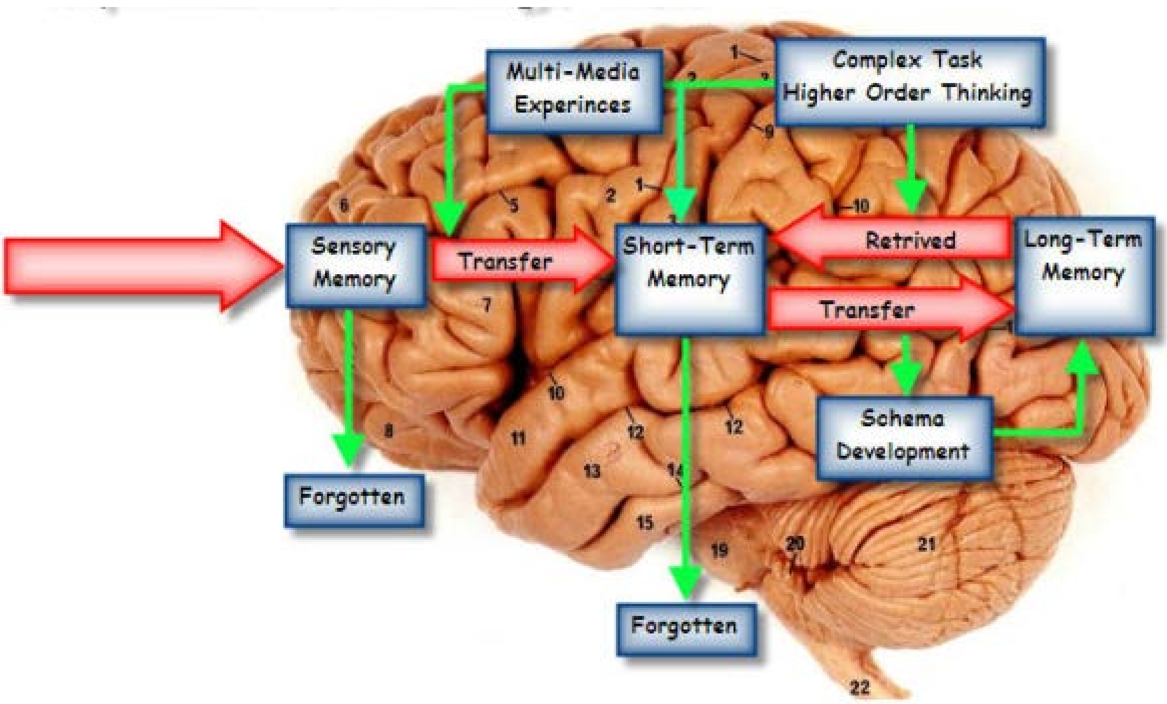

Figure 6. Information processing model.

Source: (Griffin, 2011)

2.6.2 The main elements of the Information Processing Model.

The three components of sensory, working and long term memory have different purposes, capacities and the length of the ability to retain information. The details are summarised in

Table 1.

The limitations of the sensory and working memory would seem that it is difficult to process anything. As seen in

Table 1 the capacity of the working memory is only 3 to 7 discrete units of information and is able to retain information for only 0.5 to 3 seconds. Decisions are based on the 0.5 to 3 seconds only and thereafter, what is not needed is discarded.

Table 1

A comparison of different components of memory

Source: (Schraw & McCrudden, 2006)

Type of memory	Purpose	Capacity	Duration of retention
Sensory	This screens the initial stimuli available to the sensory organs	3 - 7 discrete units	0.5 to 3 s
Working	Assigning meaning to stimuli and linking individual pieces of info to larger units. Visual and spatial mental operations can be performed.	7 – 9 units of information	5 to 15 s without rehearsing
Long term	Provides a permanent repository for different types of knowledge	Infinite	Permanent

What is passed on to the working memory is 7 – 9 units of information if not rehearsed it takes 5 to 15 seconds in the working memory. Information that goes beyond the working memory to the long term is kept forever. The existence of the long term memory explains why we remember. The information is permanently stored provided it was not discarded in the beginning before proceeding to permanent memory. Learning hinges mainly on the ability to transfer learning to long term memory after what is being learnt has been processed in the working memory (Burke, 2007). In order for one to learn, there is need for guidance (Stull & Mayer, 2007; Kirschner, Sweller, & Clark, 2006). Guidance at the beginning and eventually there should be a fading experience so that the learners start being more involved and implement a decreasing control by the educator or instructor so as learners to gradually take charge of their own learning also described as scaffolding. Therefore the information processing model can be relevant in a teacher centred approach.

2.7 Theories that were Relevant to the Study

Two theories relevant to the study are the Sweller's Cognitive Load Theory and Mayer's Cognitive Theory of Multimedia Learning. They underpin the Information processing model of learning and take as their starting point that information comes through the sensory to the working and end up in the long term. This will be dealt with in more detail in the next sections.

2.7.1 Cognitive load theory.

The Cognitive Load Theory operates within the Information processing model, and it deals with how what is learned ends up in the long term memory. It can also be referred to as Sweller's Cognitive Load Theory (CLT) (Deschri, Jones, & Hekkinen, 1997; Plass, Hommer, & Hayward, 2009; Zheng, Yang, Garcia, & McCadden, 2008). There are three types of memories (see

Table 1), however this study will concentrate mainly on the working memory and the information that proceeds to the long term memory. Sweller's CLT posits that the knowledge and skills that end up in the long term memory do so after passing through the working memory (Burke, 2007). It is important to note that not all that goes to the working memory continues to the long term memory, some is discarded. It is discarded because the working memory is limited with regard to how much information it can process at a given time. According to this theory, the learner's attention and working memory is limited. The limited attention a learner has can be directed to any of the three loads: intrinsic, germane and extraneous.

The intrinsic load is based on what is being learnt or the subject. The nature of the subject determines the intrinsic load since it is dependent on the subject matter. Different learning imposes different learning loads based on what is in it. In other words processing is where the attention is directed to with regard to learning content or the subject itself.

Germane load has to do with the deeper processing of content into existing representations which also involve organising what is learnt into what is known. The germane is the desired load for learning. The general organisation of knowledge is called schemas or chunks. A schema is where smaller units of knowledge are aggregated into a single large unit. An example could be the ease of recalling someone's mobile number as a unit. When knowledge and skills are organised in schemas they are easy to store in the long term memory. .

Extraneous load comes from the instructional material itself, what the educator uses so as to teach or deliver what is to be learnt. The examples, explanations and the different connections he uses so as to help learning constitute the extraneous load.

Learning process.

The aim of instruction and use of this theory would be, if possible, to direct all attention to the germane processing. This is where deeper learning takes place. The main purpose would be to reduce the extraneous load so that most of the memory resources are directed to the germane. The extraneous load is the load associated with the instructional material, what is being presented for the learner to learn.

In general, our processing memory or working memory is not unlimited, the little memory we have is then made in such a way that it caters for the three loads alluded to. The three loads also process issues in different ways as elaborated. In this regard, what is being learnt is the same but using different approaches, it means that there is the same intrinsic load. What will be different will be the extraneous and also the germane. When the extraneous load is reduced then we have more memory resources for the germane processing. More memory resources are then available for what will be processed or what is to be learnt.

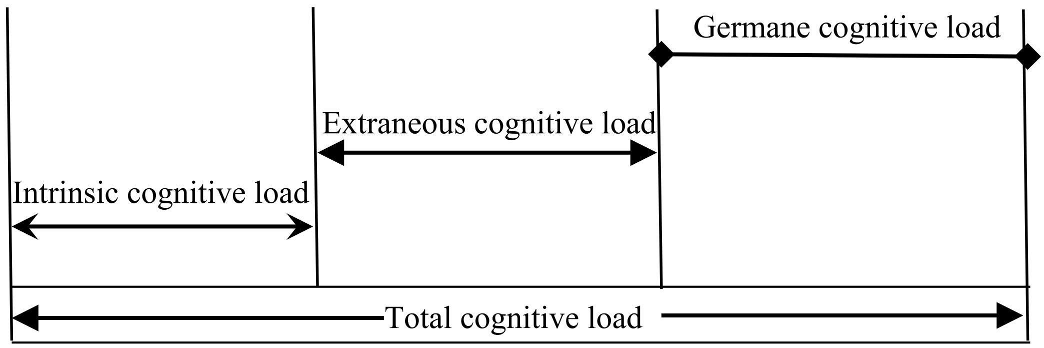

Figure 7. The working memory with the associated cognitive load.

Source: adopted from (Khalil, Paas, Johnson, & Payer, 2005)

The working memory could be compared and contrasted with the limited short term memory capacity theory. The theory posits that we have a limited short memory capacity which can only take in 7 chunks of memory segments (Miller, 1956) and more recently Cowan, reduced the number to four (Cowan, 2001). These two papers opine that short term memory has a limited storage capacity. It is this limited storage that we work with at a given time.

The importance of Sweller's CLT to this study is if something is almost totally unrelated to what the learners are working on, they may choose to work in a position where they will only process the work given to them on a superficial level. To ascertain what they have learnt it would show that it was superficial. Their current situation, the supporting instructional materials, simulations, experiments and language could add a dimension where most of the memory requirements will be taken up to handle the instruction instead of what is being learnt. If an educator does not know the context of the learners it is possible that the examples given may be unrelated to the learners, something that could then become difficult to comprehend and as such makes it even harder for the learners (Hwang, Hong, Cheng, Peng, & Wu, 2013). In this case the extraneous load increases and as it does the germane load decreases. What is being introduced should be in such a way that it does not take up the limited memory they have for learning.

2.7.2 Cognitive theory of multimedia learning.

This theory considers the cognitive processes and the use of multimedia. The cognitive theory of multimedia learning is a theory about three important processes (Muller, Sharma, & Reimann, 2008; Plass, Hommer, & Hayward, 2009; Liu, Andre, & Greenbowe, 2008). First, visual and auditory information is processed in different channels, despite there being two coding systems, that is, verbal and visual, they are independent but interconnected. Secondly, the processing power of each channel is limited, only a small part of the information can be processed at a time. Finally, learning is an active process, which involves constructing mental representations and integrating them into existing knowledge structures.

The above three processes are important to this study with regard to the limitation of the information to be processed. Not all information that is presented is always taken in or processed or understood. In other words, if what is expected to be learnt is not seen, then it could be that there was an information overload. The channels are limited hence take in limited information. Care should be taken not to overload the visual and auditory channels. Again, it is important that whatever process is being used in learning, learners should be involved since learning is an active process.

As a way of elucidation, when we get information from the media it is processed in the visual, and auditory channels. These are separate channels. They are not one and the same. These channels also are limited in capacity; they do not just absorb what is being learnt.

The CLT and the Cognitive Theory of Multimedia Learning are considered jointly, due to their relevance to the use of simulations in the classroom. In this study we are dealing with computer simulations manipulated by the teacher. Both the visual and the audio parts are dealt with. We will be using the simulations to study the effects they have on acquisition of knowledge and skills in geometrical optics. The influences the simulations have on the acquisition of knowledge and skills are very important since visual overload may lead to some parts being missed. The audio will also be in such a way that it should have impact on the acquisition of the geometrical optical knowledge and skills. The use of this theory will guide the selection of the software and also will help to decide areas where there could have been an overload.

2.7.3 The evolutionary learning theory.

In a recent learning theory, the knowledge to be processed is explained in evolutionary terms (Geary, 2008). This revised theory posits that nature has learnt how to organise learning in an efficient and effective way, in such a way that to learn certain knowledge and skills we do not have to be trained in schools or other environments. Geary explains there is biologically primary competence or biologically primary knowledge (called so by Paas & Sweller (2012). The biologically primary knowledge could be like language, which seems to be gained effortlessly and one does not need to go to school to learn how to speak. Another example given is the competence to recognise faces. Biologically secondary knowledge is the knowledge we learn in schools or from culture and is called biologically secondary knowledge. For example the mathematics or physics content, learning a second language. Geometrical optics is considered as these are biologically secondary knowledge.

The main focus to ease learning would be to try to make the biologically secondary knowledge as close to the biologically primary knowledge so that the same systems are used. Since the cognitive load of learning in the biologically primary knowledge is very low, it could be possible to align the learning to follow the low paths for the biologically secondary knowledge. This however is beyond the scope of the thesis and for the current study we will try to investigate what computer simulations do to the cognitive load.

The importance of the evolutionary learning theory in this study is the need to see that whatever simulations we use, we have to make sure they do not put a heavy load on the learner. It could also indicate that long use of certain methods like the teacher centred experiences may have brought out ways of making learning easier, if it is the case then the learner will be able to accommodate the knowledge presented to him/her easily.

The process that will be focused on in this study is to use the working memory on the germane processing since this leads to schema formation. If computer simulations is used in such a way like a picture and text at the same time, the cognitive load will be more hence all the information that the learner is receiving may not be all useful in that situation. This issue will be taken further when we consider the cognitive theory of multimedia learning in the next section.

2.8 Theoretical Framework

In the model drawn in Figure 8, is a combination of the Sweller's Cognitive Load Theory and the Cognitive Theory of Multimedia Learning and forms our theoretical framework. When learners are introduced to new knowledge or skills their working memory resources are limited and as a result they use the limited working memory to learn the available information. As they process the information, according to the Cognitive Load Theory, it will depend on interplay between the teaching approaches on instructional method (extraneous load) which will determine how much germane memory is available in the working memory to work on what they are learning. If the learner spends a lot of memory on the teaching approach and less on germane then he will process less information, form fewer schemas which will not lead to deeper understanding. This means more working memory resources have been expended on extraneous memory and hence less on the germane memory. The more the working memory is available for germane processing then the more the chances they will form schemas which will lead to the schemas going to long-term memory which has unlimited capacity.

The pictorial analogy used is a hydraulic pump which can move up and down where if it moves down it means the extraneous load increases, the extraneous is represented by the space in the upper part of the syringe while the germane load decreases, which is represented by the lower part of the syringe. For a given knowledge or skills area or section the intrinsic load represented by the part attached to the plunger remains the same (Kaheru, Mpeta, & Kriek, 2011).

The Cognitive Multimedia theory of learning has three main points for the theoretical framework. The two channels of visual and audio in which information enters are separate and independent and they are limited in terms of what information they can hold (or contain). If the instructional method, directs this visual and / or auditory channels in such a way that they lead to the germane load, learning is increased. If most of what comes in is used up by the instructional method then little learning takes place. Also, care should be taken that there is no overload of the two channels, since if an overload occurs then only a certain small part of information presented will be taken in by the germane load of the working memory. Active processing of the information is germane and it helps to form schemas. If learners are in a position to interact with the instructional material, then they are actually learning and the chance of information going to long-term memory is greater.

In the case of a teacher centred approach without the use of computer simulations, the teacher used the transmission mode, where the teacher was at the centre presenting new information in this study new knowledge and skills in geometrical optics. It was assumed that learning took place and that the mode of teaching reduced the extraneous load so as to lead to more germane load hence formation of schemas which would lead to the long term memory.

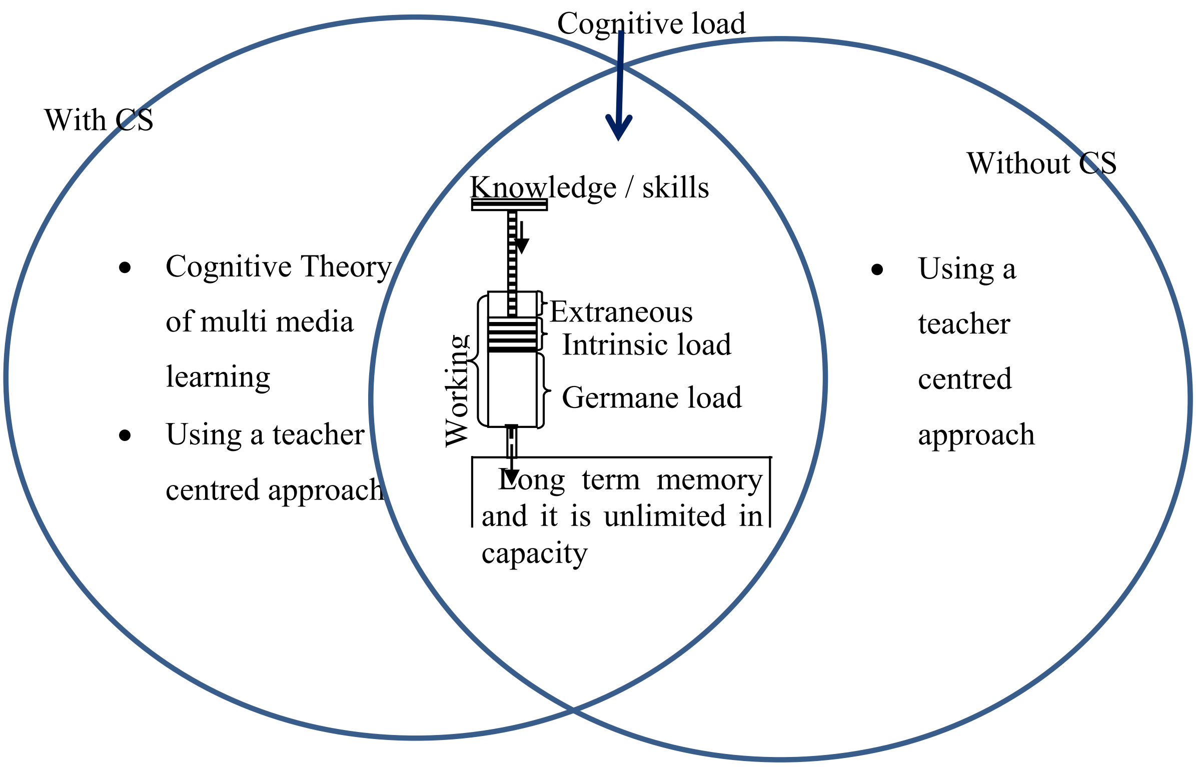

Figure 8 Information processing model of the theoretical framework based on computer simulations.

In this research, the curricula materials led to several new terms in geometric optics prescribed by the department of education. Some of the terms may have been introduced to the learners for the first time; the intrinsic load came from the content area which is geometrical optics and the skill specifically describing relationships between variables in this section. Depending on the instructional method, a teacher centred approach was used the only difference was use of computer simulations or without computer simulations. This research posited that there would be varying degrees of extraneous load and hence the limited overall working memory which would available would have varying resourcing for germane processing. Through the use of instruments to measure the cognitive load one would be able to ascertain which of the instructional methods had a greater cognitive load. A test at the end of the instructional period would be able to ascertain how much of what was learnt was able to be processed with regard to germane load and ended up in long term memory. The long term memory information could be distinguished by two things it cannot be forgotten and also the speed at which it is processed is very high.

When the learnt knowledge and skills go to the long term memory, they are easy to process. They can easily be retrieved. The process of retrieval is like automatic and hence the speed of the retrieval is fast and therefore included in a research question on measuring the speed of writing the test (see section 1.6).

2.9 Summary

Relevant literature was used to position the study. A theoretical framework has been developed from of two theories, namely the Sweller's Cognitive Load Theory and Mayer's Cognitive Theory of Multimedia Learning. The evolutionary learning theory has been added as a possible way of how nature fast tracks learning important information.

Chapter 3

Research Methodology

3.1 Introduction

This study was about teaching with and without Computer Simulations (CS) in a teacher centred environment. The study involved four schools teaching learners in Grade 11 geometrical optics in the physical science class for two weeks. Educators were trained in the use of computer simulations and how to set up the computer and the data projector. In the first week the learners of two schools were taught with computer simulations while the other two schools were taught by using the teacher centred approach only. In the subsequent week, the two schools who were using CS, started with a teacher centred approach only while the other two schools who were not using CS then switched to CS.

The study considered the effect of the use of the computer simulations on increasing or lowering the cognitive load in a teacher centred environment. This was later compared with the effect of the use of the teacher centred approach on the cognitive load without the use of CS. The study considered other issues as in effect of CS on performance based on knowledge and skills. Furthermore the influence of gender was also considered with and without using CS in a teacher centred approach.

Three research instruments used were (a) the Test of describing relationships between variables in geometrical Optics (TDRV-GO) (b) a Cognitive Load Rating Scale (CLRS) and (c) a Split- timer. In addition there was also a Focus Group protocol to collect data from the different groups of learners.

A quantitative research approach was used and the analysis was based on MANOVA, independent samples t-tests, paired samples t-tests, Mann-Whitney U test and Wilcoxon ranked tests.

3.2 Research Sample

3.2.1 Schools.

Four schools participated in the study. The schools were chosen purposively and depended on the following factors: first, schools whose students were most likely to participate until the end of the study based on their ease of acceptance or reluctance to accept the invitation to be researched. It was decided to choose the schools that responded eagerly to the call to participate especially by the principal and the educator. This was done to reduce the school or educator attrition (Kothari, 2004), which could compromise the research if educators withdrew. Secondly, the grade 12 matriculation results over a period of five years were used to determine how closely related the schools were to avoid using dysfunctional schools in the study (see Table 2). The schools selected had to have a cumulative pass rate of above 50% over the past five years. Thirdly, the schools were easily accessible to the researcher.

Uniformity of the schools should increase the internal validity. On the other hand the use of a generally uniform group would increase the generalisability (external validity) of the results (McMillan & Schumacher, 1993). The situation of the cut off entrance determined the general level of the learners involved in the study. Statistical analysis of the baseline was done to determine where the learners were if the learners in the groups were comparable at the beginning of the research.

Table 2

School Facilities Description

School	Facilities	General school environment	Average matric pass rate over five years
A	Not well supplied but had power in selected classrooms.	The school was on a feeding scheme. There was a staff room and 1 office	70
B	Had power points in the rooms, had a computer lab, BUT hardly used.	Were on a feeding programme. There was a staff room and 4 offices.	70
C	Had a science storeroom, used classroom for classes. Had a computer room with 10 -20 computers	No feeding programme. There was a staffroom and 3 offices.	60
D	Has a science laboratory but used classes for science lessons. Had a computer room with 50 -60 computers	Were not on a feeding programme. Well serviced. There was a staffroom and 15 staff offices.	95

The average grade 12 pass rate over the past five years was comparable, but not in terms of school facilities

3.2.2 Educators.

The educators in the four schools were responsible for teaching Grade 11 physical science, paper 1, the physics part of the physical science paper. The researcher for this project consulted them first to determine interest in working together in the research project, and then approached the school principals. The first consultation was informal, followed by a consultation with the principal to confirm the relationship.

Table 3

Information of Educators Who Participated in the Study

Educator	Sex	Age range	Teaching experience	Use of computer	Use of overhead projector
A	Male	20-30	1	Had own laptop	Had to be taught
B	Male	20-30	4	Had own laptop and helped school in computer related work	Had to be taught
C	Male	40^{+}	20	Had own laptop, had programming knowledge	Was used.
D	Female	31-40	10	Had a working knowledge of computers and were using them for typing tests and examinations.	Had to be taught

Educator A refers to the educator in School A as referred to in the research and same with the others as in Educator B, C and D referring to educators in schools B, C and D respectively (see Table 3).

The educators had to be introduced to simulations then trained in the use of the PhET simulations as well as how to use the data projector. It was only Educator C that used a data projector with confidence. The others had to be trained.

3.2.3 Learners.

The unit of analysis of the research was the learner and as such the population was the learners of physical science in Grade 11 in the schools in Vhembe district.

The study sample was made up of learners from the four selected schools which had single streams of physical science. This means there was only one class in the school taking physical science.

Table 4

Information of Learners

School	Male	Female	Total	1st phase used.	2nd phase used.
A	9	10	19	without CS	CS
B	11	16	27	without CS	CS
C	14	9	23	CS	without CS
D	16	19	35	CS	without CS
Total	50	54	104		

The total number of participants was 104 learners (50 male and 54 female). The distribution in the learners who participated in the study in the various schools is indicated in

Table 4.

3.3 Research Design

3.3.1 Non-equivalent group design.

A non-equivalent quasi experimental design was chosen whereby learners in four schools took part in the study (Trochim, 2006). It was chosen since the schools which participated would have to work with intact schools not part of the classes, to avoid disrupting the school systems. Learners were assigned randomly to classes the beginning of the school year. The learners participated intact and were not divided differently from what they normally were. For the purposes of the research, it was the same educators in each of the schools who taught the same classes. The number of learners was not made equal but the one provided was used. The timetable remained the same and could not be altered to address the researcher’s needs, because the learners had to follow the sequence of topics at the same time allocated as it was prescribed in the “Pace setters” (see Appendix C). The only difference was the use of computer simulations different from their normal classroom situation.

3.3.2 Switching replications design and description.

Within the non-equivalent group design a switching replications design (Trochim, 2006; Alexander & Winne, 2006) was used. By design each of the treatment groups had a control built in. The switching replications design was chosen for this study since it increased internal validity with regard to subjects that may have contact with one another, it reduced rivalry (Kothari, 2004). Each group had turns at becoming a treatment and control in the course of the study. The disadvantage of this could be that there could be a continual improvement even after the treatment would have been withdrawn (Trochim, 2006). For the purposes of this research, it was to be presumed that if a treatment was strong enough to even continue after the treatment has been withdrawn then it would mean it had a very strong effect.

N	O	X	O		O
N	O		O	X	O

Figure 9. Switching replications design for research

The N (see Figure 9) indicates that it was a non-random sampling and assigning of the groups. Schools were requested to participate and where they accepted it was decided which school would start as an experimental group and which would be in the treatment group.

The O (see Figure 9) indicates the observations made where a research instrument was used. The instruments used in this research were the Test of Describing Relationships between Variables in Geometrical Optics (TDRV-GO), cognitive load rating scale (CLRS) and split timer (see section 3.4). The significance of the O means it was the same instrument used. To further explain the top line, it can be summarised as OXOO where the three O's in the order they appear are pre-test, post-test1 and post-test2. These tests were the same.

The X (see Figure 9) indicates the use of computer simulations with a teacher centred approach during that period. Where there is just a space between the Os, it indicates that no computer simulations were used instead, it was simply a teacher centred approach.

The two lines in which the design is shown are also significant. As shown in *Figure 9*, if one considers the first arrangements in the top line of OXO and the bottom arrangement of OO it means in the first instance there is a group using computer simulations on top (treatment) and one which is not using computer simulations, the one below. Then the treatment is switched and now the top group is the control of the bottom group.

3.4 Instruments

Three data collection instruments were used for the pre-test, the first post-test and the second post-test to determine the effect of the computer simulation for cognitive load change using a teacher-centred approach. Quantitative data analysis was done by using the three instruments.

3.4.1 Test of describing relationships between variables in geometrical optics (TDRV-GO).

This instrument was developed to collect data to measure the acquisition of the learners' geometrical optics content knowledge and the skill of describing relationships among the variables. The instrument had items adapted from the following instruments: a Test of Integrated Process Skills (TIPSII) (Burns, Okey, & Wise, 1985); a Test of science process skills (TISP); and another instrument developed for the local conditions by Kazeni (2005) which also included achievement test items for geometrical optics. There were 26 items in the TDRV-GO instrument. Of the 26 items: seven questions were on knowledge and one on application and when combined they made eight for knowledge; the other 18 questions were on the skill of describing relationships between variables. It was a two-tier test, each of the items had four (4) alternate answers of which one (1) was correct and a further quality check to determine the degree of confidence the learner had in the answer chosen.

3.4.2 Cognitive Load Rating Scale.

The Cognitive Load Rating Scale was used with permission from Fred Paas from Erasmus University, Rotterdam. This is a nine item rating scale that measures how the learners perceived the mental load when performing a certain task. The scale rating is as listed below:

In solving or studying the preceding problem I invested

1. very, very low mental effort
2. very low mental effort
3. low mental effort
4. rather low mental effort
5. neither low nor high mental effort

6. rather high mental effort
7. high mental effort
8. very high mental effort
9. very, very high mental effort (Paas, 1992).

To clarify the explanations for the learners for each of the categories some explanatory comments were added as indicated below:

In studying the work we have done in the last two days I invested:

1. very, very low mental effort (I found it very very easy)

3.4.3 Split timer.

The exact time a learner took in writing the test was needed to determine the speed which could indicate that the information was stored in the long term memory and limited effort is needed by the learner to present the knowledge and skills. The time was taken with a special stop watch which was able to take split times as the learners handed in the test scripts after finishing writing. It was able to measure individual times of each and every learner who wrote the test. This "stop watch" is referred to as a digital split timer and issued with a digital split timer start button that is pressed as soon as learners started writing. In order to cater for mistakes or miss pressing of buttons there were two devices set off so that in case a wrong button was pressed there would be an appropriate, accurate reading with the other instrument.

The instrument was used in such a way that it was started when the test started and as each learner would finish the split timer would be pressed and a number would be written on the answer-sheet. The first person to finish had 1, the second 2 until the whole group had a number on the answer sheet. The number and the split times were then indicated on the answer sheets for data entry.

Figure 10. Split-timer with split times indicated

The split timer was used for the pre-test, post-test 1 and post-test 2.

3.5 Validity and Reliability of the Instruments

3.5.1 TDRV-GO.

3.5.1.1 The validity of TDRV-GO.

The items for TDRV-GO were based on the premise of the high correlation between the written test and the practical tests where it was shown that a written test could indicate the skills a learner had (Burns, Okey, & Wise, 1985; Kazeni, 2005).

The items were written out and compared with the content of the National Curriculum Statement (NCS) for physical sciences in geometrical optics. The items were sent to 2 educators one educator had 19 years of teaching experience in teaching physical science and was a Chief Examiner of physical science, the other had 22 years of teaching experience teaching physical science and was an award winner of the best Mathematics and Physical science Educator of South Africa. Furthermore, this instrument was also sent to a professor of Physics Education, a professor of Chemistry education and a lecturer of science education in 3 different tertiary institutions. They were given the curriculum and the questions and were asked to indicate suitability on a five point scale of the different items. After following their suggestions of inclusion or adjusting the questions, a 26-item question test was accepted. In a pilot test (see section 3.7) with 39 learners to check if the level of the language was appropriate as well as what was expected from the curriculum was covered. After the pilot suggestions were implemented and the instrument was adjusted to the final instrument (see Appendix Q) it was ready to be used for the study.

3.5.1.2 Reliability of TDRV-GO.

The test was paper based and had been found to be valid in the testing of the process skills. The items in this instrument had been tested for reliability in their original forms, with TIPS II (Burns, Okey, & Wise, 1985) having a reliability of 0.86; the reliability using the instrument developed by Kazeni (2005) tested in Limpopo province was 0.81 using the split-half reliability. Coupled with these, there were also questions on content knowledge from tests which were set from the common examinations which were written at the provincial level. They were incorporated in the TDRV-GO

The instrument was pilot tested (see section 3.7) and a test-retest reliability of 0.83 was established using SPSS version 19.

3.5.2 Cognitive Load Rating Scale (CLRS).

3.5.2.1 Validity of the Cognitive Load Rating Scale (CLRS).

The Cognitive Load Rating Scale (CLRS) was used with permission from Fred Paas of the Erasmus University, Rotterdam, Netherlands. In using the CLRS, Paas, Tuovinen, Tabbers, and Van Gerven (2003) and Pass and Van Merriënboer (1994) (see Appendix O) compared the instrument with the physiological measures like the one where heart beats or the observation of the pupil dilation were used in the different researches. They found that the CLRS was quite stable, meaning how a person perceived difficulty was more stable and valid to just a mere observation of the pupil dilation and the other measures. It was thus found to be valid. The CLRS was also easier and cheaper to use in this particular research situation. One was able to use it with the large group and was more appropriate than other tests, for example, the testing of the heart beat for every question answered or done.

When this instrument was administered in the schools, it was explained to the learners what the questions meant. It was emphasised to the learners that the understanding was referring to how they perceived what had been taught. The questions had to be read again to the learners in the research situation, so that it was clear what the Cognitive Load (see also Appendix P) was referring to.

3.5.2.2 Reliability of the Cognitive Load Rating Scale (CLRS).

The reliability of the CLRS was determined wherein the internal consistency of the instrument was found to be 0.90 (Paas & Van Merriënboer, 1994). The instrument has been used for over 20 studies and was found to be more consistent over a big range than use of pupil dilation and heartbeat (Paas, Tuovinen, Tabbers, & Van Gerven, 2003).

For the local situation extra explanatory phrases were added to the instrument to make it more understandable to the learners to make sure that all ambiguity is clarified.

3.5.3 Split timer.

3.5.3.1 Validity of the split timer.

The timer would be started when the learners started writing the test. It was important that all the learners who were in the class would be started off at the same time. As soon as the learner indicated that he had finished then the split timer would be stopped for that particular learner. The order in which he had finished would be written on the script. It was important that the research assistants were given the same training and the same understanding of how to take readings and use the split timer. This was done to ensure that the times written would be the same. There were practice times to check if it was done in the same way to make sure there was consistency.

Sources of not being valid would be where the learners arrive after the test had started. In order not to affect the actual times, the learner would have to have his own starting time so that the actual finishing time would be taken for the individual participant. This happened only in School A when three learners arrived after the test had started for the second post-test where each of the learners' times were taken separately.

3.5.3.2 Reliability of the split timer.

The reliability of the split timer would be the user starting it on time and also stopping it when it would be necessary. There could be sources of error with regard to the timer not being started on time and not being stopped on time. Other sources of error included (a) the users not taking the reading correctly (b) the zero error of the split timer was + - 0.0005 seconds. The systematic error be in starting late would be larger however as indicated all these were very small. Since the times being discussed were of the order of 17 minutes, the split timer readings were very reliable.

3.6 Research Procedure

Intact groups were used in the schools and they were named as A, B, C and D in order not to ensure protection of their identity.

"Pace setters" had to be adhered to as this was the prescribed content by the Province where the study was done. With this constraint, the research was mainly in two phases where in the first week school A and B were not using computer simulations and the educators were teaching as they normally did. They were told to teach in the same way as they had been doing in the previous year(s). However, one educator was teaching for the first time and had no previous experience.

The other two schools C and D used computer simulations in the first week. The simulations used were the PhET simulations on Geometrical optics which have been described in section 2.5.2. A teacher centred approach was followed with the use of CS. The same content was taught.

The TDRV-GO instrument was administered as a pre-test before the intervention and then again after week 1 as post-test 1 and finally when the second week was over the learners were given the post-test2 in the week after they were done with the second week. It was the same instrument.

The CLRS was administered twice in week 1 for each of the control and treatment groups. It was administered at the beginning of the week and at the end of the week. In the second week, the same procedure was done as in week 1 for the CLRS. The CLRS was designed in such a way that the questions asked about how the participant experienced the cognitive load, the strain on his mind with regard to what was being taught (Paas, 1992).

A general summary of the research procedure is given (see Figure 11). The Research procedure clearly indicates when the different activities were done and administered. Before the intervention, a pre-test of the TDRV-GO was administered to all learners and a split timer was also used to determine the speed they wrote the test. Both groups used a teacher centred approach and one school used computer simulations additionally.

The cognitive load was measured twice during week 1 as well as twice during the second week when the activities switched. Post-test 2 was written and was also measured.

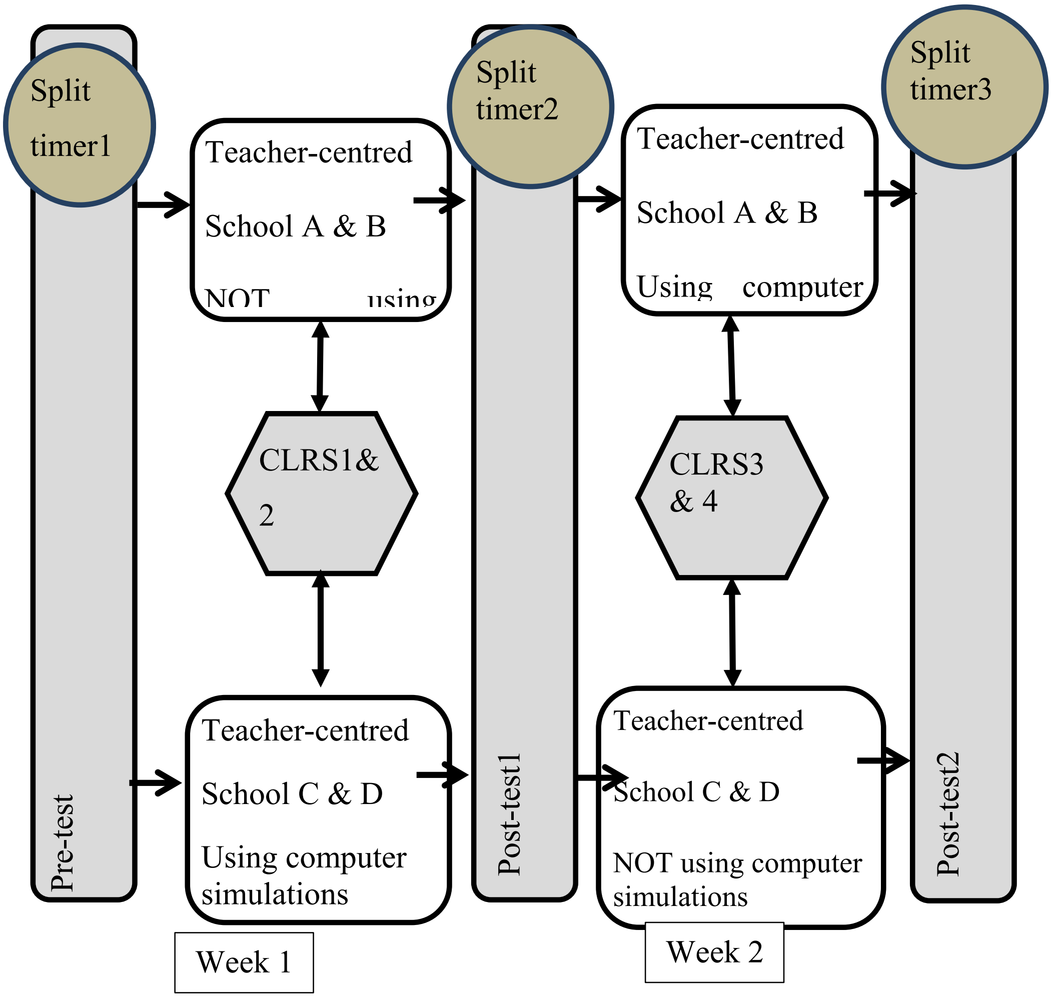

Figure 11. Research procedure.

3.7 Pilot Study

The pilot study took place in three stages.

3.7.1 Stage 1.

At this stage after the instruments had been constructed, the language of the instruments was tested by four learners to determine whether the language was appropriate. What was not clear to the learners was adjusted and put in easier sentence construction. Adjustments were made namely with regard to the question of measuring the focal length.

3.7.2 Stage 2.

A mock pilot where pre-service student teachers were introduced to the use of the PhET software was done which also included using the overhead projector. While they were using it they were observed by the researcher. The pre-service teachers were then asked to use it in a teaching demonstration in such a way that this could help in the actual training of the educators.

What was learnt from this exercise was not to take the use of the data projector for granted as the simulations were expected to be used using a data projector. This was then considered while training the educators.

3.7.3 Stage 3.

The TDRV-GO, CLRS instruments and the split-timer were tried and pilot tested in an environment akin to the study which it was going to take place. It was a tried out in a school 60 km away from where the four schools who were involved in the study were situated. The number of learners who participated was 39 in grade 11. During this pilot study, the learners were asked to sit for the pre-test and after a week they re-wrote the test. It was actually a test-retest. The school however was very keen in learning more about simulations and was visited after the research to give them opportunity to learn about all the computer simulations.

The results of the test-retest were analysed and the reliability of the test determined as seen in section 3.5.1.2. It was also helpful in determining how the split timer would be used. It also showed the ease of having groups of not more than 40 especially while using the split timer.

3.8 Ethical Considerations

Permission for ethical clearance was sought and granted from the University ethics committee for this research to be done see Appendix D

Permission was also sought and granted from the Vhembe District Manager (see Appendix E). The condition on which it was granted by the district manager was that not to interrupt the day to day “running” of the schools and to inform the circuit managers (see Appendix F). For that reason, two circuit managers were notified and they accepted and granted me access to the schools.

Permission was sought and consent was given by the following: Vhembe District Manager (Appendix E); the principals (Appendix G and Appendix H); educators involved directly with the study (Appendix I and Appendix J); parents of the learners who were younger than 18 (Appendix K and Appendix L); and learners older than 18 (Appendix M). It was not straight forward as indicated by the principal of one of the schools that most of the learners were living in child-headed families and in their invitations to the parents they get several learners coming as parents. This was a condition for one of the schools; it is for these and other learners that we hope that the outcomes of this study will make a difference. Acknowledgements were also requested from the Circuit managers, (Appendix F), to comply with the District Manager’s instruction.

3.9 Data Analysis Strategies

3.9.1 Quantitative data analysis.

The use of quantitative data analysis ensues from the use of the quantitative data collected. The data included several variables: gender, different schools (sites), performance with knowledge and skills items from the different instruments used and the cognitive load measures as well as the speed in writing the tests. The following statistical analytic tests were used: Multivariate Analysis of Variance (MANOVA); Independent t-tests; paired samples t-tests; Mann-Whitney U test and the Wilcoxon Ranked Samples test for the main analysis. Other tests were included because of the type of data which was collected such as the being worked on like Shapiro-Wilk and Kolmorogov-Smirnov tests to determine normality. The

Software Package for Social Statistics SPSS –IBM version 19 was used to analyse the data. It was also necessary to compare the effects of the interventions and t-tests used for the within groups and also for the independent samples to establish how similar the different groups used were. Effect sizes were used to determine if a particular intervention had made a difference. Effect sizes are also advocated by American Psychological Association (APA) to always be reported other than just an indication of significance or no significance (Wilkinson, L & APA Board of Scientific Affairs, 1999).

Parametric statistics.

3.9.1.1 Multivariate Analysis of Variance (MANOVA).

A multivariate analysis of variance (MANOVA) was used because there were several correlated dependent variables and it was necessary instead of performing multiple individual tests for the dependent variables. For MANOVA to be used the data had to satisfy nine assumptions (French, Macedo, Poulsen, Waterson, & Yu, 2002).

The MANOVA assumptions:

1. Two or more dependent variables (DV) had to be measured at the interval or ratio level, the completion times was taken to be ratio and also the test scores were interval.
2. The independent variable (IV) must consist of 2 or more categorical groups, the use of computer simulations and not using the computer simulations were categorical groups.
3. No participant must be in more than one group, this was satisfied as the participants were in different sites.
4. The data had to be normalised. The data was tested for normality and the condition was also met (see section 4.2.2.1 Meeting Independent Samples t-test, Paired Samples t-test and MANOVA assumptions).

5. There must be homogeneity of variances; there must be equality of the variances between the independent groups.
6. The sample size must be adequate in such a way that the numbers of cases is more than the dependent variables.
7. There must not be univariate or multivariate outliers and no univariate outliers in each group of the independent variables. Outliers are values with an unusual combination of scores.
8. There is a linear relationship between each pair of dependent variables for each group of independent variables. If they are not linearly related then the power of the test is reduced.
9. There must be no multicollinearity.

MANOVA was chosen since there were two independent variables that of using computer simulations and not using computer simulations. The dependent variables were the tests of knowledge, skills and combined, gender and the speed to write the tests.

In order to satisfy the nine assumptions of MANOVA, the following had to be done. Assumptions 1 to 3 have been adhered to as indicated above, however for 4, the test for the normality of data was used. The Shapiro-Wilk test or the Kolmogorov-Smirnov test of normality could be used. If the significance level p is greater than the 0.05 level, the alternative hypothesis can be rejected and concluded that the data comes from a normal distribution. Q-Q plots and histograms (IBM SPSS, 2011) could be used where the values could be noted and then a conclusion can be made of whether the data comes from normalised data. If the data comes from a large set the Shapiro-Wilk test may be indicated significant when it is actually not (Gordon, 1968).

In order to satisfy Assumption 5, to demonstrate if there is homogeneity of variances, so as to use the MANOVA analysis, Box's test, test of the equality of the covariance, were used. The Box test of equality of covariances checks the assumption of homogeneity of covariance across the groups using $p < 0,001$ as criteria. If p is greater than 0,001 then the alternative hypothesis is rejected and the condition of the homogeneity of the variances is upheld. When $p > 0.001$ we could also use Wilk's Lambda to interpret the significance and also the effect size using eta squared. On the other hand if $p < 0.001$ it would mean that the condition of homogeneity and normalization is not upheld and we could use Pillai's Trace Test which is very "robust and not linked to assumptions about normality of the distribution of data" . These particular Box Test cases are discussed in Chapter 4 (see Table 4).

In order to satisfy Assumption 6, the data case was made up of 105 cases which was an adequate sample size.

Assumption 7 indicates that there must not be univariate or multivariate outliers. In order to determine whether data has outliers, it is important to use box plots or the leaf (Sejwal, Jangra, & Sangwan, 2012; Identifying and Addressing Outliers; IBM SPSS, 2011). A Mahalanobis distance measure could also be used and by using the SPSS measure to determine this. There were no outliers.

To satisfy Assumption 8 a scatter plot diagram was used to determine whether there was a linear relationship between each pair of dependent variables for each group of independent variables. Measures included the use of SPSS package wherein the relationships were indicated and assessed. The scatter plot diagram plotted all the points so that the relationship would be ascertained if indeed it is linear.

The final assumption was Assumption 9, where there had to be no multicollinearity in the dependent variables (Gordon, 1968; O'Brien, 2007). The SPSS uses an iterative process where all the dependent variables are checked for one by one to determine if there was any multicollinearity. If the Variance Inflation Factor (VIF) was high—10.20 or more, this could indicate that there was multicollinearity of the data. There are "rules of thumb" (O'Brien, 2007, p. 674), which may or may not give the threshold of where multicollinearity could start. Low VIF at levels as low as 3, could indicate that there was no multicollinearity.

These nine Assumptions could be met and the MANOVA could be used in the analysis of the data.

3.9.1.2 Independent Samples t-test.

The independent samples t-test is used for determining whether two samples are similar or not. The means of the two samples is used to determine whether there is a significant difference between the two and looks at possible scenarios where the variances between the samples are equal or not. This test was used to determine whether the means in the tests of the learners in the first week that used the computer simulations and those who did not were the same. This was important for the study as it was necessary to determine if a change took place as a result of the intervention (see section 4.2). The Independent samples t-test was also used to test the different levels of performance at the time when the learners had written Test 2 (Posttest1), that is, the groups Without CS and the With CS and also the final Test 3 (Post-test 2) for the same conditions as in Test 2.

The independent samples t-test uses the Levene's test to determine where the variances of the samples are equal and depending on whether they were equal or not it would go to test whether the means of the samples were equal or not. The test works on a null hypothesis that the variances are equal and if the difference is significant it means the variances are not equal, however the Levene's test offers two positions where the variances are equal and also where the variances are not equal. If Levene's test is significant it means the second position is taken. And the Independent t-test also tests for the means. A null hypothesis is also taken for the difference in the means of the samples; if the case for the means is significant then it means the samples are different. The Independent Samples t-test was used to determine if the means for the different positions of intervention or no intervention were different.

3.9.1.3 Paired Samples Student t-test.

The paired samples t-test is used to determine the relationships between the same sample under different conditions. This could be done in instances where there is need to ascertain whether there are differences from the baseline conditions after the use of an intervention (IBM SPSS, 2011).

The paired samples t-test uses the assumption of a null hypothesis where if there is a significant difference then the intervention created the difference. If there is not a significant difference it means the intervention did not make a difference.

In this study, the paired samples test was used to determine the differences in terms of knowledge, skills and combined from Test 1 to Test 2 and also Test 2 to Test 3. The independent samples test was also used to determine whether there were differences in the performances of the learners in terms of gender.

This paired samples t-test was also used to determine the effect of computer simulations on the speed of writing the test, the differences in the speed for the different administrations of the tests (see Section 4.2).

3.9.1.4 Effect size - Cohen's d

Cohen's d based on the means was used to determine the effect size for the independent samples t-test and the paired samples t-test. The formula is:

$$\frac{\bar{x}_1 - \bar{x}_2}{\sqrt{S_p^2}}$$

Where S_p is the pooled variance of the two samples, given as:

$$\frac{(n_1 - 1)S_1^2 + (n_2 - 1)S_2^2}{(n_1 + n_2 - 2)}$$

To guide with the interpretation of the effect size, Cohen suggested three effects namely a small, medium or large. He also indicated that it should be taken with caution, that different subject areas' effect sizes could be interpreted differently (Cohen, 1988). The following were used as a guide for the analysis (Cohen, 1994; Cohen, 1988):

- 0.2 a small effect;
- 0.5 a medium effect and
- 0.8 a large effect,

A practical explanation of the effect sizes is given by Hattie as "To give what the effect sizes mean practically, an effect size of d = 1.0 indicates an increase of one standard deviation… A one standard deviation increase is typically associated with advancing children's achievement by two to three years, improving the rate of learning by 50%, or a correlations between some variable (e.g. amount of homework) and achievement of approximately r = 0.50. When implementing a new program, an effect size of 1.0 would mean that, on average, students receiving that treatment would exceed 84% of students not receiving that treatment." (Hattie J. A., 2009, p. 8)

Hattie (2003) analysed studies that had already been conducted and the corresponding effect sizes. The graph is adapted and presented in Figure 12.

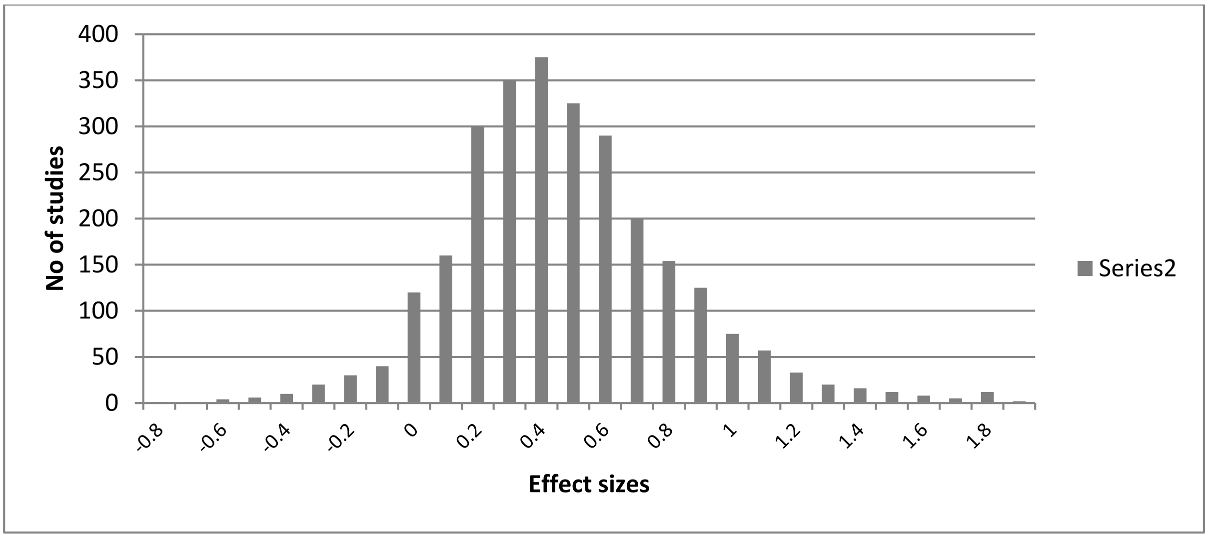

Figure 12. Graph showing interventions and effect size.

Adapted from (Hattie, 2003).

Non-parametric statistics.

The Mann-Whitney U test is the non-parametric equivalent of the parametric Independent Samples t-test (Field, 2009). And the Wilcoxon Signed Ranks Test is the non-parametric equivalent of the parametric paired samples t-test.

3.9.1.5Mann-Whitney and Wilcoxon Signed-Ranks test.

The Mann-Whitney U test is done when a normal distribution does not apply to the data or even the data does not have the properties of an equal interval scale. In the Cognitive Load Rating Scale (CLRS) what was used was that a load of 9 is more than 8. It does not mean that the interval scales are equal. The Mann-Whitney U test ranks the data points and the analysis is based on the median. The statistics dealt with include the p value where if p is small, one can reject idea that the difference is due to chance and conclude that the populations have different medians (Field, 2009). If the p value is large it would mean that the data does not give us any reason to have a different conclusion that the medians differ.

The conditions of use of the Wilcoxon are the same as the ones given for the Mann-Whitney U test in the previous paragraph. The Wilcoxon Signed Ranks Test ranks all the values of the combined samples and ranks all of them from 1. Where there are several values which are equal they take on the average of their values and when added they should equal the numbers that would have been assigned them had they not been equal. Consider the value 35, 35, 35, 35 as standing for the 20^{th}, 21^{st}, 22^{nd} and the 23^{rd} ranks or positions. The ranks are added and the average is the rank of each one of them. In this case each would be 21.5. The analysis which is done then leads to the determination of the significance or not of the findings.

Both tests were used to compare the effect of the intervention (CS) in a teacher centred approach from Test 1 to Test 2 and also Test 2 to Test 3 for the different conditions. The effect on the acquisition of skills, knowledge and both knowledge and skills were tested. It was also used to ascertain the effect of the intervention on gender. A comparison was made with regard to whether the CS affected the cognitive loads.

3.9.1.6 Effect size: Non parametric statistics: Mann-Whitney and Wilcoxon Signed-Ranks test.

The effect size of the Mann-Whitney and Wilcoxon Signed-Ranks test can be calculated by considering $r = \frac{z}{\sqrt{N}}$. Where z is the z-score and N is the number of the learners in our case involved in that particular calculation. The effect size may be considered under the following guidelines if r = 0.1 it is small; r = 0.3 it is medium and r = 0.5 it is a large effect size (Field, 2009, pp. 539-583).

3.10 Summary

In this chapter, the researcher for this project described the research and the research design. In so doing, the researcher presented the validity and reliability of all the instruments.

Summarized the research procedure in a figure, discussed ethical considerations and the three stages of the pilot study, and offered the quantitative data analysis strategies.

Chapter 4

Data and Analysis for Knowledge and Skills Items

4.1 Introduction

This study was on cognitive load change in the acquisition of knowledge and skills. Knowledge as defined and described in chapter 2 in sections 2.2.1 and 2.3.2 and one process skill that of defining relationships between variables as discussed in chapter 2 (see section 2.2.2). Cognitive load is defined as the amount of memory space used (See Fig 6 in Chapter 2) when trying to learn a curriculum unit or a skill. When the cognitive load is high it means a lot of memory space is taken up, if less then little. The aim of this research was to make use of interactive computer simulations to reduce the cognitive load, (see section 2.7.2).

Four schools were identified (see section 3.3.1) for the study. To determine the baseline and before any intervention all learners were subjected to a pre-test (see Table 5). In the first week, 2 schools were taught using computer simulations in a teacher centred environment while the other 2 schools were taught in the same way as they had been doing in the previous year(s) (teacher centred). After this week, all learners wrote post test1 (see Table 5). In the second week the learners who previously were being taught without computer simulations now received treatment by using computer simulations and the group taught with computer simulations were now taught in the same way as in previous years. They then had to write post-test2 (see Table 5). All three tests were exactly the same (see Appendix Q).

This study followed a switching replications design within a non-equivalent quasi experimental design (see Section 3.2.2). Data was collected quantitatively by using three instruments namely a Test of Describing Relationships between Variables – Geometrical Optics (TDRV-GO) (see section 3.4.1); and the CLRS (see section 3.4.2), as well as a split timer (see section 3.4.3).

Table 5

Abbreviated Names of Tests in Analysis Tables

Pre-test 1	Post-test1	Post-test2
Pre-test -Test1	Post-test1 Test2	Post-test2 –Test3
Pre-test knowledge -Test1K	Post-test1 knowledge - Test2K	Post-test2 knowledge- Test3K
Pre-test skills -Test1S	Post-test1 skills -Test2S	Post-test2 skills Test3S

With computer simulations	– With CS
Without computer simulations-	Without CS

The research questions 1 to 4 (see section 1.6) were investigated in this chapter.

The presentation and analysis of data in this section considers the effect on Grade 11 learners' performance in the TDRV_GO test in terms of gender (male/female) when the topic geometrical optics is taught using a teacher centred approach in the acquisition of:

RQ1 Knowledge *with* the use of computer simulations?

RQ2 Knowledge *without* the use of computer simulations?

RQ3 Skills *with* the use of computer simulations?

RQ4 Skills *without* the use of computer simulations?

The researcher analysed the extent to which the use of CS or lack of CS contributed to the acquisition of the content knowledge in geometrical optics. Also the use of CS or lack of use of CS was analysed and how it contributed or not contributed to the acquisition of the skill of describing relationships among variables.

4.2 Quantitative Presentation and Analysis of Data

4.2.1 Meeting Independent Samples t-test, Paired Samples t- test and MANOVA assumptions.

In this section the researcher discusses some of the pre-analysis issues since the three tests mentioned above are used for the analysis. As discussed in Section 3.9.1, to avoid erroneous conclusions as a result of some of the assumptions not being met, this section analyses what was done to show the appropriate corrective measures taken. Where certain assumptions were not met, there were other measures taken into consideration so that the conclusions made were valid and consistent with what was observed. This section summarises these issues with regard to the data collected.

1. *Two or more dependent variables being measured at the interval or ratio level-* the test result for knowledge, skills and cognitive load was at interval level and it was continuous. While the time it took to write the test was at the ratio level.
2. *The independent variable was expected to consist of two or more categorical independent groups*. Gender consists of two independent variables namely male and female; the intervention also consists of two independent variables namely the use of computer simulations and not using computer simulations; and the schools in some analytical situations were looked at as two entities however there were cases where they were looked at as four.
3. *No participant must be in more than one group*. There should be an independence of observations. The researcher addressed this because the participants in each of the groups were unique and the learners were confined in their respective sites of research.
4. *The sample size must be adequate in such a way that the numbers of cases is more than the dependent variables*. The number of cases or participants in each group

was greater than the dependent variables. Our sample size had a total of 105 participants. Not one of the groups had less than 19 participants and therefore this condition was satisfied.

5. *There were no univariate or multivariate outliers.* With regard to the big groups of With CS and Without CS this was satisfied. There were no univariate outliers all the data fitted within (see the Box plots in Figure 13).

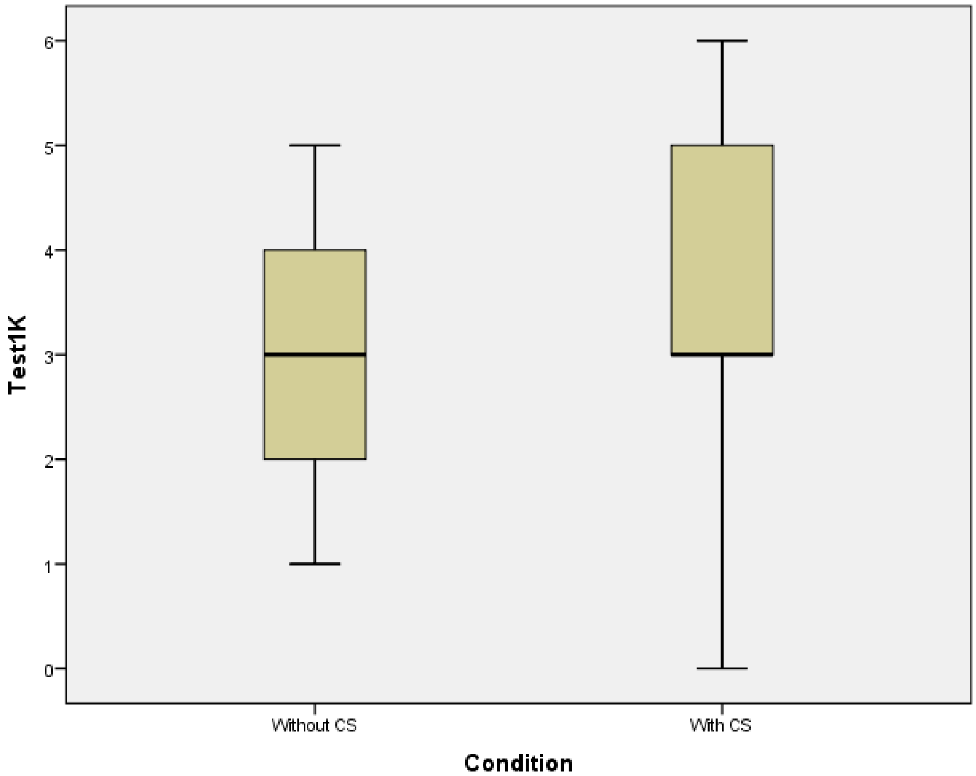

Figure 13 Box plot for knowledge items With CS and Without CS

6. *The data had to be normalised.* This condition is difficult to prove though it could be done by the Shapiro-Wilk test of normality. After analysing the data, the Shapiro Wilk test of normality where $\alpha = .001$ (Meyers, Gamst, & Guarino, 2006; Powell, 2007) see Table 6 this shows that the four groups (of With CS and Without CS for the conditions of knowledge and skills) were normally

distributed, since the p values were less than 0.05 and as such the condition was satisfied. This concurs that the bigger the sample the greater it tends to approximate a normal distribution (Jushan & Serena, 2005).

Table 6

Results of the Shapiro-Wilk Test of Normality

Group description	Shapiro-Wilk for α = 0.001 p values
Without CS knowledge items	.033
With CS knowledge items	.004
Without CS skills items	.02
With CS skills items	.03

Ghasemi and Zahediasl (2012, p. 486) stated that when there are “large enough sample sizes (>30 or 40), the violation of the normality assumption should not cause major problems” (p. 486). They also stated that “in large samples (>30 or 40), the sampling distribution tend to be normal…. we can look for normality visually by using normal plots” (p. 486). This is also supported by Altman & Bland (1995) who showed that at times a sample from a normal distribution may not look normal but by inspection can ascertain if it is or not.

7. There is a linear relationship between each pair of dependent variables for each group of the independent variables. The scatter plot matrices would show this.

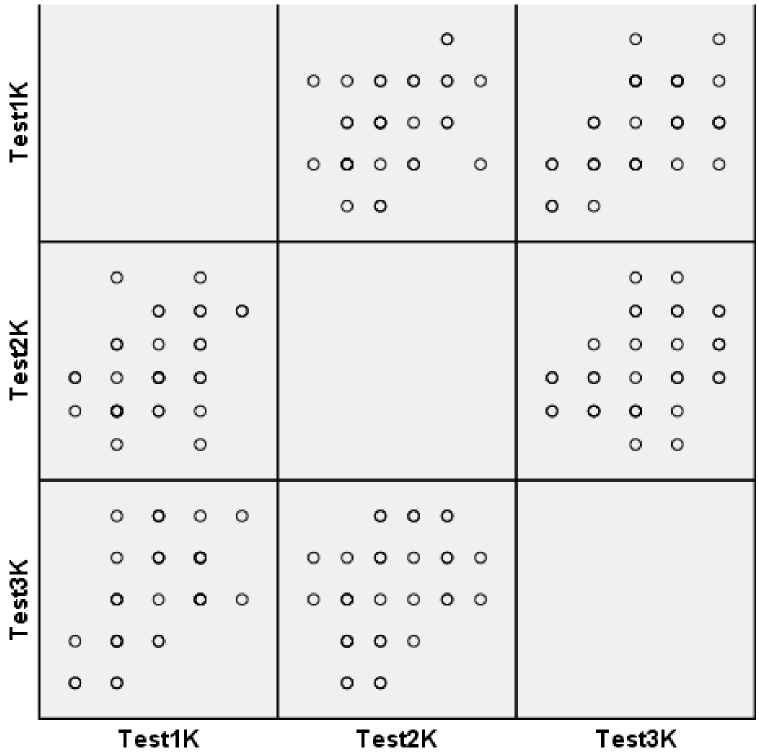

Figure 14. Scatter plot matrix for the Test1K, Test2K and Test3K knowledge items for the group without CS.

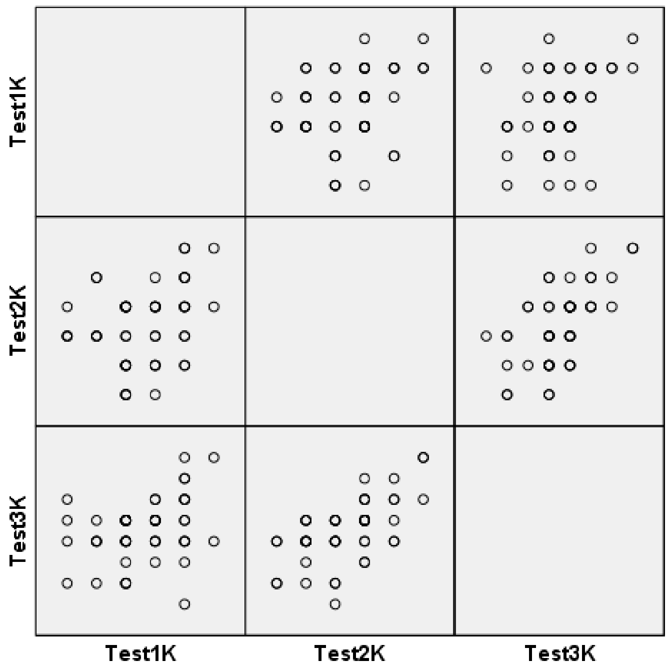

Figure 15 Scatter plot matrix for Test1K, Test2K and Test3K knowledge items for the group with CS.

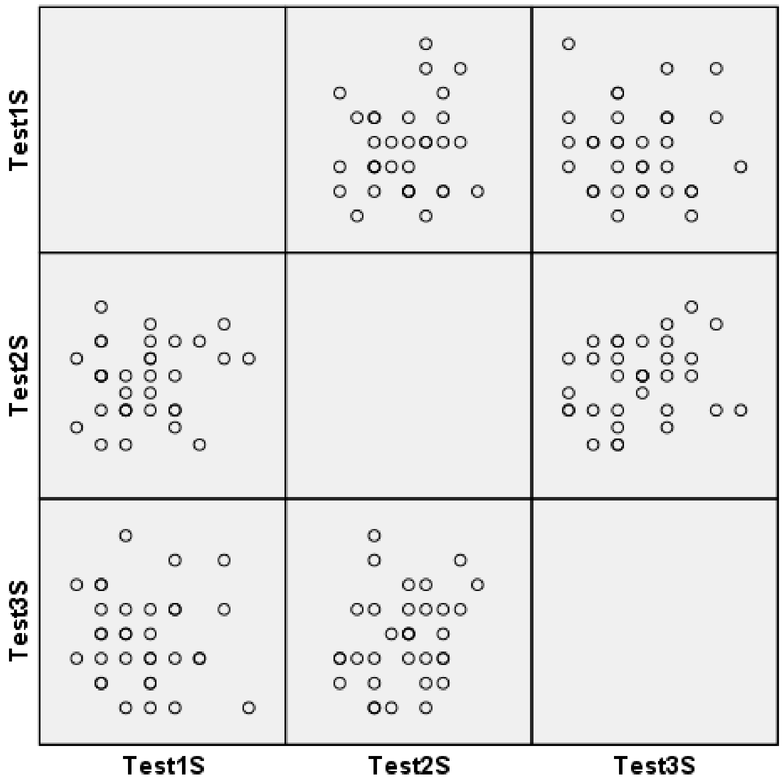

Figure 16 Test1S, Test2S and Test3S for skills items for the group without CS.

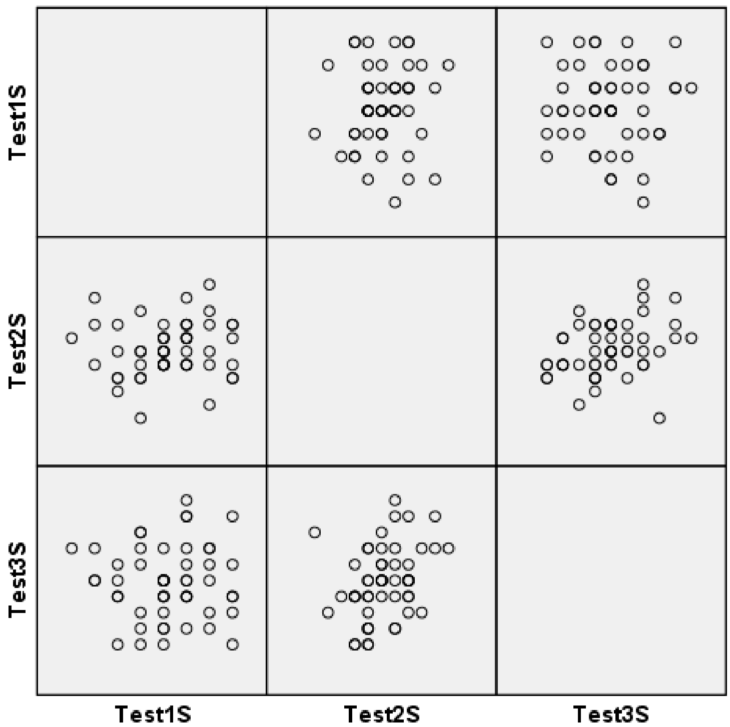

Figure 17 Test1S, Test2S and Test3S for skills items for the group with CS.

8. *There must be homogeneity of variances; there must be equality of the variances between the independent groups.* There is homogeneity of variance – covariance matrices as indicated by the Box's M test of equality of variances. This is shown in Table 7 and Table 9.

Table 7

Subject Factors for TDRV-GO Knowledge Items

		Value Label	N
Condition	1	Without CS	33
	2	With CS	54

The descriptive statistics with test marks and descriptions are shown see Table 8. The maximum mark for knowledge items in the test was 8 where application of the knowledge was added as an item. When the mean is 3.9 it means it is 3.9 out of 8.

Table 8

Descriptive Statistics for the TDRV-GO Knowledge Items

	Condition	Mean	Std. Deviation	N
Test1K	Without CS	2.91	1.100	33
	With CS	3.52	1.356	54

	Condition	Mean	Std. Deviation	N
	Total	3.29	1.293	87
Test2K	Without CS	3.30	1.380	33
	With CS	4.37	1.293	54
	Total	3.97	1.418	87
Test3K	Without CS	3.18	1.286	33
	With CS	4.52	1.437	54
	Total	4.01	1.521	87

In order to use the multivariate analysis the condition for homogeneity of covariance must be satisfied. This condition will be satisfied when "sig" is more than 0.001 ($p > 0.001$). After analysis it is .22 ($p = .22$) (see Table 9).

Table 9

Box's Test of Equality of Covariance Matrices[a]

Box's M	8.68
F	1.39
df1	6
df2	30313.52
Sig.	.22

a. Design: Intercept + Condition

The assumption of homogeneity is not violated so the use of multivariate analysis would be appropriate. To check the homogeneity of variances, see Table 9. It is noted that since the significance was greater than 0.05 it implies the condition of homogeneity, one of the nine assumptions, was also fulfilled.

9. *There is no multi-collinearity* due to the fact that the level of Variance Inflation Factor (VIF) has a threshold of 3 in order to indicate if there is multi-collinearity. In this study the values were ranging from 1.05 to 1.55 (See Table 10). These values are low when compared to the 5 as suggested as threshold (O'Brien, 2007; Gordon, 1968). O'Brien (2007) discussed literature wherein a VIF of 10 would indicate serious cases of multi-collinearity. A higher VIF would indicate a large degree of correlation with other variables wherein it would not really be necessary to have those variables together (De Mars, 2011). In our study since all our variables were independent we did not have cases of multi-collinearity. Tests for multi-collinearity indicated that a very low level of multi-collinearity was present see Table 10. The results were an indication that the multi-collinearity condition was met.

Table 10

Variance Inflation Factors for Post-Test1, Post-Test2 for Knowledge and Skills

Condition	Variance inflation factor
Post-test1 knowledge	1.50
Post-test 2 knowledge	1.55
Post-test1 skills	1.05
Post-test2 skills	1.29

The nine conditions as indicated above were satisfied and this meant the multivariate analysis of variance (MANOVA) (see section 3.9.1 and 5.2.2.1); independent t-tests (see 4.2.3.1, 4.2.3.2, and 4.2.3.3 among the many instances) and paired samples t-tests (see 4.2.4.1 (a), 4.2.4.1 (c), and 4.2.4.2 (b) among the many instances) could be used.

4.2.2 Baseline conditions.

It was important to establish whether the two groups that we had from the four schools were similar in terms of knowledge and skills in Geometrical Optics. The four schools were randomly assigned to two groups. One group was chosen to be treated with computer simulations (With CS) and the other group assigned to not receiving any treatment and therefore was without computer simulations (Without CS) during the first week. In order to establish whether the two groups were the same, an independent samples t-test as well as the Levene's test were used. The independent samples t- test was used to establish similarity of the means while Levene's test was to indicate whether the variance was homogeneous or not. The pre-test scores for the two groups for both knowledge and skills items in the TDRV-GO was compared (see 4.2.3.1). One single test (TDRV-GO) was used and comprised of items on (a) knowledge (b) skills and (c) knowledge and skills combined (see Appendix Q, Appendix R, Appendix S and Appendix T). Analysis of the data in this test is presented in the same sequence.

4.2.2.1 Data and analysis of knowledge items of Test 1.

Independent samples t-test.

An independent samples t-test was conducted to compare the knowledge items of the TDRV-GO for the group Without CS and with the group With CS for the Test 1 situation. There was no significant difference ($p > .05$) in the scores for the group Without CS (M = 2.95; SD = 1.25) and the group With CS in the first week (M = 3.43; SD = 1.37) (see

Appendix BB) conditions t(99) = -1.8, *p* = .08, (see Table 11) and d = 0.36 (small effect section 4.2.2.7).

Levene's test assumes the null hypothesis of the homogeneity of variances. The null hypothesis in this case is that the variance between the two samples is equal. After analysis the Levene's test indicated equality of variances *p* = .4 (see Table 11). These results indicate that the two groups Without CS and With CS were not significantly different before the intervention started with regard to the knowledge items and were therefore comparable.

Table 11
Levene's and Independent Samples test for knowledge items in Test 1

		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
Test1K	Equal variances assumed	0.71	.40	-1.80	99.00	.08	-0.48	0.27	-1.00	0.05
	Equal variances not assumed			-1.82	94.52	.07	-0.48	0.26	-1.00	0.04

It was important to establish if the two groups comprising of four different schools were comparable because there were some differences in terms of the facilities at the schools (see section 3.2.1). According to the independent t-test and the Levene's test these groups were comparable with regard to the knowledge items, and it was decided to compare the skills and both knowledge and skills combined of the two groups.

4.2.2.2 Data and analysis of skills items of Test 1.

Independent samples t-test.

An independent samples t-test was also used to analyse the skills items of the TDRV-GO. It was noted that there was no significant differences ($p > .05$) between the two groups (See Appendix CC and Table 12), Without CS (*M* = 5.86, *SD* =1.89) and With CS (*M* = 6.09, *SD* =1.80) conditions t(99) = -0.61, *p* = .54 (see Table 12) and d = 0.13 (small effect see section 4.2.2.7).

Levene's test indicated equality of variances, *p* = .82 (see Table 12).

Table 12

Levene's Test and Independent Samples Test for Skills Items in Test 1.

		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
Test1S	Equal variances assumed	.06	.82	-0.61	99.00	.54	-0.23	0.37	-0.96	0.51
	Equal variances not assumed			-0.61	88.26	.55	-0.23	0.37	-0.97	0.51

The independent samples t-test and Levene's test indicated that the means were not significantly different, that is to say they were the same with regard to the performance on the skills items in the test and therefore it was assumed that the two groups were at the same level in terms of skills.

4.2.2.3 Data and analysis of knowledge and skills items of Test 1.

Independent samples t-test.

Given that the homogeneity of variance by the Levene's test, F(1, 97) = 0.012, p = .91 (see Table 13) was upheld, a test assuming equality of variances was calculated. The result of this test indicated that there was no significant difference in the scores t(99) = -1.44 and p = .15, and d = 0.29 (section 4.2.4.7). These results suggest that the conditions were the same; those in the group Without CS (*M =8.81; S.D. =2.54*) and those in the group With CS (*M =9.52; S.D. = 2.36*) (see Appendix DD). It was therefore a homogeneous group.

Table 13

Levene's Test and Independent Samples Test for All items for Test 1

		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
Test1	Equal variances assumed	.01	.91	-1.44	99.00	.15	-0.70	0.49	-1.68	0.27
	Equal variances not assumed			-1.42	86.74	.16	-0.70	0.50	-1.69	0.28

After the analysis of the data it could be concluded that for all the three related cases there was no significant difference in the groups and this could be taken to indicate that when the computer simulation interventions were started it could show that the two groups were at a similar baseline and therefore at the same level. Given that the two groups consisted of four schools, it can be taken to be the same from the analysis.

4.2.2.4 Data and analysis of knowledge items based on gender of Test 1.

Independent samples t-test.

Given that the homogeneity of variance by the Levene's test, $F(1, 47) = 0.38$, $p = .54$ ($p > .05$) was upheld for the male learners, a test assuming equality of variances was calculated (see Table 14). The result of this test indicated that there was no significant difference in the means $t(47) = -1.27$ and $p = .21$ (see Table 14) and $d = 0.36$ (small effect see section 4.2.4.7). These results suggest that the male learners in the group Without CS (M =3.09, SD =1.27) and in the group With CS (M = 3.59, SD = 1.45) conditions were the same (see Appendix EE). The independent t-test for the equality of means indicates that the difference in the means was not significant, given their respective standard deviations and $p = .21$. There was a higher mean for the group With CS which as indicated already was not significantly different from that of the Without CS. This indicates that there was no difference in the two groups of males before teaching started in the section of geometric optics.

Table 14

Levene's Test and t-Test for Equality of Means for Test 1 in Knowledge Items for Gender

		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
Male	Equal variances assumed	0.38	.54	-1.27	47	.21	-0.50	0.39	-1.29	0.29
	Equal variances not assumed			-1.29	46.72	.20	-0.50	0.39	-1.28	0.28
Female	Equal variances assumed	0.06	.81	-1.33	50	.19	-0.48	0.36	-1.21	0.25
	Equal variances not assumed			-1.34	44.14	.19	-0.48	0.36	-1.20	0.24

For the female learners given that the homogeneity of variance by the Levene's test, F(1, 50) = 0.06, *p* = .81 (p > .05) was upheld, and a test assuming equality of variances was calculated (see Table 14). The result of this test (see Table 14) indicated that there was no significant difference in the means t(50) = -1.33 and p = .19 and d = 0.38 (small effect section 4.2.4.7). These results suggest that the female learners in the group Without CS (*M* =2.81, *SD* =1.25) and group With CS (*M* = 3.29, *SD* = 1.30) conditions were the same (see Appendix EE). The independent t-test for the equality of means indicates that the difference in the means was not significant, given their respective deviations and p = .19. There was a higher mean for the group With CS which as indicated was not significantly different from that of the Without CS. This indicates that there was no difference in the two groups of females before teaching started in the section of geometric optics.

4.2.2.5 Data and analysis of skills items based on gender of Test 1.

Independent samples t-test.

Given that the homogeneity of variance by the Levene's test, $F(1, 47) = 2.10$, $p = .15$ ($p > .05$) was upheld for the male learners, a test assuming equality of variances was calculated (see Table 15). The result of this test indicated that there was no significant difference in the scores $t(47) = -1.19$ and $p = .24$ and $d = 0.34$ (small effect see section 4.2.4.7). These results suggest that the male learners in the group Without CS ($M = 6.09$, $SD = 2.02$) and the group With CS ($M = 6.67$, $SD = 1.36$) conditions were the same (see Appendix FF). It is indicated that there was no difference in the two groups of males learners before teaching started.

Table 15

Levene's Test and t-Test for Equality of Means for Skills in Test 1 Based on Gender

		Levene's Test for Equality of Variances		t-test for Equality of Means						
						Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
		F	Sig.	t	df				Lower	Upper
Male	Equal variances assumed	2.10	.15	-1.19	47	.24	-0.58	0.49	-1.55	0.40
	Equal variances not assumed			-1.14	35.4	.26	-0.58	0.50	-1.60	0.45
Female	Equal variances assumed	1.73	.20	0.07	50	.94	0.04	0.54	-1.04	1.12
	Equal variances not assumed			0.07	46.7	.94	0.04	0.52	-1.01	1.09

For the female learners that the homogeneity of variance by the Levene's test, F(1, 50) = 1.73, p = .20 ($p > .05$) was upheld, and a test assuming equality of variances was calculated (see Table 15). The result of this test indicated that there was no significant difference in the scores t(50) = 0.07 and p = .94 and d = 0.02 (very small effect see section 4.2.4.7). These results suggest that the female learners in the group Without CS (M = 5.62, *SD* =1.75) and group With CS (*M* = 5.58, *SD* = 2.00) conditions were the same (see Appendix FF). This indicates that there was no difference in the two groups of females before teaching started with regard to skills in geometric optics.

4.2.2.6 Analysis of knowledge and skills items based on gender of Test 1.

Independent samples t-test.

Given that the homogeneity of variance by the Levene's test, F(1, 47) = 4.57, p = .04 ($p < .05$) wasnot upheld for the male learners, a test assuming unequal variances was calculated (see Table 16). The result of this test indicated that there was no significant difference in the means t(35) = -1.60 and p = .12 and d = 0.54 (medium effect' see section 4.2.4.7). These results suggest that the male learners in the group Without CS (M = 9.18, *SD* =2.72) and in the group With CS (*M* = 10.26, *SD* = 1.77) conditions were the same (see Appendix GG).

Table 16

Levene's Test and t-Test for Equality of Means for Test 1 Based on Gender

		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	T	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference Lower	Upper
Male	Equal variances assumed	4.57	.04	-1.67	47	.10	-1.08	0.64	-2.37	0.22
	Equal variances not assumed			-1.60	34.6	.12	-1.08	0.67	-2.44	0.29
Female	Equal variances assumed	0.77	.38	-0.62	50	.54	-0.44	0.71	-1.87	0.99
	Equal variances not assumed			-0.64	46.3	.53	-0.44	0.70	-1.84	0.96

For the female learners that the homogeneity of variance by the Levene's test, F(1, 50) = 0.77, *p* = .38 (p > .05) was upheld, and a test assuming equality of variances was calculated (see Table 16). The result of this test indicated that there was no significant difference in the means t(50) = -0.62 and p = .54 and d = 0.17 (small effect; see section 4.2.4.7). These results suggest that the female learners in the group Without CS (M = 8.43, *SD* = 2.34) and group With CS (*M* = 8.87, *SD* = 2.63) conditions were the same (see Appendix GG). This indicates that there was no difference in the two groups of females before teaching started with regard to knowledge and skills in geometric optics.

4.2.2.7 Effect sizes.

Cohen's d effect sizes: 0.2 – small effect; 0.5 - medium effect; 0.8 large effect (Cohen, 1973; Cohen, 1990).

The effect sizes were calculated based on how section 4.2.4 was arranged:

1. Cohen's d for knowledge items using the independent samples test:

   Cohen's d = 0.36 where the With CS is higher than Without CS; this is a small effect for the Test1K.

2. Cohen's d for skills items using the independent samples test:

   Cohen's d for Without CS and With CS for Test1S = 0.13, a small effect.

3. Cohen's d for both knowledge and skills items, the independent samples test:

   Cohen's d = 0.29 using Test1, a small effect.

4. Cohen's d for the effects when gender is a factor.

Table 17

Cohen's d for the Independent t-Tests for Test 1 When Gender is a Factor

Condition	Cohen's d	Direction of effect	Size of effect
Male Without CS Male With CS	0.36	Increasing	small
Female Without CS Female With CS	0.38	Increasing	small
Skills items for independent t-test			
Condition	Cohen's d	Direction of effect	Size of effect
Male Without CS Male With CS	0.34	Increasing	small
Female Without CS Female With CS	0.02	Decreasing	Very small
Both knowledge and skills for independent t-test			
Condition	Cohen's d	Direction of effect	Size of effect
Male Without CS Male With CS	0.54	Increasing	medium
Female Without CS& Female With CS	0.17	Increasing	small

4.2.2.8 Summary of Test 1.

The purpose of the analysis of Test 1 was to determine if the two groups (4 schools) were at the same level in terms of knowledge, skills and gender. The independent samples t-tests used was to indicate that the two groups those Without CS and With CS do not significantly differ at the start of the intervention.

4.2.3 Data and analysis for Research Questions 1 and 2 on knowledge items for groups Without CS and With CS.

The data analysis that follows used the independent samples t- test and the paired samples t -test for the knowledge items for the two conditions were the groups were using computer simulations (With CS) and Without CS. Analysis also involved gender where male and female performances were reviewed and analysed separately.

Research questions 1 and 2.

To show whether there was an effect on Grade 11 learners' performance in the TDRV_GO test in terms of knowledge an independent samples t- test was used to compare the two conditions (of With CS and Without CS) for Test 1K, Test2K and Test3K. An independent samples test with regard to gender was also used for the knowledge items for these tests. After the independent samples t- test a paired samples t- test was used to determine the change from the initial condition of Test1K to Test2K. This was repeated for both male and female. A further paired samples test was used for Test2K and Test3K and also repeated to compare the gender.

A summary of the statistical tests used for analysing the knowledge aspect of the instrument is indicated in this section and summarised in Table 18. The table represents independent samples t- test and the paired samples t- test, as well as the effect size (see section 4.2.2.7).

Table 18

Statistical Tests and Test Instruments Used in Section 4.2.3

Statistical tests	Knowledge (K) aspect instrument (Section)	Skills (S) aspect instrument (Section)
4.2.3.1Independent samples t-test for Test 2	(a) Test2K (4.2.3.1(a) (b) Test 2K (m/f)†(4.2.3.1 (b))	Test2S (4.2.4.1 (a)) Test 2S (m/f) †(4.2.4.1 (b))
4.2.3.2 Independent samples t-test for Test 3	(a) Test3K (4.2.3.2 (a)) (b) Test 3K (m/f) †(4.2.3.2(b))	Test3S (4.2.4.2 (a)) Test3S(m/f) †(4.2.4.2 (b)
4.2.3.3 Paired Samples t-test	Test1K :Test2K (4.2.3.3 (a)) Test2K:Test3K (4.2.3.3 (b))	Test1S -Test2S (4.2.4.3 (a)) Test2S:Test3S (4.2.4.3 (b))
4.2.3.3 Paired Samples t-test	Test1K:Test2K (m/f) †(4.2.3.3(c)) Male group Without CS Male group With CS Female group Without CS Female group With CS Test2K:Test3K (m/f) † (4.2.3.3 (d)) Male group Without CS Male group With CS Female group Without CS Female group With CS	Test1S:Test2S (m/f) †(4.2.4.3(c)) Male group Without CS Male group With CS Female group Without CS Female group With CS Test2S:Test3S (m/f) † (4.2.4.3 (d)) Male group Without CS Male group With CS Female group Without CS Female group With CS
4.2.3.4 Effect size, Cohen's d	(a) Test 2K: With CS and Without CS (b) Test 2K: With CS and Without CS (m/f) (c) Test 3K: With CS and Without CS (d) Test 3K: With CS and Without CS (m/f) (e) Test1K:Test2K Without CS (f) Test 1K: Test2K With CS Etc. for other paired tests including m/f†	(a) Test 2S: With CS and Without CS (b) Test 2S: With CS and Without CS (m/f) (c) Test 3S: With CS and Without CS (d) Test 3S: With CS and Without CS (m/f) (e) Test1S:Test2S Without CS (f) Test1S: Test2S With CS Etc. for other paired tests including m/f C

†male and female

All the statistical tests and the various instruments used for the knowledge effect on the geometric optics with regard to Test 1 have been summarized in Table 18. This could help in a summary of what was used.

4.2.3.1 Data and analysis of knowledge items for the groups With CS and Without CS of Test 2K.

(a) Independent samples t-test for Test2K.

Given that the homogeneity of variance by the Levene's test, F(1, 101) = 3.25, p = .07 (p > .05) was upheld, a test assuming equality of variances was calculated (see Table 19). The result of this test indicated that there was a significant difference in the scores t(101) = -3.45; p = .001 (see Table 19) and d = 0.68 (medium effect see section 4.2.2.7). These results suggest that those learners in the groups Without CS (*M* =3.35, *SD* =1.57) and With CS (*M* = 4.32, *SD* = 1.28) conditions were significantly different (see Appendix HH). A difference in the two groups was indicated after the intervention. It is important to note the Levene's test for Test1 had indicated that the two groups had the equality of variance.

Table 19

Levene's Test and t-Test for Equality of Means for Test 2K in Knowledge Items

		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
Test2K	Equal variances assumed	3.25	.07	-3.45	101	.00	-0.97	0.28	-1.53	-0.41
	Equal variances not assumed			-3.38	86.57	.00	-0.97	0.29	-1.54	-0.40

(b) Independent samples t-test based on gender for Test2K.

Given that the homogeneity of variance by the Levene's test, F(1, 48) = 2.25, *p* = .14 (p > .05) was upheld for the male learners, a test assuming equality of variances was calculated (see Table 20). The result of this test indicated that there was no significant difference in the scores t(48) = -1.00 and p = .32 (see Table 20) and d = 0.28 (small effect see section 4.2.2.7). These results suggest that the male learners in the group Without CS (*M =4.00, SD =1.51*) and in the group With CS (*M* = 4.37, *SD* = 1.12) conditions were not significantly different (see Appendix II).

Table 20

Levene's Test and t-Test for Equality of Means for Test2K for Knowledge Based on Gender

		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
Male	Equal variances assumed	2.25	.14	-1.00	48	.32	-.37	.37	-1.12	.38
	Equal variances not assumed			-.97	39.93	.34	-.37	.38	-1.14	.40
Female	Equal variances assumed	.32	.57	-4.03	51	.00	-1.57	.39	-2.35	-.79
	Equal variances not assumed			-4.06	48.66	.00	-1.57	.39	-2.35	-.79

For the female learners, since the homogeneity of variance by the Levene's test, F(1, 51 = 0.32, *p* = .57 (p > .05) was upheld, a test assuming equality of variances was calculated.

The result of this test (see Table 20) indicated that there was a significant difference in the scores t(51) = -4.03 and p = .00 and d = 1.12 (large effect see section 4.2.2.7). These results suggest that the female learners in the group Without CS (*M* = 2.70, *SD* =1.36) and group With CS (*M* = 4.27, *SD* = 1.44) conditions were significantly different (see Appendix II). It was indicated that there was a big difference in the two groups of females in Test2K for the Without CS and With CS. In both groups despite their having been no differences in the groups before the intervention the groups that started with the CS (With CS) performed much better than the group Without CS.

4.2.3.2 Data and analysis of knowledge items With CS and Without CS of Test3K.

(a) Independent samples t-test for Test3K.

Given that the homogeneity of variance by the Levene's test, F(1, 88) = 0.040, *p* = .84 (p > .05) was upheld, a test assuming equality of variances was calculated (see Table 21). The result of this test indicated that there was a significant difference in the scores t(88) = -4.24, p = .000 (p < .001) (see Table 21) and d = 0.92 a large effect see section 4.2.2.7. These results suggest that those in the group Without CS (*M* = 3.23, *SD* =1.35) and With CS (*M* = 4.51, *SD* = 1.43) conditions were significantly different (see Appendix JJ). It is indicated that there was a difference in the two groups after the teaching using the computer simulations compared to the group Without CS. In an earlier analysis (of Test 2) the group With CS also outperformed the group Without CS. What makes this different was the fact that the Without CS were using CS while the With CS were not using CS.

Table 21

Levene's Test and t-Test for Equality of Means for Test3 in Knowledge Items

		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
Test3K	Equal variances assumed	0.04	.84	-4.24	88	.000	-1.28	0.30	-1.88	-0.68
	Equal variances not assumed			-4.29	75.4	.000	-1.28	0.30	-1.88	-0.69

(b) Independent samples t-test based on gender for Test3K.

Given that the homogeneity of variance by the Levene's test, F(1, 41) = 0.16, *p* = .69 (p > .05) was upheld for the male learners, a test assuming equality of variances was calculated. The result of this test indicated that there was a significant difference in the scores t(41) = -2.79 and p = .01, (see Table 22) and d = 0.87 (large effect see section 4.2.2.7). These results suggest that the male learners in the group Without CS (*M =3.06, SD =1.30*) and in the group With CS (*M* = 4.31, *SD* = 1.52) conditions were significantly different (see Appendix KK). There was a higher mean for the male learners in the group With CS. It is indicated that there was a significant difference between the males in the two groups.

Table 22

Levene's Test and t-Test for Equality of Means for Test3K for Knowledge Items Based on Gender

		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
Male	Equal variances assumed	.16	.69	-2.79	41	.01	-1.25	.45	-2.15	-.35
	Equal variances not assumed			-2.88	37.97	.01	-1.25	.43	-2.13	-.37
Female	Equal variances assumed	.21	.65	-3.16	45	.003	-1.30	.41	-2.13	-.47
	Equal variances not assumed			-3.12	34.56	.004	-1.30	.42	-2.15	-.45

For the female learners since the homogeneity of variance by the Levene's test, $F(1, 45) = 0.21$, $p = .65$ ($p > .05$) was upheld, a test assuming equality of variances was calculated (see Table 22. The result of this test (see Table 22) indicated that there was a significant difference in the scores $t(45) = -3.16$ and $p = .003$ and $d = 0.95$ (large effect see section 4.2.2.7). These results suggest that the female learners in the group Without CS (*M* = 3.39, *SD* =1.42) and group With CS (*M* = 4.69, *SD* = 1.34) conditions were significantly different (see Appendix KK). The effect size, Cohen's d = 0.95 was large. It is indicated that there was a big difference in the two groups of females in Test3K.

Summary

Both genders did benefit in terms of acquisition of knowledge, using CS, however the female learners outperformed their male counterparts. The female learners improved more than the male learners as indicated by the greater effect sizes see sections section 4.2.3.2 (b)

4.2.3.3 Paired samples t-test for Tests.

(a) Paired samples t-test for Test1K and Test2K.

Group Without CS.

To determine if there was a change in the performance from Test1K to Test2K a paired samples t-test was used for those learners without CS (see Table 23). There was a significant difference in the scores for the group Without CS Test1K ($M = 2.95, SD = 1.25$) (see Appendix LL) and the Without CS Test2K ($M = 3.51$, $SD = 1.47$) conditions; $t(42) = -2.61$, $p = .013$ ($p < .05$) (see Table 23) and d = 0.45 (small effect see section 4.2.2.7). The results show that there is a difference in the test scores on knowledge using a teacher centred approach without CS.

Group With CS.

The paired samples t-test compared the performance on Test1K to Test 2K for the group With CS (see Table 23). There was a significant difference in the scores for the group With CS Test1K ($M = 3.47$, $SD = 1.34$) (see Appendix LL) and the group With CS Test2K ($M = 4.32$, $SD = 1.28$) conditions; $t(56) = -4.18$, $p = .000$ ($p < .001$) and d = 0.65 (medium effect see 4.2.2.7).

Table 23

Paired Samples t-Test of Test1K and Test2K

Condition			Paired Differences							
						95% Confidence Interval of the Difference				
			Mean	Std. Deviation	Std. Error Mean	Lower	Upper	T	df	Sig. (2-tailed)
Without CS	Pair 1	Test1K - Test2K	-0.56	1.40	0.21	-0.99	-0.13	-2.61	42	.013
With CS	Pair 1	Test1K - Test2K	-0.84	1.52	0.20	-1.25	-0.44	-4.18	56	.000

(b) Paired samples t-test for Test2K and Test3K.

Group Without CS.

In order to determine if there is a specific change in the performance with regard to the test on knowledge from the performance from Test2K to Test3K a paired samples t- test was done. The paired samples t-test compared the performance on Test2K and Test3K for the group Without CS. There was no significant difference in the scores for the group Without CS in Test2K (*M* = 3.14, *SD* = 1.50) (see Appendix MM) and in Test3K (*M* = 3.23, *SD* = 1.35) conditions; t(34) = -0.28, *p* = .78 (2-tailed) (*p* > .05*) (see* Table 24*)* and d = 0.063 *(*small effect see section 4.2.2.7).

Table 24

Paired Samples t-Test of Test2K and Test3K

Condition			Paired Differences							
			Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference		t	Df	Sig. (2-tailed)
						Lower	Upper			
Without CS	Pair 1	Test2K – Test3K	-0.09	1.79	0.30	-0.70	0.53	-0.28	34	.78
With CS	Pair 1	Test2K – Test3K	-0.15	1.20	0.16	-0.48	0.18	-0.90	53	.37

Group With CS.

The paired samples t-test compared the performance on Test2K for the group With CS and the Test3K. There was no significant difference in the scores for the With CS Test2K (*M* = 4.37, *SD* = 1.29) (see Appendix MM) and the With CS Test3K (*M* = 4.52, *SD* = 1.44) conditions; t(53) = -0.90, *p* = .37(2-tailed) (*p* > .05) (*see* Table 24) and d = 0.11 (small effect see section 4.2.2.7). These findings indicate that not using simulations did not significantly improve the performance on the TDRV-GO items for the learners from Test2K to Test3K. Although there was no improvement in the means, there is a small Cohen's d

(c) Paired samples t-test for Test1K and Test2K based on gender.

The paired samples t-test compared the performance on Test1K to Test 2K for the group Without CS when the gender was considered separately.

Male group Without CS.

There was a significant difference in the scores for the male group Without CS Test1K: (*M = 3.09, SD = 1.27*) (see Appendix NN) and the group Test2K (*M* = 4.09, *SD* = 1.48) conditions;

t(21) = -3.17, *p* = .005 (*p* < .05) (*see* Table 25*)* and d = 0.72 medium effect see section 4.2.2.7). These findings indicate that for male participants not using CS improved their performance on the TDRV-GO items for the learners.

Male group With CS.

There was a significant difference in the scores for the With CS Test1K for males: (*M* = 3.59, *SD* = 1.45) (see Appendix NN) and the With CS Test2K males (*M* = 4.37, *SD* = 1.12) conditions; t(26) = -3.08, *p* = .005 (*p* < .01) (*see*Table 25) and d = 0.60 medium effect see section 4.2.2.7). The male learners with CS and without CS had a medium effect although the mean of the learners using CS was higher in Test2K

Female group Without CS.

The paired samples t-test compared the performance of females on Test1K to Test2K Without CS. There was a not significant difference in the scores for the group Without CS Test1K for females: (*M* = 2.81, *SD* = 1.25) (see Appendix NN) and the group Without CS Test2K females (*M* = 2.90, *SD* = 1.22) conditions; t(20) = -0.37, *p* = .72 (*p* > .05) (*see* Table 25*)* and d = 0.07 small effect see section 4.2.2.7). Although there was a small change in median which would be expected, these findings indicate that the effect was small without CS on their performance on the TDRV-GO items for the learners.

Female group with CS.

The paired samples t-test compared the performance of females on Test1K to Test2K for the group With CS. There was a significant difference in the scores for the females With CS Test1K: (*M* = 3.37, *SD* = 1.25) (see Appendix NN) compared to Test2K (*M* = 4.27, *SD* = 1.44) conditions; t(29) = -0.90, *p* = .007 (*p* < .05) (*see* Table 25*)* and d = 0.67 medium effect see section 4.2.2.7). These findings indicate that use of computer simulations for female participants significantly improved their performance on the TDRV-GO items. The difference in performance is greater for the female learners when using CS. The change was more significant when using CS compared to not using the CS.

Table 25

Paired Sample t-Test for Test1K and Test2K for Male and Female

Condition	Gender			Paired Differences							
				Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference Lower	Upper	t	df	Sig. (2-tailed)
Without CS	Male	Pair 1	Test1K - Test2K	-1.00	1.48	0.32	-1.66	-0.34	-3.17	21	.005
	Female	Pair 1	Test1K - Test2K	-0.10	1.18	0.26	-0.63	0.44	-0.37	20	.72
With CS	Male	Pair 1	Test1K - Test2K	-0.78	1.31	0.25	-1.30	-0.26	-3.08	26	.005
	Female	Pair 1	Test1K - Test2K	-0.90	1.71	0.31	-1.54	-0.26	-2.88	29	.007

(d) Paired samples t-test for Test2K and Test3K based on gender.

In order to determine if there was a specific change in the performance with regard to the test on knowledge from the performance from Test2K to Test3K a paired samples t- test was done.

Male group Without CS.

The paired samples t-test compared the performance of males in group Without CS on Test2K with Test3K Without CS. There was not a significant difference in the scores for the males Without CS Test2K: (M = 3.76, SD = 1.48) (see Appendix OO) and the Without CS Test3K (M = 3.06, SD = 1.30) conditions; t(16) = 1.90, p = .08 (2 tailed) ($p > .05$) (*see* Table

26*)* and d = 0.50 medium effect see section 4.2.2.7)). This was a switch where the Without CS used CS in this week. These findings indicate that use of CS for male participants did not significantly improve their performance on the TDRV-GO knowledge items in fact their performance decreased.

Male group With CS.

The paired samples t-test compared the performance of males on Test2K With CS and the Test3K With CS. There was no significant difference in the scores for the males With CS Test2K: (M = 4.38, SD = 1.13) (see Appendix OO) and Test3K (M = 4.31, SD = 1.52); t(25) = 0.31, p = .76 ($p > .05$) (*see* Table 26) and d = 0.05 (very small effect see section 4.2.2.7).

These findings indicate that not using CS for male participants decreased their performance on the TDRV-GO knowledge items for the learners. When CS was used the effect size was medium for the Without CS group and not using CS led to a very small effect size which also was not significant. This supports the consistency which is developing of the superiority of the CS.

Female group Without CS.

The paired samples t-test compared the performance of females on Test2K to Test3K Without CS. There was a not significant difference in the scores for the females Without CS Test2K: (M = 2.56, SD = 1.30) (see Appendix OO) compared to Test3K (M = 3.39, SD = 1.42) conditions; t(17) = -2.05, p = .06 ($p > .05$) (*see* Table 26) and d = 0.61 (medium effect). These findings indicate that use of CS for female participants did not significantly improve their performance on the TDRV-GO knowledge items for the learners.

Table 26

Paired Sample t-Test for Test2K and Test3K Based on Gender

				Paired Differences							
							95% Confidence Interval of the Difference				
Condition	Gender			Mean	Std. Deviation	Std. Error Mean	Lower	Upper	t	df	Sig. (2-tailed)
Without CS	Male	Pair 1	Test2K – Test3K	0.71	1.53	0.37	-0.08	1.49	1.90	16	.08
	Female	Pair 1	Test2K – Test3K	-0.83	1.72	0.41	-1.69	0.02	-2.05	17	.06
With CS	Male	Pair 1	Test2K – Test3K	0.08	1.26	0.25	-0.43	0.59	0.31	25	.76
	Female	Pair 1	Test2K – Test3K	-0.36	1.13	0.21	-0.80	0.08	-1.67	27	.11

Female group With CS.

There was no significant difference in the scores for the females With CS Test2K (*M* = 4.36, *SD* = 1.45) (see Appendix OO) compared to Test3K (*M* = 4.71, *SD* = 1.36) conditions; t(27) = -1.67, *p* = .11 (*p* > .05) (*see* Table 26) and d = 0.25 (small effect see 4.2.2.7). These findings indicate that female participants not using computer simulations did not significantly improve their performance on the TDRV-GO knowledge items. Although there was no significant difference in the scores, the means did increase. The use of CS for the Without CS female had a medium effect size and the lack of use of CS had a small effect size. It is important to note that both of them were not significant. This also is consistent with the emergent findings that CS improved performance.

4.2.3.4 Effect sizes for Research Question 1 and 2.

Cohen's d effect sizes were calculated for all the conditions (see Table 27). It is important to note that in Table 27 in the independent samples t-test for Test 2K the effect size for all learners was medium (= 0.68) and by looking at the effect sizes based on the gender the greatest contributors to the medium effect size were the female learners in favour of those using CS.

Furthermore the independent samples t-test for Test 3K the effect size for all learners was large (= 0.92) in a similar fashion the greatest contributors were again female. However, it is important to note that, in the second week there was switching, from using CS to not using them and vice versa. To avoid confusion, the naming of the groups remained the same throughout. With CS had CS in the first week and did not use CS in the second week. On the other side, Without CS did not use CS in the first week but used CS in the second week. What emerges is in the second week the male students did not improve, the mean score reduced however it reduced more in the group which was using CS where the medium effect size was 0.50 (with the mean score decreasing) and a small effect size of 0.05 for the teacher not using CS (also with a lower mean score in the second week) (see Table 27).

Another result which does not seem to be consistent with the emerging theme was the paired samples t-test for the 1K and 2K for males With CS compared to the male learners Without CS. The effect size was lower and significant. This could suggest that the use of teacher centred approach without use of the CS was important. The role of the teacher can therefore not be unnoticed.

The female learners improved noticeably more through the use of the CS than without using the CS. A large effect size of 1.12 is intimated when the female learners using CS are compared with those not using CS. The improvement is remarkable especially in the light of Hattie's work on effect sizes (Hattie, 2003) also see section 3.9.1.4.

The female learners continued to show improvement with the CS, where the use of CS in the second week led to a 0.61 medium effect size which was an increase compared to the group that did not use the CS with a small effect size of 0.25 (see Table 27)

Table 27

Effect Sizes for Research Questions 1 and 2

Variable	For	Cohen's d	Significant	Effect size	Higher
Independent Samples Test 2K					
2K	Without CS and With CS	0.68	Yes	medium	With CS
2K	Male Without CS and With CS	0.28	No	Small	With CS
2K	Female Without CS and With CS	1.12	Yes	Large	With CS
Independent Samples Test 3K					
3K	Without CS and With CS	0.92	Yes	Large	With CS
3K	Male Without CS and With CS	0.87	Yes	Large	With CS
3K	Female Without CS and With CS	0.95	Yes	Large	With CS
Paired samples					
	1K and 2K Without CS	0.45	Yes	Small	2K
	1K and 2K With CS	0.65	Yes	Medium	2K
	2K and 3K Without CS	0.063	No	V Small	3K
	2K and 3K With CS	0.11	No	V Small	3K
	1K and 2K Without CS male	0.72	yes	Medium	2K
	1K and 2K With CS male	0.60	Yes	Medium	2K
	1K and 2K Without CS female	0.075	No	V small	2K
	1K and 2K With CS female	0.67	Yes	Medium	2K
	2K and 3K Without CS male	0.50	No	Medium	2K
	2K and 3K With CS male	0.05	No	V small	2K
	2K and 3K Without CS female	0.61	Yes	Medium	3K
	2K and 3K With CS female	0.25	No	Small	3K

It is important to put the data into context. Our sample size was 105 grade 11 learners from four rural schools. For this particular research, it is a strong indicator that computer simulations could have great effects especially with regard to improving female learners' performance. The best effect size performance for the female learners was recorded as 1.12. Referring to the diagram (see *Figure 12* in chapter 3) it would be interpreted as the female learners who used CS were better than 87% of the learners who did not use CS! This could be of particular importance to an education system. Even more important in rural areas in South Africa for example, the average mark for Grade 9 in mathematics in the Annual National Assessment (ANA) for Vhembe district (Department of Basic Education, 2013) was 9.5%. An improvement by an effect size of 1.12 would take them to approximately 16%. Although the percentage indicated is not very good, but it would provide a start.

4.2.3.5 Summary for Research question 1 and 2.

Data was presented and analysed to answer research questions on the effect of CS or lack of use of Cs on acquisition of knowledge for the learners. The means improved in all tests when CS were used, both in general and when gender was considered. The independent samples tests indicate that there was a significant difference in favour of the learners in the group With CS in all three tests (Test 1K, Test2K and Test3K). A medium effect size was d = 0.68 (see section 4.2.5.1 under (b)) were calculated in general. When the same analysis was done for male and female learners separate, there was a small effect size for the male learners (d = 0.28) and the difference was not significant. However, for the female learners there was a significant difference and a very large effect size of 1.12 (see 4.2.3.4).

A paired samples t- test was used to determine the change from the initial condition of Test1K to Test2K. This was repeated for both male and female. A further paired samples test was used for Test2K and Test3K and also repeated to compare the gender. In the first week, with regard to the changes as measured by paired samples tests, the use of CS improved the results of the learners significantly with medium effect size of 0.65 (see 4.2.5.3 under (a)).

In contrast, for the second week, the group that used CS improved little with no significant increase and a very small effect size (see 4.2.3.4). An analysis for the gender indicates the female who used CS improved by medium effects, 0.61 while the male decreased with a medium effect of 0.50. These results could indicate that the use of CS did not have the same effect on the learners in terms of the acquisition of knowledge.

The study of the effect of without CS on acquisition of knowledge for the learners and also with regard to gender indicated interesting outcomes. There was a strong effect shown by significance and also the effect sizes when compared with the CS. The independent samples tests indicated that there was a significant difference in favour of the learners With CS group compared to the Without CS group. The Without CS was lower than those who used CS. The effect size was a medium one of 0.68. When the analysis was done for male and female, there was a small effect size and the difference was not significant. However, the female was significant and a very large effect size of 1.12 in favour of the With CS (see 4.2.5.1 under (b)) was seen. The With CS had a greater difference than the Without CS.

With regard to the changes as measured by paired samples tests, the use of no CS improved the results of the learners significantly with small effect size of 0.45 (see 4.2.5.3 under (a)). In contrast, for the second week, the group which used no CS improved little with no significant increase and a very small effect size of 0.11 (see 4.2.5.3 under (b)). An analysis for the gender indicates the male who used no CS decreased slightly and it was not significant and the effect size was small with $d = 0.25$. The female who used no CS did not significantly improve, $p = .11$ in the performance they improved by a small effect size.

4.2.4 Data and analysis for Research questions 3 and 4 on skills items for groups Without CS and With CS.

The researcher presented data to answer research questions 3 and 4:

- Research Question 3:

  What is the effect on Grade 11 learners (male/female) when the topic Geometrical Optics is taught using a teacher centred approach in the acquisition of skills *with* the use of computer simulations?

- Research Question 4:

  What is the effect on Grade 11 learners (male/female) when the topic Geometrical Optics is taught using a teacher centred approach in the acquisition of skills *without* the use of computer simulations?

4.2.4.1 Independent samples t-test for Test2S.

(a) Independent samples t-test for Test2S.

Given that the homogeneity of variance by the Levene's test, $F(1, 101) = 1.40$, $p = .24$ ($p > .05$) was upheld, a test assuming equality of variances was calculated (see Table 28). The result of this test indicated that there was no significant difference in the scores $t(101) = 1.09$ and $p = .28$ and $d = 0.25$ (small effect see section 4.2.2.7). These results suggest that those in the Without CS ($M = 6.74$; $SD = 2.23$) and With CS ($M = 6.28$; $SD = 2.02$) conditions were not different (see Appendix PP).The mean of the groups was not significantly different for the With CS and Without CS. This indicates that there was no difference in the two groups after the intervention. It is important to note that the analysis of Test 1 had indicated that the two groups were not different (see 4.2.4.1).

Table 28

Levene's Test and t-Test for Equality of Means for Test 2 for Skills Items

		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
Test2S	Equal variances assumed	1.40	.24	1.09	101.00	.28	0.46	0.42	-0.37	1.29
	Equal variances not assumed			1.08	92.15	.28	0.46	0.42	-0.38	1.30

(b) Independent samples t-test based on gender for Test2S.

Given that the homogeneity of variance by the Levene's test, F(1, 48) = 4.40, *p* = .04 (p < .05) was not upheld for the male learners, a test not assuming equality of variances was calculated (see Table 29). The result of this test indicated that there was no significant difference in the scores t(40) = -0.88 and p = .38 (see Table 29) and d = 0.26 (small see section 4.2.2.7). These results suggest that the male learners in the group Without CS (M = 6.65, *SD* = 2.42) and in the group With CS (*M* = 6.11, *SD* = 1.81) conditions were not significantly different (see Appendix QQ). There was a higher mean for the male learners Without CS. There was no difference in the male groups after intervention.

Table 29

Levene's Test and t-Test for Equality of Means for Test2S for Skills Items Based on Gender

		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
Male	Equal variances assumed	4.40	.04	.90	48	.37	.54	.60	-.66	1.75
	Equal variances not assumed			.88	40.12	.38	.54	.61	-.70	1.78
Female	Equal variances assumed	.10	.75	.66	51	.51	.39	.60	-.81	1.59
	Equal variances not assumed			.67	49.13	.51	.39	.59	-.80	1.58

For the female learners since the homogeneity of variance by the Levene's test, F(1, 51) = 0.10, *p* = .75 (p > .05) was upheld, a test assuming equality of variances was calculated (see Table 29). The result of this test (see Table 29) indicated that there was no significant difference in the scores t(51) = .66 and p = .51 and d = 0.18 (small effect see section 4.2.2.7). These results suggest that the female learners in the group Without CS (*M* = 6.83, *SD* = 2.06) and group With CS (*M* = 6.43, *SD* = 2.22) conditions were not significantly different (see Appendix QQ). There was a higher mean for the Without CS group. There was a small difference in the two groups of females in Test2K for the Without CS and With CS. In both groups despite their having been no differences in the groups the groups that started with the CS (With CS) performed much better than the Without CS.

There was no difference in the female groups after intervention. It is important to note also that in this case there was a slight higher mean with the female learners who had not used simulations

4.2.4.2 Data and analysis of skills items for the Without CS and With CS of Test 3S.

(a) Independent samples t-test for Test3S.

Given that the homogeneity of variance by the Levene's test, $F(1, 87) = 0.56$, $p = .46$ ($p > .05$) was upheld, a test assuming equality of variances was calculated (see Appendix RR and Table 30). The result of this test indicated that there was no significant difference in the scores $t(87) = -0.26$, $p = .80$ ($p > .05$) and $d = 0.06$ (very small see section 4.2.2.7). These results suggest that those in the Without CS ($M = 6.66$, $SD = 1.92$) and With CS ($M = 6.78$, $SD = 2.27$) conditions with regard to skills were the same (see Appendix RR).

Table 30

Levene's Test and t-Test for Equality of Means for Test3S in Skills Items

		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
Test3S	Equal variances assumed	0.56	.46	-0.26	87	.80	-0.12	0.47	-1.05	0.80
	Equal variances not assumed			-0.27	80.84	.79	-0.12	0.45	-1.01	0.77

(b) Independent samples t-test for Test3S based on gender.

Given that the homogeneity of variance by the Levene's test, F(1, 41) = 0.25, *p* = .62 (p > .05) was upheld for the male learners, a test assuming equality of variances was calculated (see Table 31). The result of this test indicated that there was no significant difference in the scores t(41) = -0.75 and p = .46, p > 0.05 (see Table 31) and d = 0.24 (small effect see section 4.2.2.7). These results suggest that the male learners in the group Without CS (M = 6.65, *SD* =1.77) and in the group With CS (*M* = 6.19, *SD* = 2.04) conditions were not significantly different (see Appendix SS).

There was no difference in the male groups after intervention. This as indicated in its being not significant.

Table 31

Levene's Test and t-Test for Equality of Means for Test3S for Skills Items Based on Gender

		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
Male	Equal variances assumed	.25	.62	.75	41	.46	.46	.60	-.77	1.68
	Equal variances not assumed			.78	37.73	.44	.46	.59	-.73	1.64
Female	Equal variances assumed	.31	.58	-.95	44	.35	-.66	.69	-2.04	.73
	Equal variances not assumed			-.98	39.41	.34	-.66	.67	-2.01	.70C

For the female learners since the homogeneity of variance by the Levene's test, F(1, 44) = 0.31, *p* = .58 (p > .05) was upheld, a test assuming equality of variances was calculated (seeTable 31). The result of this test (see Table 31) indicated that there was no significant difference in the scores t(44) = -0.95 and p = .35 and d = 0.31 (small effect see section 4.2.2.7). These results suggest that the female learners in the group Without CS (*M* = 6.67, *SD* = 2.11) and group With CS (*M* = 7.37, *SD* = 2.40) conditions were not significantly different (see Appendix TT).

There was no difference in the female groups after intervention.

4.2.4.3 Paired Samples t-tests.

(a) Paired samples t-test for Test1S and Test2S.

Group Without CS.

In order to determine if there was a specific change in the performance with regard to the test on skills from the performance from Test1S to Test2S without CS a paired samples t-test was done. There was a significant difference in the scores for the Without CS Test1S (*M* = 5.86, *SD* = 1.89) (see Appendix UU) and the Without CS Test2S (*M* = 6.70, *SD* = 2.20) conditions; t(42) = -2.29, *p* = .03 (*p* < .05*) (see* Table 32) and d = 0.41 (small effect see section 4.2.2.7) These findings indicate that the group who did not use CS improved the performance on the skill items in the TDRV-GO test.

Table 32

Paired Samples t-Test of Test1S and Test2S

Condition			Paired Differences: Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference: Lower	Upper	t	df	Sig. (2-tailed)
Without CS	Pair 1	Test1S - Test2S	-0.84	2.40	0.37	-1.58	-0.10	-2.29	42	.03
With CS	Pair 1	Test1S - Test2S	-0.16	2.58	0.34	-0.84	0.53	-0.46	56	.65

Group With CS.

The paired samples t-test compared the performance on Test1S to Test2S for the With CS. There was no significant difference in the scores for the With CS Test1S (*M* = 6.12, *SD* = 1.79) (see Appendix UU) and the With CS Test2S (*M* = 6.28, *SD* = 2.02) conditions; t(56) = -0.462, *p* = .65 (*p* > .05) (*see* Table 32) and d = 0.08 (a very small effect see section 4.2.2.7). These findings indicate that use of computer simulations did not improve significantly the performance on the skill items of TDRV-GO test for the learners. When compared in this way, what emerges is there was a better improvement in the skills as a result of not using CS than the use of CS.

In the first week it can be summarised that CS did not have any effect on the acquisition of skills.

(b) Paired samples t-test for Test2S and Test3S.

Group Without CS.

In order to determine if there is a specific change in the performance with regard to Test2S to Test3S (without CS) a paired samples t-test was done. There was no significant difference in the scores for the Without CS Test2S (*M* = 6.69, *SD* = 2.18) (see Appendix VV) and the Without CS Test3S (*M* = 6.66, *SD* = 1.92) conditions; t(34) = 0.07, *p* = .95 (*p* > .05) (see Table 33) and d = 0.015 (a very small effect see section 4.2.2.7). These findings indicate that use of a CS did not significantly improve the performance from Test2S to Test3S on the TDRV-GO items. There was a very small decrease in the mean from Test2S to Test3S.

Table 33

Paired Samples t-Test of Test2S and Test3S

Condition			Paired Differences							
			Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference		t	df	Sig. (2-tailed)
						Lower	Upper			
Without CS	Pair 1	Test2S – Test3S	0.03	2.54	0.43	-0.84	0.90	0.07	34	.95
With CS	Pair 1	Test2S – Test3S	-0.62	2.50	0.34	-1.31	0.07	-1.82	52	.08

Group With CS.

The paired samples t-test compared the performance on Test2S to Test 3S for the With CS. There was no significant difference in the scores for the With CS Test2S (*M* = 6.17, *SD* = 1.98) (see Appendix VV) and the With CS Test3S (*M* = 6.79, *SD* = 2.29) conditions; t(52) = -1.82, *p* = .08 (*p* > .05) (*see* Table 33) and d = 0.29 (a small effect see section 4.2.2.7). These findings indicate that the intervention did not significantly improve the performance on the skill items of TDRV-GO s for the learners from Test2S to Test3S.

(c) Paired samples t-test for Test1S and Test2S based on gender.

Male group Without CS.

In this section, the researcher for this project discusses the effect of the intervention with regard to gender.

The paired samples t-test compared the performance on Test1S to Test2S for the Without CS when it was split for male and females. There were four different pairs in all. There was no significant difference in the scores for the Without CS Test1S for males: (*M* = 6.09, *SD* = 2.02) (see Appendix WW) and the Without CS Test2S males (*M* = 6.50, *SD* = 2.37) conditions; t(21) = -0.75, *p* = .47 (*p* > .05) (*see* Table 34) and d = 0.19 (a small effect see section 4.2.2.7). These findings indicate that use of no CS for male participants did not significantly improve the performance of the male learners in the Without CS on the TDRV-GO skills items. Cohen's d = 0.19 was a small effect size.

Male group With CS.

The paired samples t-test compared the performance on Test1S for the With CS and the Test2S With CS conditions when it was split for male and females. What is considered here is the analysis for the males in the With CS. There was no significant difference in the scores for the With CS Test1S for males: (*M* = 6.67, *SD* = 1.36) (see Appendix WW) and the With CS Test2S males (*M* = 6.11, *SD* = 1.81) conditions; t(26) = 1.43, *p* = .17 (*p* > .05) (*see* Table 34) and d = 0.35 (a small effect see section 4.2.2.7). These findings indicate that use of computer simulations for male participants did not improve their performance on the TDRV-GO skill items, actually the performance decreased.

Female group Without CS.

The paired samples t-test compared the performance on Test1S for the Without CS and the Test2S Without CS conditions when it was split for male and females This part looks at the female in the without simulations group. There was a significant difference in the scores for the Without CS Test1S for females: (*M* = 5.62, *SD* = 1.75) (see Appendix WW) and the Without CS Test2S females (*M* = 6.90, *SD* = 2.05) conditions; t(20) = -2.71, *p* = .01 ($p < .05$) (*see* Table 34) and d = 0.67 (medium effect see section 4.2.2.7). These findings indicate that use of no CS for female participants significantly improved their performance on the TDRV-GO skills items.

Female group With CS.

There was no significant difference in the scores for the With CS Test1K for females: (*M* = 5.63, *SD* = 2.00) (see Appendix WW) and the With CS Test2S females (*M* = 6.43, *SD* = 2.22) conditions; t(29) = -1.52, *p* = .17 ($p > .05$) (*see* Table 34) and d = 0.39 (a small effect see section 4.2.2.7). These findings indicate that use of computer simulations for female participants did not significantly improve their performance on the TDRV-GO skills items.

Table 34

Paired Sample t-Test for Test1S and Test2S Based on Gender

				Paired Differences							
							95% Confidence Interval of the Difference				
Condition	Gender			Mean	Std. Deviation	Std. Error Mean	Lower	Upper	t	df	Sig. (2-tailed)
Without CS	Male	Pair 1	Test1S - Test2S	-0.41	2.58	0.55	-1.55	0.73	-0.75	21	.47
	Female	Pair 1	Test1S - Test2S	-1.29	2.17	0.47	-2.27	-0.30	-2.71	20	.01
With CS	Male	Pair 1	Test1S - Test2S	0.56	2.03	0.39	-0.25	1.36	1.43	26	.17
	Female	Pair 1	Test1S - Test2S	-0.80	2.88	0.53	-1.88	0.28	-1.52	29	.14

(d) Paired samples t-test for Test2S to test3S based on gender.

In this section, the researcher discusses the effect of intervention with regard to gender for the Test2S and Test3S.

Male group Without CS.

The paired samples t-test compared the performance on Test2S for the Without CS and the Test3S Without CS conditions when it was split for male and females. There were four different pairs in all. There was no significant difference in the scores for the Without CS Test2S for males: (M = 6.12, SD = 2.32) (see Appendix XX) and the Without CS Test3S males (M = 6.65, SD = 1.77) conditions; t(16) = -0.80, p = .43 (p > .05) (*see* Table 35) and d = 0.26 (small effect see section 4.2.2.7). These findings indicate that use of CS for male participants did not significantly improve their performance on the TDRV-GO knowledge items for the learners, the performance increased but not significantly.

Male group With CS.

The paired samples t-test compared the performance on Test2S for the With CS and the Test3S With CS conditions when it was split for male and females. There were four different pairs in all. There was no significant difference in the scores for the With CS Test2S for males: (M = 5.92, SD = 1.55) (see Appendix XX) and the With CS Test3S males (M = 6.19, SD = 2.04) conditions; t(25) = -0.60, p = .55 (p > .05) (*see* Table 35) and d = 0.15 (a small effect see section 4.2.2.7). These findings indicate that use of no CS for male participants did not significantly increase their performance on the TDRV-GO skills items for the learners.

Female group Without CS.

The paired samples t-test compared the performance on Test2S for the Without CS and the Test3S Without CS conditions when it was split for male and females. There were four different pairs in all. There was a not significant difference in the scores for the Without CS Test2S for females: (M = 7.22, SD = 1.96) (see Appendix XX) and the Without CS Test3S females (*M* = 6.67, *SD* = 2.11) conditions; t(17) = 1.01, *p* = .33 (*p* > .05) (*see* Table 35) and d = 0.27 (small effect see section 4.2.2.7). These findings indicate that use of CS for female participants did not significantly improve their performance on the TDRV-GO knowledge items for the learners. The performance decreased. It is worth to note that the group was using CS.

Table 35

Paired Sample t-Test for Test2S and Test3S for Male and Female

				Paired Differences							
							95% Confidence Interval of the Difference				
Condition	Gender			Mean	Std. Deviation	Std. Error Mean	Lower	Upper	t	df	Sig. (2-tailed)
Without CS	Male	Pair 1	Test2S – Test3S	-0.53	2.70	0.65	-1.92	0.86	-0.81	16	.43
	Female	Pair 1	Test2S – Test3S	0.56	2.33	0.55	-0.60	1.72	1.01	17	.33
With CS	Male	Pair 1	Test2S – Test3S	-0.27	2.27	0.45	-1.19	0.65	-0.60	25	.55
	Female	Pair 1	Test2S – Test3S	-0.96	2.70	0.52	-2.03	0.10	-1.86	26	.08

Female group With CS.

There was no significant difference in the scores for the With CS Test2S for females: (*M* = 6.41, *SD* = 2.33) (see Appendix XX) and the With CS Test3S females (*M* = 7.37, *SD* = 2.40) conditions; t(26) = -1.86, *p* = .08 (*p* > .05) (*see* Table 35) and d = 0.41 (small effect see section 4.2.2.7). These findings indicate that use of no CS for female participants did not significantly improve their performance on the TDRV-GO skills items for the learners, however Test3S was higher than Test2S.

4.2.4.4 Effect sizes for Research questions 3 and 4.

Cohen's d effect sizes: 0.2 – small effect; 0.5 - medium effect; 0.8 large effect (Cohen, 1973; Cohen, 1990).

Table 36

Effect Sizes for Research Questions 3 and 4

Variable	For	Cohen's d	Significant	Effect size	Higher
Independent Samples Test 2S					
2S	Learners Without CS and With CS	0.25	no	small	Without CS
2S	Male Without CS and With CS	0.26	No	Small	Without CS
2S	Female Without CS and With CS	0.18	No	V small	With CS
Independent Samples Test 3S					
3S	Learners Without CS and With CS	0.06	no	V small	With CS
3S	Male Without CS and With CS	0.24	No	small	Without CS
3S	Female Without CS and With CS	0.31	no	small	With CS
Paired samples					
	1S and 2S Without CS	0.41	Yes	Small	2S
	1S and 2S With CS	0.08	No	V small	2S
	2S and 3S Without CS	0.015	No	V Small	2S
	2S and 3S With CS	0.29	No	Small	3S
	1S and 2S Without CS male	0.19	no	small	2S
	1S and 2S With CS male	0.35	no	small	2S
	1S and 2S Without CS female	0.67	yes	medium	2S
	1S and 2S With CS female	0.39	no	small	2S
	2S and 3S Without CS male	0.26	No	small	2S
	2S and 3S With CS male	0.15	No	V small	3S
	2S and 3S Without CS female	0.27	no	small	2S
	2S and 3S With CS female	0.41	No	Small	3S

The independent Samples test for Test2S based on gender indicates a decrease in the mean marks when comparing the Without CS and With CS groups, see Table 36. What was favoured in this case was the Without CS except for the female participants though the difference was not significant and the effect size of 0.18 (see Table 36) was a very small one when the independent samples t-test considered Test2S for the With CS and Without CS.

When the independent samples t-test is used for Test 3S, what is found is Without CS seems to have an edge except where when With CS is considered there is a very small effect size and it was not significant. It is worth mentioning the not using of CS in the second week seemed to help the female participants also (see Table 36) since they performed well in the With CS for the 2K to 3K, the effect size of 0.41 is greater than the 0.27 for Without CS which was about using CS. With regard to skills the lack of CS seemed to be better than where simulations were used.as indicated by: the independent t-test for 2S: (a) for the case of male (b) paired samples t-test for 1S:2S; 2S:3S in the With CS group; 1S:2S female for the Without CS and 2S:3S With CS female.

The instances where the CS brought better effect sizes was: In the independent samples t-test for Test 2S based on gender in particular female where d = 0.18 which is a very small effect size; the paired samples t-test 1S:2S With CS for male, d = 0.35 compared to Without CS , d = 0.19 and also a paired samples t-test for the Without CS male 2S:3S who were using CS in week 2 d = 0.26 compared to 0.19 for the With CS who were not using CS.

The effect of skills on the acquisition of skills when considering the effect sizes ranged from very small to small. It was not significant.

4.2.4.5 Summary for Research Questions 3 and 4.

The research question was the effect of CS or no CS on acquisition of skills for the learners and also with regard to gender. There was no significant difference between the effects of With CS and Without CS and the effect sizes on the effect of CS was small, d =

0.25. The independent samples tests indicate that there was no significant difference in favour of the learners in With CS group compared to the Without CS group. The effect size was also a small one of 0.26 for the male learners. Also the female was not significant and it too was a small effect size of 0.18 (see 4.2.4.4).

With regard to the changes as measured by paired samples tests, the use of CS did not improve the results of the learners significantly, and the effect size of 0.08 (see 4.2.4.) was a very small effect. In contrast, for the second week, the group which used CS decreased a little but not significantly with a very small effect size of 0.015(see 4.2.6.3 under (b)). An analysis for the gender indicates both male and female did not improve significantly with a small effect size of d = 0.19 and 0.39 respectively (see 4.2.6.3 under c and d). The items on skills were not affected much by the use of CS.

The results in this section also indicate that the teacher centred approach can increase performance. This is exemplified in the skills area. It is more powerful than the use of CS for the acquisition of skills with regard to the samples considered.

4.3 Summary of Findings

Data was presented and analysed quantitatively to answer research questions one to four. It was needed to determine whether computer simulations were effective in the acquisition of knowledge and skills in a teacher centred environment compared to not using them in the same environment. Gender was also considered. Computer simulations were found to be very effective in the improvement of knowledge but not the skill items. The learners who did not use computer simulation in a teacher centred approach also improved in the knowledge items but not as much as when using the computer simulations. The female learners improved remarkably with the use of computer simulations compared to their male counterparts with regard to knowledge. The improvement of the female learners with regard to knowledge was evident throughout the period of study when the paired t tests were done. CS did not have a significant effect on the acquisition of skills.

Chapter 5

Data and Analysis of Cognitive Load and Speed

5.1 Introduction

The researcher presented the data and analysis in Chapter 4 to determine the effect of the CS on the acquisition of knowledge and skills of Grade 11 learners in geometrical optics.

The study followed a switching replications design within a non-equivalent quasi experimental design (see Section 3.2.2). Data was collected quantitatively by using 3 instruments namely a Test of Describing Relationships between Variables – Geometrical Optics (TDRV-GO) (see section 3.4.1); the Cognitive Load Rating Scale (CLRS) (see section 3.4.2) as well as a split timer (see section 3.4.3).

In Chapter 5, the researcher for this project discusses research questions 5 through 8 (see section 1.6). The data collected using the Cognitive Load Rating Scale (CLRS) was used to answer research questions 5 and 6 and is presented and analysed (see section 5.2.1). Consequently, another set of data was collected through a split timer which was used to answer research questions 7 and 8 and the analysis was done (see section 5.2.2).This section of the study was on cognitive load change in the acquisition of knowledge and skills when CS is used. Knowledge as defined and described in chapter 2 in sections 2.2.1 and 2.3.2 and one process skill that of defining relationships between variables as discussed in chapter 2 (see section 2.2.2). Cognitive load is defined as the amount of memory space used (See Fig 6 in Chapter 2) when trying to learn a curriculum unit or a skill. When the cognitive load is high it means a lot of memory space is taken up, if less then little. The aim of this research was to make use of interactive computer simulations to reduce the cognitive load which would lead to gains in learning or ending up in the long term memory (see section 2.7.2). Automation is one of the outcomes of the long-term memory and, therefore, it was assumed that when no effort is needed, a task can be performed quicker or with increased speed.

5.2 Research questions 5 -8

The presentation and analysis of data in this section considers the following questions: what is the effect on Grade 11 learners in terms of gender (male/female) when the topic geometrical optics is taught using a teacher centred approach in the acquisition of:

RQ5 knowledge and skills with the use of computer simulations on the cognitive load?

RQ6 knowledge and skills without the use of computer simulations on the cognitive load?

RQ7 knowledge and skills with the use of computer simulations on the speed of writing a test?

RQ8 knowledge and skills without the use of computer simulations on the speed of writing a test?

The conditions and the necessity to meet the assumptions was discussed (see section 4.2.2.1) and is not repeated.

5.2.1 Data and analysis for research questions 5 and 6 for the cognitive load for the Without CS and With CS groups.

Cognitive load is experienced as one learns old and new things. If what is being learnt cannot be understood well, or has many pieces of knowledge that have to be understood then it becomes hard and it can be said that the cognitive load is high. Cognitive load can be reduced by instruction. In this research the cognitive load was measured at the beginning of the week so that it could be ascertained how the participants perceived the cognitive load (Paas, Tuovinen, Tabbers, & Van Gerven, 2003; Mayer, 2004). In the theoretical framework, the cognitive load is discussed (see section 2.8). When the cognitive load decreases the germane load increases (see section 2.7.1) and this means more knowledge and skills will be sent to the long term memory and will be easily remembered.

Data was collected using the Cognitive Load Rating Scale (CLRS) wherein learners indicated how they felt in terms of the cognitive load used on a rating scale ranging from very low to very high cognitive load in order to answer RQ 5 and 6.

In the first two days of week one, the Cognitive load 1 (CL1) was determined and at the end of the first week Cognitive load 2 (CL2). In the first two days of the second week, Cognitive load 3 (CL3) was determined and at the end of the second week, Cognitive load 4 (CL4).

5.2.1.1 Data and analysis of cognitive load for Without CS and With CS for CL1.

In order to understand the change in cognitive load one needs to remember that initially baseline data was captured for the groups in terms of knowledge and skills (see section 4.2.2). It was found that there was no significant difference between the four schools and therefore the two groups (see section 4.2.2).

(a) Mann-Whitney U test for CL1 for the first week.

A Mann-Whitney U-test was used to determine whether there was a significant difference in the Cognitive load measured in the first week in the first two days with the groups using or not using computer simulations. A Mann-Whitney U-test was chosen instead of the Independent samples t- test because the statistics for the cognitive rating scale were not interval statistics and was not normally distributed.

A Mann-Whitney U-test indicated that the cognitive loads were significantly different for the groups with CS and without CS in the first two days of the first week $U(104) = 899.50$, $Z = -2.06$, $p = .04$ (2 tailed), $r = .21$. (See 5.2.1.5) The cognitive load for the group Without CS was higher (Mdn = 5) compared to the group With CS (Mdn = 2). The Mean rank of the group Without CS was 56.08 and the group With CS was 44.56 (see Appendix YY). The cognitive load as indicated was due to the instructional method, one group was using a teacher centred approach without CS while the other was using the teacher centred approach with CS. The group With CS felt a lower cognitive load while the Without CS felt a higher cognitive load.

(b) Mann-Whitney U test for CL1 for the first week based on gender.

A Mann-Whitney U-test was used to determine the cognitive load relationship between the groups Without CS and With CS at the beginning of week1 with regard to gender

Male.

The test indicated that the cognitive loads were not significantly different for the male learners who were using computer simulations and those not using the computer simulations in the first two days of the first week U(47) = 263, Z = -0.46, p = .65 (2 tailed), r = .07 (see Appendix AAA and section 5.2.1.5). The cognitive load for the male group Without CS was higher (Mdn = 5) compared to the group With CS (Mdn = 2) (see Appendix BBB). The mean rank of the male learners in the group Without CS who were not using the simulations in the first week was 25.48 and the mean rank of the group With CS who were being taught by using CS was 23.74 at the beginning of the week (see Appendix CCC). The male learners in the group With CS had a lower cognitive load than the group Without CS though as indicated it was not significant. The effect size r = 0.07 (see section 5.2.1.5) was a very small effect.

Female.

The test indicated that the cognitive loads were significantly different for the female learners With CS and those Without CS in the first two days of the first week U(49) = 199, Z = -2.11, p = .04 (2 tailed) (see Appendix AAA), r = .30 (medium effect, see section 5.2.1.5). The cognitive load for the female learners Without CS (Mdn = 4.5) was higher compared to the group With CS (Mdn = 2), (see Appendix BBB). The mean rank of the female learners in the group Without CS who were not using the simulations in the first week was 30.52 and the group With CS who were being taught by using CS was 21.86 at the beginning of the week (see Appendix CCC). The females With CS had a lower cognitive load than the Without CS as indicated was significant.

5.2.1.2 Data and analysis of cognitive load Without CS and With CS for Cl3.

(a) Mann-Whitney U test for CL3 for the second week.

It is important to note that the study used a switching replications design where by the second week, the group Without CS used the computer simulations and the group With CS did not use computers (see 3.2.2).

A Mann-Whitney U-test was used to determine the cognitive load relationship between the groups Without CS and With CS at the beginning of week 2. This would be an indication of the cognitive loads differences which they started week 2 with. The test indicated that the cognitive loads were not significantly different for those who were using computer simulations and those not using the computer simulations in the first two days of the second week $U(57) = 342$, $Z = -0.72$, $p = .48$ (2 tailed) (see Appendix DDD), $r = .10$ (small effect see section 5.2.1.5). The cognitive load for the groups Without CS (Mdn = 3) was higher than the group With CS (Mdn = 2), (see Appendix EEE). The mean rank of the group Without CS who were using the simulations in this week was 30.23 and the mean rank of the group With CS who were being taught by not using CS only was 27.05 at the beginning of the week (see Appendix FFF).

(b) Mann-Whitney U test forCL3 for the second week based on gender.

A Mann-Whitney U-test was used to determine the cognitive load relationship between the groups Without CS and With CS at the beginning of week 2 with regard to gender

Male.

The test indicated that the cognitive loads were not significantly different for the male learners in the group Without CS and group With CS in the first two days of the second week

U(49) = 74, Z = -0.58, p = .57 (2 tailed) (see Appendix GGG), r = 0.08 (very small effect, see section 5.2.1.5). The cognitive load for the male learners Without CS (Mdn = 4) is higher compared to the group With CS (Mdn = 2), (see Appendix HHH). The mean rank of the male learners in the group Without CS who were using the simulations in the second week was 13.35 and the mean rank of the group With CS who were being taught by not using CS was 15.10 at the beginning of the week 2 (see Appendix III). The Without CS (who were now using simulations) had a lower cognitive load than the With CS (who were not using simulations) though as indicated it was not significant. .

Female.

The test indicated that the cognitive loads were not significantly different for the female learners in the group Without CS and With CS in the first two days of the second week U(54) = 78.5, Z = -1.28, p = .20 (2 tailed) (see Appendix GGG), r = 0.17 (a small effect see section 5.2.1.5 . The cognitive load for the female learners Without CS (Mdn = 3) is higher compared to the group With CS (Mdn = 2), (see Appendix HHH). The mean rank of the female learners in the group Without CS who were using the simulations in the second week was 17.14 and the mean rank of the group With CS who were being taught by not using CS was 13.04 at the beginning of the week (see Appendix III). The With CS (not using CS) had a lower cognitive load than the Without CS (who were using CS) though as indicated it was not significant.

5.2.1.3 Wilcoxon Signed Ranks tests.

A Wilcoxon Signed Ranks test was used *to determine the within cognitive load changes in the first week* for the different groups in the first two days and the last day of the week for the groups Without CS and With CS. The reasons for the use of the Wilcoxon Signed Ranks test was the need to determine how the cognitive load was changing within the week as the learners use CS. The second reason was, the Cognitive load not being an interval scale and the fact that the distribution was not a normal one (See Appendix JJJ) since the Shapiro-Wilk statistic indicated the significance was less than .05.

(a) Wilcoxon Signed Ranks tests for CL1 and CL2 for the first week.

Group Without CS.

A Wilcoxon Signed Ranks test indicated that the cognitive load decreased in group Without CS from the first two days (*Mdn* = 5) of the first week to the last day of the week (*Mdn* = 4) W(42) = 191.50, Z = -2.63, p = .004 (1 tailed) (see Appendix KKK and Appendix LLL), r = 0.29 (medium effect size see section 5.2.1.5). The change was significant.

It was noted that the cognitive load decreased moderately (a medium effect) during the week for the case where there was no use of CS. The cognitive load started from an average of 5.07 to an average low of 3.95 (see Appendix MMM).

Group With CS.

The group With CS the Wilcoxon Signed Ranks test the cognitive load decreased from the first two days (*Mdn* = 5) of the first week to the last day of the same week (*Mdn* = 4), W(56) = 53.50, Z = -0.76, p = .45 (2 tailed), r = 0.10 (see Appendix KKK, Appendix LLL and Section 5.2.1.5), the change was not significant and the effect size of 0.10 was small.

An observation with regard to the data is that the changes of the group With CS were not significant however when one considers the mean of the readings in the first two days of the first week (see Appendix MMM) the cognitive load decreased from 4.20 to 3.88. The cognitive load was already low.

The use of the no CS significantly reduced the cognitive load from a median value of 5 in the first two days to a median value of 4 in the first week as well as the use of CS decreasing the cognitive load also a median of 5 to 4 but not to the same extent. There was a larger effect size by the Without CS group.

(b) Wilcoxon Signed Ranks test for CL3 and CL4 for the second week.

Group Without CS.

A Wilcoxon Signed Ranks test indicated that the cognitive load increased in the group Without CS from the first two days (*Mdn* = 3) of the second week to the last day of the week (*Mdn* = 4) W(35) = 133, Z = -2.28, p = .02 (2 tailed) (See Appendix NNN and Appendix PPP), r = 0.27. (medium effect see section 5.2.1.5). The change was significant (see Section 5.2.1.5 and Appendix OOO).

Group With CS.

For the group With CS group using the Wilcoxon Signed Ranks test the cognitive load increased from the first two days (*Mdn* = 3) of the second week to the last day of the same week (*Mdn* = 3.5), (See Appendix PPP) W(22) = 18, Z = -1.70, p = .09 (2 tailed) (see Appendix NNN, Appendix OOO), r = 0.26 (medium effect, see section 5.2.1.5) the change was not significant . When they did not use CS the cognitive load increased with a medium effect despite its not being significant.

(c) Wilcoxon Signed Ranks test for CL1 and CL2 for the first week based on gender.

Male group Without CS.

A Wilcoxon test was conducted to determine whether the CL2 increased or not as a result of without CS in the teaching of the male participants in the first week.

For the male participants, the results indicated a significant difference and therefore indicated that there was a decrease in the cognitive load of the males in favour of the load decreasing. The Wilcoxon signed ranks test indicated a decrease in the cognitive load 1 (Mdn = 5) (see Appendix QQQ) to less (Mdn = 4), Z = -2.16, p = .03 (2 tailed) with r = 0.47 see Table 38. The effect size of 0.47 (see section 5.2.1.5) was a large effect size. These findings indicate that not using computer simulations significantly decreased the cognitive load of the male learners in the first week from the beginning to the end of the week. It is important to note the cognitive load started at *M = 4.90.* And indication of the Mean Rank of the negative ranks was equal to 11.21 when compared to the positive Ranks where the Mean Rank was 6.08 see Table 37. This shows that when not using the CS, the cognitive load also reduced. An important indication that even teacher centred learning can reduce the cognitive load.

Table 37

A Wilcoxon Signed Rank Test for the Cognitive Load 1 (CL1) and Cognitive Load 2 (CL2) for the Without CS Based on Gender Showing Ranks

Experimental Conditions	Gender			N	Mean Rank	Sum of Ranks
Without CS	Male	CL2-CL1	Negative Ranks	12[a]	11.21	134.50
			Positive Ranks	6[b]	6.08	36.50
			Ties	3[c]		
			Total	21		
	Female	CL2-CL1	Negative Ranks	14[a]	10.50	147.00
			Positive Ranks	6[b]	10.50	63.00
			Ties	1[c]		
			Total	21		

a. CL2< CL1

b. CL2 > CL1

c. CL2 = CL1

Table 38

A Wilcoxon Signed Rank Test for the Cognitive Load 1 (CL1) and Cognitive Load 2 (CL2) for the Without CS and With CS Based on Gender Showing the Test Statistics

Experimental Conditions	Gender		CL2-CL1
Without CS	Male	Z	-2.16[a]
		Asymp. Sig. (2-tailed)	0.03
	Female	Z	-1.59 [a]
		Asymp. Sig. (2-tailed)	0.11

a. Based on positive ranks.t

Male group With CS.

For the male participants in the group With CS, the results indicated no significant difference and therefore indicated that there was a decrease (Mdn = 4) (see Appendix QQQ) in the cognitive load of the males in favour of the load decreasing (Mdn = 3) Z = -1.29, p = .20 (2 tailed) (see Table 40). The effect size of r = 0.25 (medium effect see section 5.2.1.5). These findings indicate that using computer simulations did not significantly decrease the cognitive load of the male learners in the first week from the beginning to the end of the week. It is important to note the cognitive load started at *M = 4.48.* An indication of the Mean Rank of the negative ranks, being equal to 10.54 when compared to the positive Ranks where the Mean Rank was 9.07 shows there was a decrease. Here the decrease in the cognitive load was a medium effect though it was not significant.

Female group Without CS.

A Wilcoxon test was conducted to determine whether the CL2 increased or not as a result of not using CS in the teaching of the female participants in the first week. The results failed to reject that there was a difference in the cognitive load change (Z = -1.59, p = .11 (2-

tailed); see Table 38, Table 37 with r = 0.35 (medium effect; see section 5.2.1.5)). The median for the CL1 was (*Mdn* = 5), while the one for CL2 was (*Mdn* = 4) (see Appendix QQQ). These findings indicate that the females in the group Without CS did not significantly decrease the cognitive load in the first week from the beginning to the end of the week. It would be important to note that the cognitive load was comparatively high (*M* = 5.24) at the start of week (see Appendix QQQ).

Table 39

A Wilcoxon Signed Rank Test for the Cognitive Load 1 (CL1) and Cognitive Load 2 (CL2) for the With CS Based on Gender Showing Ranks

Experimental Conditions	Gender			N	Mean Rank	Sum of Ranks
With CS	Male	CL2-CL1	Negative Ranks	12[a]	10.54	126.50
			Positive Ranks	7[b]	9.07	63.50
			Ties	7[c]		
			Total	26		
	Female	CL2-CL1	Negative Ranks	14[a]	8.93	125.00
			Positive Ranks	5[b]	13.00	65.00
			Ties	10[c]		
			Total	29		

a. CL2< CL1

b. CL2 > CL1

c. CL2 = CL1

Female group With CS.

A Wilcoxon Signed Rank test was done to determine whether the CL2 increased or not as a result of using CS in the teaching of the female participants in the first week. The results fail to reject that there was a difference in the cognitive load change; Z = -1.26, p = .21 (2 tailed) (see Table 39 and Table 40) with r = 0.23 (small effect size see section 5.2.1.5). The median for the CL1 (*Mdn = 4*) while the one for CL2 (*Mdn* = 4) (see Appendix QQQ). These findings indicate that use of CS did not significantly increase the cognitive load of the female learners in the first week from the beginning to the end of the week. It can be said however that the cognitive load at the beginning of the week was *M = 3.93* (which is low) see Appendix QQQ.

Table 40

A Wilcoxon Signed Rank Test for the Cognitive Load 1 (CL1) and Cognitive Load 2 (CL2) for the With CS Based on Gender Showing the Test Statistics

Experimental Conditions	Gender		CL2- CL1
With CS	Male	Z	-1.29 [a]
		Asymp. Sig. (2-tailed)	0.20
	Female	Z	-1.26 [a]
		Asymp. Sig. (2-tailed)	0.21

b. Based on positive ranks.t

(d) Wilcoxon Signed Ranks test for CL3 and CL4 for the second week based on gender.

Male group Without CS.

A Wilcoxon signed rank test was used to determine whether the CL4 increased from CL3 or not as a result of using CS in the teaching of the male participants in the second week. The results fail to reject that there was a difference in the cognitive load change; $z = -0.51$, $p = .61$ (2 tailed) (see Table 41) with $r = 0.12$ (small effect see section 5.2.1.5). The median for the CL3 (*Mdn = 4*) while the one for CL4 (*Mdn* = 3) (see Appendix RRR). These findings indicate that use of CS did not significantly decrease the cognitive load of the male learners in the second week from the beginning to the end of the week. It can be said however that the cognitive load was low at the start of the second week *M = 3.59* see Appendix RRR.

Table 41

A Wilcoxon Signed Rank Test for the Cognitive Load 3 (CL3) and Cognitive Load 4 (CL4) for the Without CS Based on Gender Showing Ranks

Experimental Conditions	Gender			N	Mean Rank	Sum of Ranks
Without CS	Male	CL4-CL3	Negative Ranks	7[a]	6.36	44.50
			Positive Ranks	7[b]	8.64	60.50
			Ties	3[c]		
			Total	17		
	Female	CL4-CL3	Negative Ranks	6[a]	4.25	25.50
			Positive Ranks	11[b]	11.59	127.50
			Ties	1[c]		
			Total	18		

a. CL4< CL3

c. d. CL4 > CL3

e. CL4 = CL3

Table 42

A Wilcoxon Signed Rank Test for the Cognitive Load 3 (CL3) and Cognitive Load 4 (CL4) for the Without CS Based on Gender Showing the Test Statistics

Experimental Conditions	Gender		CL4-CL3
Without CS	Male	Z	-.514[b]
		Asymp. Sig. (2-tailed)	.608
	Female	Z	-2.432[b]
		Asymp. Sig. (2-tailed)	.015

b-Based on negative ranks.

Male group With CS.

A Wilcoxon test was conducted to determine whether the CL4 increased or did not as a result of not using CS in the teaching of the male participants in the second week. The results fail to reject that there was a difference in the cognitive load change; z = -1.13, p = .26 (2 tailed) (see Appendix RRR, Table 43, Table 44) with r =0.36 (medium effect size, see section 5.2.1.5).

The median for the CL3 (*Mdn=4*) while the one for CL4 (*Mdn* = 4) (see Appendix RRR). These findings indicate that the use of CS did not significantly increase the cognitive load of the male learners in the second week from the beginning to the end of the week. It can be said, however, that the cognitive load was low at the start of the second week (*M = 3.70;* see Appendix RRR).

Female group Without CS.

A Wilcoxon test was conducted to determine whether the CL4 increased or did not as a result of using CS in the teaching of the female participants in the second week. The results indicated that there was a significant difference in the cognitive load change; z = -2.43, p = .02

(2 tailed) (see Table 41 and Table 42) with r = 0.57 (large effect size see section 5.2.1.5). The median for the CL3 (*Mdn = 3*) while the one for CL4 (*Mdn* = 5) (see Appendix RRR).

Table 43

A Wilcoxon Signed Rank Test for the Cognitive Load 3 (CL3) and Cognitive Load 4 (CL4) for the With CS Based on Gender Showing Ranks

Experimental Conditions	Gender			N	Mean Rank	Sum of Ranks
With CS	Male	CL4-CL3	Negative Ranks	1[a]	2.00	2.00
			Positive Ranks	3[b]	2.67	8.00
			Ties	6[c]		
			Total	10		
	Female	CL4-CL3	Negative Ranks	3[a]	3.00	9.00
			Positive Ranks	5[b]	5.40	27.00
			Ties	4[c]		
			Total	12		

a. CL4< CL3

b CL4 > CL3

c CL4 = CL3

These findings indicate that use of CS significantly increased the cognitive load of the female learners in the second week from the beginning to the end of the week. It can be said however that the cognitive load was a low one already *M = 3.33* and increased to *4.83 (*see Appendix RRR).

Table 44

A Wilcoxon Signed Rank Test for the Cognitive Load 3 (CL3) and Cognitive Load 4 (CL4) for the With CS Based on Gender Showing the Test Statistics

Experimental Conditions	Gender		CL4-CL3
With CS	Male	Z	-1.13^{b}
		Asymp. Sig. (2-tailed)	.26
	Female	Z	-1.29^{b}
		Asymp. Sig. (2-tailed)	.20

b-Based on negative ranks.t

Female group With CS.

A Wilcoxon test was conducted to determine whether the CL4 increased or did not as a result of not using CS in the teaching of the female participants in the second week. The results indicate there was no significant difference in the cognitive load change; z = -1.29, p = .20 (2 tailed) (see Table 44) with r = 0.37 (medium effect see section 5.2.1.5). The median for the CL3 (*Mdn=2.50*) while the one for CL4 (*Mdn* = 3.00) (see Appendix RRR). These findings indicate that use of no CS did not significantly increase the cognitive load of the female learners in the second week from the beginning to the end of the week. It can be said however that the cognitive load was a low one already *M = 2.67* and increased to *3.42 (*see Appendix RRR).

5.2.1.4 Pearson's correlation for the cognitive loads and performance on items of TDRV-GO.

A Pearson correlation was used to determine if the cognitive load changed or not and the relationship to the use of CS with the related instrument to assess understanding and acquisition of knowledge and skills. It was important to determine if there was any causal relationship.

An analysis is based on Pearson's correlation between the cognitive load 1, 2 3 and 4 and the performance in the TDRV-GO tests written that is Test1, Test2 and Test3 (see Appendix SSS). Since the cognitive load measures were written twice in the first week and also twice in the second week, all the correlations were done to check which were significant. The significance with respect to the correlations was taken at $p = 0.05$ where the chances that the result was obtained by chance was 5%. The analysis was done using SPSS version 19.

Group Without CS.

There was a Pearson correlation of .47 between the cognitive load 1 (beginning of week 1) and cognitive load 3 (beginning of week 2) the significance was $p = .001$ indicating a strong positive relationship (see Table 45 and Appendix SSS). It is important to note that by the time the learners were starting without CS the cognitive load1 had a strong positive relationship to when they were starting to use CS as shown by the cognitive load 3.

A moderate relationship was found between the cognitive load 2 and the cognitive load 3 with $p = .03$.

The relationship between the cognitive load and the tests was not significant.

Group With CS.

There was a very strong positive relationship of .72 between cognitive load 1 and cognitive load 2 which was highly significant at $p < .0001$ (see Table 45 and Appendix SSS).

Table 45

Pearson Correlation for the Cognitive Loads and Test for Items Where There is Significance

Condition			CL1	CL2	CL3	CL4	Test1	Test2	Test3
Without CS	CL1	Pearson Correlation	1	.12	.47**	.03	-.08	-.02	-.11
		Sig. (2-tailed)		.45	.001	.85	.61	.89	.55
		N	46	42	46	35	43	46	35
	CL2	Pearson Correlation	.12	1	.34*	.06	-.11	-.12	.05
		Sig. (2-tailed)	.45		.03	.75	.51	.44	.77
		N	42	42	42	35	39	42	35
	Test1	Pearson Correlation	-.08	-.11	-.07	-.02	1	.50**	.10
		Sig. (2-tailed)	.61	.51	.64	.91		.001	.60
		N	43	39	43	33	43	43	33
	Test2	Pearson Correlation	-.02	-.12	-.03	.05	.50**	1	.53**
		Sig. (2-tailed)	.89	.44	.84	.78	.001		.001
		N	46	42	46	35	43	46	35
With CS	CL1	Pearson Correlation	1	.72**	-.11	.28*	-.02	-.08	-.15
		Sig. (2-tailed)		.00	.41	.04	.86	.56	.28
		N	58	56	58	56	57	56	53
	CL2	Pearson Correlation	.72**	1	.01	.39**	-.06	-.04	-.12
		Sig. (2-tailed)	.00		.94	.004	.66	.80	.41
		N	56	56	56	54	55	55	51
	CL3	Pearson Correlation	-.11	.01	1	.09	-.39**	-.31*	-.26
		Sig. (2-tailed)	.41	.94		.49	.002	.02	.06
		N	58	56	59	56	58	57	54
	CL4	Pearson Correlation	.28*	.39**	.09	1	-.35**	-.14	-.24
		Sig. (2-tailed)	.04	.004	.49		.008	.30	.09

Condition			CL1	CL2	CL3	CL4	Test1	Test2	Test3
		N	56	54	56	56	56	55	53
	Test1	Pearson Correlation	-.02	-.06	-.39**	-.35**	1	.34*	.25
		Sig. (2-tailed)	.86	.66	.002	.008		.01	.07
		N	57	55	58	56	58	57	54
	Test2	Pearson Correlation	-.08	-.04	-.31*	-.14	.34*	1	.56**
		Sig. (2-tailed)	.56	.80	.02	.30	.01		.00
		N	56	55	57	55	57	57	53

**. Correlation is significant at the .01 level (2-tailed).
*. Correlation is significant at the .05 level (2-tailed).

This could show the strength of the CS maintaining the cognitive loads at low levels It is also worth mentioning the weak positive relationship between the cognitive load 1 and cognitive load 4 of +.28 at p = .04. It is important to remember that Cognitive load 1 was when the CS were being used and cognitive load 4 was when there were no CS being used. The cognitive load 2 interestingly had a moderate positive relationship to the cognitive load 4 and a high significance of p = .004 (see Table 45 and Appendix SSS). One can surmise that the CS decreased the cognitive load and almost sustained the low levels throughout. In the same table and appendix, cognitive load 3 had a moderately negative relationship with both Test 1 and Test2. It is important to note again that this is when the CS was being used. As the marks increased the cognitive load decreased. Cognitive load 4 also had a moderate negative relationship which was significant with Test 1.

Pearson's correlation coefficient indicates that there was a moderately negative relationship with the Test 1 and Test 2 marks. To determine the relationship with Test 3 for the CS group, it can be seen that the relationship was not significant (see Appendix SSS). By the time the learners wrote Test 3, they had experienced both the CS and not using the CS.

We may be looking at a combination of the effects of both, hence there not being a relationship of the cognitive load and Test 3.

5.2.1.5 Effect sizes for research question 5 and 6.

Effect sizes for the non-parametric equation using r (see section 3.9.1.6) where the effect size may be considered under the following guidelines if $r = 0.1$ it is small; $r = 0.3$ it is medium and $r = 0.5$ it is a large effect size (Field, 2009, pp. 539-583).

The effect sizes as indicated in Table 46 are derived from the use of non-parametric equations. Lower cognitive loads are found when CS are used. Effect sizes are larger where the CS are used when the female learners are involved, see Table 46 and compare with for the Mann-Whitney U test for CL1 effect size 0.30 compared to the male of 0.07; in the Wilcoxon signed ranked test where the effect sizes for the male and female are compared the female are higher. The highest effect size is a CS one of 0.57 and it was a large effect size.

The cognitive loads differed depending on the use of CS or not and at times these differences were not significant (see Table 46). The effect sizes with regard to cognitive loads are small, there are very few medium and only one large effect size. A Mann-Whitney comparison for the cognitive load for the Without CS and With CS for the female participants indicated a difference. The difference was significant and the female Without CS had a higher cognitive load. This is an important result since the female learners performed better in the knowledge items of the test with the use of CS. It is observed or it can be inferred that the use

Table 46

Effect Sizes of the Non-Parametric Tests for Research Questions 5 and 6

Variable	For	r	Significant?	Effect size	Higher
Mann-Whitney U test					
CL1	Learners Without CS and With CS	0.21	yes	small	Without CS
CL3	Learners Without CS and With CS	0.10	No	Small	Without CS
CL1	Male Without CS and With CS	0.07	No	V small	Without CS
CL1	Female Without CS and With CS	0.30	yes	medium	Without CS
CL3	Male Without CS and With CS	0.08	No	small	Without CS
CL3	Female Without CS and With CS	0.17	No	small	Without CS
Wilcoxon signed ranked test					
CL1- CL2	Without CS	0.29	Yes	medium	CL1
CL1- CL2	With CS	0.10	No	small	CL1
CL3-CL4	Without CS	0.27	Yes	Small	CL4
CL3-CL4	With CS	0.26	No	small	CL4
CL1- CL2	Male Without CS	0.47	yes	Medium	CL1
CL1-CL2	Male With CS	0.25	No	Small	CL1
CL1- CL2	Female Without CS	0.35	No	Medium	CL1
CL1-CL2	Female With CS	0.23	No	Small	CL1=CL2
CL3-CL4	Male Without CS	0.12	No	Small	CL3=CL4
CL3-CL4	Male With CS	0.36	No	medium	CL3=CL4
CL3-CL4	Female Without CS	0.57	Yes	Large	CL4
CL3-CL4	Female With CS	0.37	No	Medium	CL4

of the CS group led to a lower cognitive load in the first two days r = 0.30 (see Table 46 for the female learners). Recall too that the female With CS performed better (see section 4.3.2.4, Table 27).

One of the anomalies in the female group Without CS where there is a large effect size when the CS were used in the second week, with a significant difference but the direction was in increasing the cognitive load. The female learners who were not using the CS increased the cognitive load in the second week and but was not a significant change because the effect size was medium. The use of a teacher centred approach without CS could also lead to a reduction in the cognitive load. A significant difference between the cognitive load in the first two days in the first week was found, the cognitive load decreased and it was a medium effect of 0.3 (when corrected to one decimal place).

In addition, the male learners in the group Without CS in the first week also showed a (strong) medium effect of 0.47 which was significant. The male learners not using CS led to a reduction in the cognitive load. This is important when one includes the result of performance improving without using the CS for the male learners in the first week (see Table 47). This was also found with the female learners in the group Without CS who had a medium effect of 0.35 despite its not being significant (see Table 46).

When one looks at all except the last result analysed, it can be surmised that it is possible to reduce the cognitive load by both CS and no CS. On which is better, the CS reduced the cognitive load except in the instance where even the no CS had not reduced it.

5.2.1.6 Summary for research questions 5 and 6.

The cognitive load was lower for the learners who were using CS with the median of 2 while those not using CS the median was 5 in the first week (see 5.2.1.1 under (a)), the difference was significant though the effect size was small $r = 0.21$.

In the second week the cognitive load at the beginning of the week for the group using CS was not significantly different from those not using CS, the median was 3 while those not using CS was 2 (see 5.2.1.1 under (b)) and the effect size was small $r = 0.10$.

When the case was considered for the gender, it was found that the mean rank for the male group With CS was 23.74 while for those With CS was 25.48 with a very small effect size $r = .07$ (5.2.1.1 under (c)). The female group was significantly different for the group

Without CS and the group With CS. The mean rank for the female learners Without CS was 30.52 while those using CS was 21.86. The effect size was medium. The female learners in With CS had a lower cognitive load than the female learners Without CS.

The second week the male group who were using CS had a mean rank of 13.35 while those not working with the CS was 15.10. The difference was not significant and the effect size was small (see 5.2.1.1 under (d)). The female group in the second week was not significantly different and the effect size was small, with those using CS having a mean rank of 17.14 and those not using at 13.04 at the beginning of the week. The female learners in the second week when using CS experienced a higher cognitive load than those who were not using the CS.

An analysis of the how the load changed (see 5.2.1.2) for the first week:

A further look at how the cognitive load was different for the within group effect, it was noted that the use of CS in the first week did not significantly reduce the cognitive load and the effect size was small r = 0.10 (see 5.2.1.2 under (a)). The mean reduced from 4.20 to 3.88. When the second week is considered there was a significant increase with a medium effect size (when corrected to one decimal place) of r = 0.27, when CS were used for the second week with the Without CS group, this was explained as something to ponder about, but since it affected both the using and not using of CS, it was seen as affecting both equally.

When the gender was taken into consideration, the cognitive load decreased in the first week but it was not significant (see 5.2.1.2 in (c)) with a medium effect size of r = 0.25. The female group on the other hand had no significant difference but there was a small effect size r = 0.23 (see 5.2.1.2 in (c)). In the second week the male who used CS there was no significant change and the effect size was a small one (see 5.2.1.2 in (c)). And the female in the second week who used CS, the change was significant and the effect size was a large one, r = 0.57. The CS increased the cognitive load from a low mean of 3.33 to a still low median of 4.83 (see 5.2.1.2 (c)). While the lack of use CS increased the cognitive load from a low mean of 2.67 to a still low mean of 3.42 (see 5.2.1.2 (d)).

5.2.2 Data presentation and analysis for research question 7 and 8 based on using speed for groups Without CS and With CS.

This section considers the effect of speed with regard to the group with CS and the group without CS. It could be argued that if one has mastered or if the skills or knowledge are in the long term memory where schemas are formed as indicated in chapter 2 section 2.7.1 it is quicker to retrieve the information (Burke, 2007).

- Research question 7:

  What is the effect on Grade 11 learners (male/female) when the topic Geometrical Optics is taught using a teacher centred approach in the acquisition of knowledge and skills with the use of computer simulations on the speed?

- Research question 8:

  What is the effect on Grade 11 learners (male/female) when the topic Geometrical Optics is taught using a teacher centred approach without the use of computer simulations in the acquisition of knowledge and skills on the speed?

5.2.2.1 Data and analysis of Research questions 7 and 8.

(a) Independent samples t-test for writing times.

Writing Time 1 Without CS and With CS.

Given that the homogeneity of variance by the Levene's test, $F(1, 101) = 0.001$, $p = .98$ ($p > .05$) was upheld, a test assuming equality of variances was calculated (see Appendix TTT and Table 47). The result of this test indicated that there was no significant difference in the scores $t(101) =- 1.09$, $p = .28$ ($p > .05$) and $d = 0.28$ (small effect see section 5.2.2.2). These results suggest that the writing time 1 of those in the Without CS (M = 24.23, *SD* =

5.18) and With CS (*M* = 23.14, *SD* = 4.91) conditions with regard to writing times were the same (see Appendix TTT).

Table 47

Levene's Test and Independent t-Test for Writing Times

		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
Writing Time 1	Equal variances assumed	.001	.98	1.09	101	.28	1:05	0:59	-0:53	03:04
	Equal variances not assumed			1.08	92.17	.28	1:05	1:00	-0:54	3:05
Writing Time 2	Equal variances assumed	12.88	.001	-1.98	99	.05	-1:25	0:43	-2:51	0:00
	Equal variances not assumed			-2.06	90.42	.04	-1:25	0:41	-2:47	-0:03
Writing Time 3	Equal variances assumed	23.41	.000	1.87	88	.07	1:22	0:44	-0:05	2:49
	Equal variances not assumed			2.20	76.34	.03	1:22	0:37	0:07	2:36

Writing Time 2 Without CS and With CS.

Given that the homogeneity of variance by the Levene's test, F(1, 99) = 12.88, *p* = .001 (p < .005) was not upheld, a test not assuming equality of variances was calculated (see Appendix TTT and Table 47). The result of this test indicated that there was a significant difference in the scores t(90) =- 2.06 p = .04 (p < .05) and d = 0.39 (small effect size, see section 5.2.2.2). These results suggest that the writing times of those in the Without CS (M =

16.16, *SD* = 2.57) and With CS (*M* = 17.58, *SD* = 4.28) conditions with regard to writing times were not the same (see Appendix TTT).

Writing Time 3 Without CS and With CS.

Given that the homogeneity of variance by the Levene's test, F(1, 88) = 1.87, *p* = .000 (p < .001) was not upheld, a test not assuming equality of variances was calculated (see Appendix TTT and Table 47). The result of this test indicated that there was a significant difference in the scores t(76) =- 2.20 p = .03 (p < .05) and d = 0.40 (small effect see section 3.9.1.5). These results suggest that the writing times of those in the Without CS (M = 14.30, *SD* = 1.63) and With CS (*M* = 12.93, *SD* = 4.13) conditions with regard to writing times were not the same (see Appendix TTT).

(b) Independent Samples t-test based on gender.

An analysis was made based on the gender of the learners in terms of the Writing time.

Male Writing time 1.

Given that the homogeneity of variance by the Levene's test, F(1, 47) = 1.51, *p* = .23 (p > .05) was upheld for the male learners, a test assuming equality of variances was calculated (see Table 48). The result of this test indicated that there was no significant difference in the writing time 1, t(47) = 1.76 and p = .09, p > 0.05 (see Table 48) and d = 0.50 (medium effect see section 3.9.1.5). These results suggest that the male learners in the group Without CS (M = 24.67, *SD* =5.30) and in the group With CS (*M* = 22.34, *SD* = 3.98) conditions were not significantly different (see Appendix UUU).There was a higher mean for the Without CS. This indicates that the male learners in the Without CS wrote for a longer time than With CS though there was no significant difference.

Table 48

Levene's Test and Independent t-Test for Writing Times Based on Gender

Gender			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
Male	Writing time1	Equal variances assumed	1.51	.23	1.76	47	.09	2:20	1:20	-0:20	5:00
		Equal variances not assumed			1.71	38.19	.10	2:20	1:22	-0:26	5:06
	Writing Time2	Equal variances assumed	3.68	.06	-.06	47	.95	-0:04	1:00	-2:04	1:56
		Equal variances not assumed			-.07	44.33	.95	-0:04	0:58	-2:01	1:54
	Writing Time3	Equal variances assumed	17.54	.000	1.53	41	.14	1:34	1:01	-0:30	3:37
		Equal variances not assumed			1.82	31.99	.08	1:34	0:51	-0:11	3:18
Female	Writing time1	Equal variances assumed	.70	.41	-.02	52	.98	-0:02	1:29	-3:01	2:57
		Equal variances not assumed			-.02	49.48	.98	-0:02	1:28	-2:59	2:55
	Writing Time2	Equal variances assumed	12.38	.001	-2.63	50	.01	-2:42	1:02	-4:45	-0:38
		Equal variances not assumed			-2.81	44.38	.01	-2:42	0:58	-4:38	-0:46
	Writing Time3	Equal variances assumed	7.87	.007	1.13	45	.27	1:12	1:04	-0:57	3:21
		Equal variances not assumed			1.32	42.12	.19	1:12	0:55	-0:38	3:03

Male writing time 2.

Given that the homogeneity of variance by the Levene's test, F(1, 47) = 3.68, $p = .06$ ($p > .05$) was upheld for the male learners, a test assuming equality of variances was calculated (see Table 48). The result of this test indicated that there was no significant difference in the writing time 1, t(47) = 0.06 and p = .95, p > 0.05(see Table 48) and d = 0.02 (very small effect see section 3.9.1.5). These results suggest that the male learners in the group Without CS (M = 16.63, *SD* = 2.73) and in the group With CS (*M* = 16.69, *SD* = 4.00) conditions were not significantly different (see Appendix UUU). There was a higher mean for the With CS. This indicates that the male learners in the With CS wrote longer than the male learners Without CS though there was no significant difference.

Male Writing time 3.

Given that the homogeneity of variance by the Levene's test, F(1, 41) = 17.54, *p* = .000 (p < .001) was not upheld for the male learners, a test not assuming equality of variances was calculated (see Table 48). The result of this test indicated that there was no significant difference in the writing time 1, t(32) = 01.82 and p = .08, p > 0.05 (see Table 48) and d = 0.48 (small effect see section 3.9.1.5). These results suggest that the male learners in the group Without CS (M = 14.21, *SD* = 1.28) and in the group With CS (*M* = 12.65, *SD* = 4.07) conditions were not significantly different (see Appendix UUU).There was a higher mean for the Without CS, who had just been taught using CS. This indicates that the male learners in the Without CS wrote longer than their counterparts With CS but with no significant difference.

Female Writing time 1.

Given that the homogeneity of variance by the Levene's test, F(1, 52) = 0.70, *p* = .41 (p > .05) was upheld for the female learners, a test assuming equality of variances was calculated (see Table 48). The result of this test indicated that there was no significant difference in the writing time 1, t(47) = 1.76 and p = .98, p > 0.05(see Table 48) and d = 0.01 (very small effect, see section 3.9.1.5). These results suggest that the female learners in the group Without CS (M = 23.80, *SD* =5.14) and in the group With CS (*M* = 23.84, *SD* = 5.57) conditions were not significantly different (see Appendix UUU). There was a higher mean for the With CS. This indicates that the female learners in the With CS wrote for a slightly longer time than With CS though there was no significant difference.

Female Writing time 2.

Given that the homogeneity of variance by the Levene's test, $F(1, 50) = 12.38$, $p = .001$ ($p < .005$) was not upheld for the female learners, a test not assuming equality of variances was calculated (see Table 48). The result of this test indicated that there was a significant difference in the writing time 2, $t(44) = -2.81$ and $p = .01$, $p < 0.05$(see Table 48) and $d = 0.76$ (medium effect, see section 3.9.1.5). These results suggest that the female learners in the group Without CS ($M = 15.69$, $SD = 2.36$) and in the group With CS ($M = 18.38$, $SD = 4.43$) conditions were significantly different (see Appendix UUU). There was a higher mean for the female learners in the group With CS. This indicates that the female learners in the group With CS wrote longer than their counterparts Without CS.

Female writing time 3.

Given that the homogeneity of variance by the Levene's test, $F(1, 45) = 7.87$, $p = .007$ ($p < .01$) was not upheld for the male learners, a test not assuming equality of variances was calculated (see Table 48). The result of this test indicated that there was no significant difference in the writing time 1, $t(42) = 1.32$ and $p = .19$, $p > 0.05$ (see Table 48) and $d = 0.34$ (small effect, see section 3.9.1.5). These results suggest that the female learners in the group Without CS ($M = 14.38$, $SD = 1.94$) and in the group With CS ($M = 13.17$, $SD = 4.25$) conditions were not significantly different (see Appendix UUU). There was a higher mean for the Without CS, who had just been taught using CS. This indicates that the female learners in the Without CS wrote for a longer time than With CS though there was no significant difference.

5.2.2.2 Effect sizes for research questions 7 and 8.

Table 49

Effect Sizes for Research Questions 7 and 8

Variable	For	Cohen's d	Significant	Effect size	Higher
Independent Samples t-test for Writing time					
Time 1	Learners Without CS and With CS	0.28	No	small	Without CS
Time 2	Learners Without CS and With CS	0.39	yes	small	With CS
Time 3	Learners Without CS and With	0.40	yes	small	Without CS
Independent Samples t-test for Writing time based on gender					
Time 1	Male in Without and With CS	0.50	No	medium	Without CS
Time 2	Male in With CS and With CS	0.02	No	v small	With CS
Time 3	Male Without CS and With CS	0.48	No	small	Without CS
Time 1	Female Without CS and With CS	0.01	No	v small	With CS
Time 2	Female Without CS and With CS	0.76	yes	medium	With CS
Time 3	Female Without CS and With CS	0.34	No	small	Without CS

In general the learners who were using CS wrote longer than their counterparts not using CS (see Table 49). This is contrary to what was expected.

5.2.2.3 Summary for research question 7 and 8.

Initially there was no difference in the groups (time 1) see section 5.2.2.1. In the analysis it was found that the group that used the CS took longer to write the test compared to the group who did not use the CS. However if the means were compared in the tests the learners who were using CS outperformed their counterparts (see section 4.2.3.3)

5.3 Summary

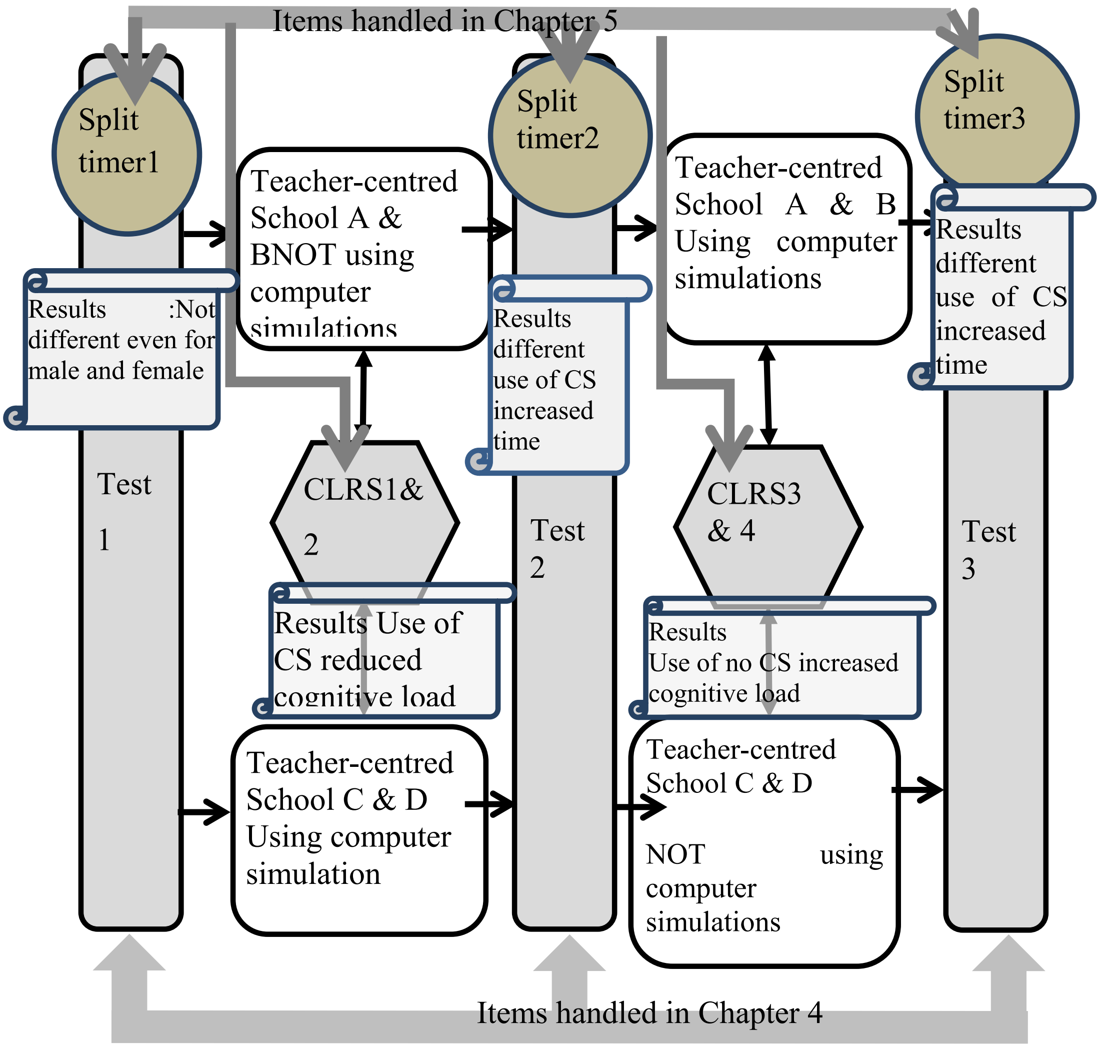

Figure 18. Summary of findings for Chapter 5.

The summary on the findings for the chapter in *Figure 18* indicate that the use of CS led to a decrease in the cognitive load in general. The cognitive load decreased for the female learners compared to their male counterparts.

The assumption was that the learners using CS will write shorter compared to their counterparts not using CS. This was supported by literature (Paas, Renkl, & Sweller, 2003; van Merrienboer, Kirschner, & Kester, 2003). However according to our findings those learners using CS wrote longer. It was found that all learners had significant improvement in the knowledge items in the test (see results Test 1K, Test 2K and Test 3K in section 4.2.2.1; 4.2.3.1 and 4.2.3.2) after using CS. It could possibly be interpreted that it was easy to retrieve information not necessarily quicker.

Chapter 6

Summary, Implications, and Recommendations

6.1 Introduction

In this chapter, the researcher for this project will summarise what was set out to be investigated. What has been found will be put together and the implications of what was found put into context. Recommendations will also be offered.

Eight research questions were formulated and will be answered individually and placed in context. Suggestions will be provided with regard to further research and implementation.

6.2 Summary of Findings

6.2.1 Research question 1.

- What is the effect on Grade 11 learners in terms of gender (male/female) when the topic geometrical optics is taught using a teacher centred approach in the acquisition of knowledge with the use of computer simulations?

The use of CS had an effect on the performance in terms of the acquisition of knowledge of 105 grade 11 learners on the topic geometrical optics.

In the analysis of the data, it was indicated that the female learners had greater improvement in their performance compared to their male counterparts on the Test of Describing the Relationships between variables in Geometrical Optics (TDRV-GO) marks as a result of the computer simulations.

Week 1.

The female learners' use of CS through independent samples t-test (see section 4.2.3.1 and Table 20) and paired samples t-test (see section 4.2.3.3 and Table 23) led to medium to large effect sizes, where the highest effect size of the study was 1.12 and due to female learners using the CS. When the male learners were compared when using CS the independent samples t-test (see section 4.2.3.1 and Table 20) and paired samples t-test (see section 4.2.5.4 and Table 23) the corresponding effect size was 0.65 and it too was significant.

Week 2.

The female learners' use of CS through independent samples t-test (see section 4.2.3.2, Table 21 and Table 23) and paired samples t-test (see section 4.2.3.3, Table 24 and Table 26) led to small effect sizes when the groups were looked at without considering the gender; while small to medium effect sizes were observed when gender was factored in. The female using CS had effect sizes of 0.6 leading to higher scores compared to males with effect size of 0.5 and decreasing scores.

In terms of the acquisition of knowledge this study extends the field because related studies in support of better conceptual understanding did not consider gender, but recorded effect sizes of 0.70 (Zacharia, 2007; Gunter, 2010). The females' gain in knowledge as a result of using CS was more pronounced in this study, the effect sizes attest to this. Literature indicates that where computers are not prevalent in societies, there is a tendency for males to be more exposed than female (Dong & Zhang, 2011). In this study females used them and they took advantage of what they had not been exposed to previously. There is evidence that this is what was observed in a study in China and in US. In advanced countries where the use of computer is prevalent, there are no great differences (Hyde & Mertz, 2009; Sentongo, Kyakulaga, & Kibirige, 2013).

When the theoretical framework of the cognitive load theory and the cognitive model of multimedia learning is taken into consideration, where the use of computer simulations are used and as a result of the visual and the supported manipulations by the educator it would be expected to increase the germane load where the amount of resources for learning are increased.

6.2.2 Research question 2 and summary of findings.

What is the effect on Grade 11 learners in terms of gender (male/female) when the topic geometrical optics is taught using a teacher centred approach in the acquisition of knowledge without the use of computer simulations?

Next, the researcher gives a week-by-week summary.

Week 1.

There was a registered improvement from a mean 2.95 in the pre-test to 3.35 in the test after the intervention. There was a 0.45 effect size in improvement (section 4.2.3.3 and Table 23). This is when the CS were not being used and it was the teacher alone. With regard to the gender and how it worked out, it was found that the male learners improved from a low mean of 3.09 to 4.09 which was significant and a 0.72 medium effect size (see section 4.2.3.3 and Table 25). On the other hand, the female learners who were not using CS improved from a low mean of 2.81 to 2.90 not significant and a very small effect size of 0.07. Indeed there was an improvement but a very small one for the female learners.

Week 2.

The not using CS for the group led to not significant small effect sizes for the group that had started off using CS (see section 4.2.3.3 and Table 26). In the same group the male learners decreased from a mean of 4.38 to 4.31, however this was not significant and it was a very small effect size. The female learners' not using CS led to a slight increase from a mean of 4.36 to 4.71 though not significant led to a small effect size (see 4.2.3.3, Table 26 and Appendix OO).

The increases in the second week are small but when the findings of week 1 and week 2 are combined, one can see the importance of the educator. Even when the CS are not being used there was an improvement in the performance.

6.2.3 Research question 3.

What is the effect on Grade 11 learners in terms of gender (male/female) when the topic geometrical optics is taught using a teacher centred approach in the acquisition of skills with the use of computer simulations?

The researcher will split the summary into week 1 and week 2.

Week 1.

The analysis showed that the acquisition of skills at the onset of the intervention were the same for the two groups, those who were in the With CS and the Without CS (see section 4.2.6.1 (a)).

The use of computer simulations within a teacher centred approach increased the acquisition of skills but not significantly with a small effect size Cohen's d of 0.25 from Test 1 to Test 2.

When the gender was compared in section 4.2.6.1 (b) with regard to the effects when computer simulations were used, the performance decreased for the male learners and Cohen's d = 0.26. The change however was not significant. On the other hand the effect on the female learners was positive and it led to an improvement in skills with Cohen's d = 0.18 a small, but not significant, effect.

Week 2.

In the analysis using the switching replications design where in one group we had computer simulations then later there was no computer simulations while the second group which started with no CS and later used the CS. When using an independent samples t-test, (see section 4.2.6.2_ the skills at the end of week 2 were the same for the two groups

In the second week when the switching had taken place the group that was not using CS did use CS. The performance on skills of the learners without CS, decreased however it was not significant and the effect size was very small d = 0.015.

When the effects on the gender were analysed for the second week, the following emerged when computer simulations were used. There was a small effect size of 0.26 for the male learners and it was not significant. Similarly it was also not significant for the female learners whereby the effect size was d = 0.27.

In a study to determine if CS could improve skills in biology, a group of students used the traditional laboratory and the others used CS. The group of students who were not using CS improved in the score in the test of understanding (Gibbons, Evans, Payne, Shah, & Griffin, 2004). In another practical exercise where the chromosomes had to be cut, the CS group improved much more than the one that used the traditional practical whereas in the group where they had to use bioinformatics there was no significant difference in the test scores.

In the current study, the items measuring skills had lower effect sizes than the items on knowledge. There was even a lower performance by the male learners than their counterparts the females. Whereas in the knowledge items we had medium to large effects the effect sizes for the skills was mostly small as shown in section 4.2.4.2. The current study points to possible evidence of a limitation of the teacher centred approach in developing skills in geometrical optics or science in general. In the Gibbons et al (2004) study, the comparison was with a traditional laboratory with a hands on approach in this case it was use of a teacher centred approach. The difference with the current study was the CS led to some gains, though the effect sizes were quite low, and there were reversals in the second week.

6.2.4 Research question 4.

What is the effect on Grade 11 learners in terms of gender (male/female) when the topic geometrical optics is taught using a teacher centred approach in the acquisition of skills without the use of computer simulations?

The analysis showed that the skills at the onset of the studies were the same for both the groups (those who were using CS and not using; see Section 4.2.4.3).

Week 1.

When the independent t-test for Test 2S was done it was not significant and there was no difference in the With CS and Without CS groups. Cohen's d = 0.25 a small effect size (see section 4.2.4.1). The trend was the same when the male and female learners were compared with those using and not using. The male d = 0.25 a small effect size and was not significant, whereas the female learners was d = 0.18 and was not significant and hence not different. The use of paired tests for the gender (see section 4.2.4.3) indicate that for the male learners there was a small effect size of 0.19 and the difference in the scores was not significant. The female learners on the other hand showed a medium effect size of 0.67 (see section 4.2.4.3) and a significant improvement as a result of not using CS. The development of skills could be as a result of close engagement and interaction and confidence. The educators being in their own comfort zone could have led to the significance noted for the female learners.

Week 2.

The independent t-test for Test 3S was done comparing the marks in the With CS and Without CS there was a very small effect size of 0.06 (see section 4.2.4.1). The independent t-test for Test2 for the gender: with regard to the male learners there was a small effect size of 0.24 and it was such that those who used CS in the second week were better than those who did not use them. While for the female learners those who used CS in the second week had less mean marks than those who were not using them.

When the paired t test was done (see section 4.2.4.3) there was a small effect size of 0.19 and the score increased but not significantly. In terms of gender the male increase was not significant and had a small effect size of 0.15 was increasing while the female was not significant but a small effect size of 0.41 (see section 4.2.4.3).

Whereas there were great gains in the acquisition of knowledge as a result of CS, what was seen was small if any gains in the skills side of describing the relationships between variables in geometrical optics. Not using CS led to a gain in acquisition of skills in the teacher centred approach. Looking at the approach where teacher centred was used one could say it would be important that a hands on minds on is needed to lead to greater gains in skills acquisition. The other issue could be a consideration of using a learner centred approach. Manipulating at an individual level could be an imperative that could be more helpful than when everyone is looking at what is being manipulated by one person. To check on this it could be an investigation where if the manipulator benefitted more than those watching or where one takes instructions from others to manipulate and checking to determine which participants benefit from this situation.

6.2.5 Research question 5.

What is the effect on Grade 11 learners in terms of gender (male/female) when the topic Geometrical Optics is taught using a teacher centred approach in the acquisition of knowledge and skills with the use of computer simulations on the cognitive load?

The importance of instruction to reduce the cognitive load can be indicated when the extraneous load up frees up cognitive resources in the germane side which increases available resources for knowledge acquisition leading to what is learnt going to the long term memory. When it is in the long term memory it will not be forgotten. Reducing the extraneous load could be reduced by use of media ((Paas & Van Merriënboer, 1994; Clark, Kirschner, & Sweller, 2012; Stull & Mayer, 2007) and at times the way instruction is structured ((Paivio, 1991).

The researcher will summarise the findings in terms of what happened in week 1 and week 2.

Week 1.

To determine the effect of CS on the cognitive load, two tests were used namely the Mann-Whitney U-test and the Wilcoxon Paired samples U test. The Mann-Whitney test indicated that there was a significantly difference in cognitive load between the groups With CS and Without CS however the effect size was small. The group With CS had a lower cognitive load in the first two days of the week when the intervention started. The cognitive load had a median score of 2 while the mean was 1.56 SD = 0.50; the mean rank of the With CS was 44.56. To put it in context the mean rank of the Without CS group was 56.08 and therefore the group With CS had a lower cognitive load.

When the Wilcoxon paired samples U test was used in general and then male and female separate for the use of CS there was a decrease in general and for the male learners for the cognitive load and for the female learners it remained the same.

The decrease in the cognitive load through use of CS for the male participants was not significant. The Wilcoxon Signed Rank test failed to reject that it since p = .20 (2-tailed). However the effect size r = 0.25 was small. The cognitive load was already low at $M = 4.48$. There was the same effect on the group the Without CS, it decreased but was not significant.

Week 2.

In Week 2 that when the switching took place the group that was not using CS used CS and the group With CS did not use CS. This section will consider when the CS were used.

When the Without CS group used computer simulations the cognitive load increased significantly with a medium effect, see section 5.2.1.2 (b). The use of CS increased the cognitive load and the effect size of the change was r = 0.27, it was a small effect. The increase was from an Mdn of 3 to an Mdn of 3.5.

The cognitive load for the male learners remained the same when the mean was considered and it was not significant. For the case of female the cognitive load increased significantly and it was a large effect. However when one considers where it started it was a very low cognitive load of 3.33 and increased to 4.83. The cognitive load ranged from 1 to 10.

According to the Cognitive load theory (Chen J. , 2010) when the extraneous cognitive load is reduced, the cognitive resources which process information the germane cognitive load increases, this should be the ultimate for learning. In this case we are observing that CS reduced the cognitive load as in section 5.2.1.5. From the theoretical framework we could say it was possible that germane load resources were available for the learners to use and process what was being taught.

Issues that could possibly reduce attention as indicated in literature could include split attention (Plass, Hommer, & Hayward, 2009). For split attention could be where the teacher and the CS were working at the same time, or the pacing of the materials so that work is not very well covered but this was reduced since the groups were not so big. Since the learners were able to observe what was happening it must have freed germane resources so as to learn.

Instances where the cognitive load increased instead of reducing could be the initial load may have been low as when the use of no CS also led to the load reducing.

6.2.6 Research question 6.

What is the effect on Grade 11 learners in terms of (male/female) when the topic Geometrical Optics is taught using a teacher centred approach in the acquisition of knowledge and skills without the use of computer simulations on the cognitive load?

The researcher will summarise these results in terms of week 1 and week 2.

Week 1.

The Mann-Whitney U-test indicated that the cognitive load due to the With CS and Without CS was significantly different however the effect size was small. It showed that the

Without CS group had a higher cognitive load as measured in the first two days of the week when the intervention started. The cognitive load had a median score of 5 while the mean was 4.57 SD = 1.84 (see Appendix ZZ); the mean rank of the Without CS was 56.08. To put it in context the mean rank of the With CS was 44.56 (see Appendix YY).

With regard to the gender, the male learners' being taught using no CS in the first week, the decrease in the cognitive load was significant and the effect size was large (see 5.2.1.2 (b)), r = 0.47. With regard to the female with no CS use of the Wilcoxon Signed Rank test, was not significant in the first week and we could not say the effect was there at p = .05 (1-tailed). However the change as not using CS was a medium effect r = 0.37 (see 5.2.1.2 (d).

Week 2.

When the With CS group did not use CS the cognitive load increased significantly with an effect size of the change was r = 0.36, it was a medium effect. When the With CS in using the teacher centred approach the cognitive load increased from a low of M = 3.14 to 3.68.

The lack of use of CS did not increase the cognitive load significantly in the second week for the With CS group. It must still be emphasised that the cognitive memory was already low at the beginning of the week.

In the second week there was no significant effect on the increase in the cognitive load for the With CS using no CS. It is important to note that the mean of the cognitive load was $M = 2.67$.

Instructional handling of materials could be another way of reducing the cognitive load (Kaylor, 2014). In the results it is noted that the cognitive load also reduced by learners who were not using simulations. The purpose of instruction is to "reduce extraneous cognitive load and redirect learner's attention to cognitive processes." (Sweller J. , 1988, p.

265). The way the educators taught the learners as well as the notes provided could have helped to reduce the extraneous cognitive load and free up the germane load for learning. The importance of this was that the role of the teacher cannot be overlooked and that the teacher centred approach used by the majority of teachers in South Africa can be conducive to reduce the cognitive load. It can be added further that schools or the department could support the development of teachers by encouraging them in the use of CS.

6.2.7 Research question 7 and 8 and summary of findings.

- Research question 7:

  What is the effect on Grade 11 learners (male/female) when the topic Geometrical Optics is taught using a teacher centred approach in the acquisition of knowledge and skills with the use of computer simulations on the speed?

It was found that whenever the test took place the group that used CS wrote longer. This was also evident when the switching was done; the groups that used CS took longer to finish the tests.

- Research question 8:

  What is the effect on Grade 11 learners (male/female) when the topic Geometrical Optics is taught using a teacher centred approach without the use of computer simulations in the acquisition of knowledge and skills on the speed?

The groups that did not use CS in the week they were writing the tests, took a shorter time to write.

6.3 Significance of Findings

6.3.1 Significance of findings for RQ1 and RQ2.

The computer simulations increased performance in the knowledge items, as indicated by current and the dated literature (Araujo, Veit, & Moreira, 2008; Balamuralithara & Woods, 2009; Bayrak, 2008; Carolus, 2009; Atash & Dawson, 1986; Chou, 1998).

The interventions that used the transmission model with a teacher centred approach only could not produce large effect sizes. The findings indicated that large effect sizes were achieved by the use of computer simulations in teacher centred classes (Adams, et al., 2008b; Chukhlomin, 2011; Chang, 2003; Kotoka & Kriek, 2014). Hake (1998) was emphatic that large effect sizes could not follow from teacher centred interventions. This study indicates that the use of computer simulations indeed result in large effect sizes contradictory to the findings of Hake (Hake, 2002). What Hake had emphasised was the large Cohen's d = 2.43 (Hake, 2002, p. 10) an effect size which interactive engagement by learners had over the traditional methods of teaching aka teacher centred approach. To him the important issue was to encourage instruction to be actively engaged other than focus on reducing gender gap. This study shows huge gains through use of CS especially with regard to the female learners.

Finally, females compared to male learners in the research improved with large effect sizes of 1.12 as a result of the use of computer simulations. According to research it is indicated that computer simulations or interventions using technology favours males or is the same for all (Hsi & Hoadley, 1997; Hwang, Hong, Cheng, Peng, & Wu, 2013). The findings in this study indicate that females gained much more and a lot. Literature that supports this finding is found in the study by Dong & Zhang (2011), where Chinese females also improved a lot in the adoption of technology. Other studies indicate that gender was not an issue (Udo & Etiubon, 2011; Sentongo, Kyakulaga, & Kibirige, 2013; Richardson & O'Shea, 2013) in a study to determine how various approaches including CS affect performance in Chemistry at high school in Nigeria, Uganda and US respectively. In the current study CS indicate a better female improvement in performance than males with regard to knowledge items.

6.3.2 Significance of findings for RQ3 and RQ4.

The use of CS were not significant in the acquisition of skills in GO. With regard to gender the male learners reduced in performance while the female learners improved by a small effect size though it was not significant. Small effect size improvements were observed generally for the learners not using CS though there was a medium effect size increase for the female learners which were also significant. The use of no CS with traditional teaching are treated as having less effects to interventions, but what is seen is medium gains for skills (Hake, 1998).

6.3.3 Significance of findings for RQ5 and RQ6.

The cognitive load decreased for the groups that used CS at the start of the week, however this increased during the week. This was observed in the first and second week. Literature indicates a reduction in the cognitive load when using computer simulations, however, the results come out inconclusively (Burke, 2007; Moreno, 2007; Muller, Sharma, & Reimann, 2008; Paas, Renkl, & Sweller, 2003; Paas & Sweller, 2012). Something that comes out of the data and analysis is that the use of no CS using a teacher centred approach is also important in decreasing the cognitive load. It is necessary to use the educators in the teaching so as to reduce the cognitive load.

There is a decrease initially, but gradually the CL increases with time. It could be the result of novelty, where a new technology or a new way of doing things is introduced people are excited and in this way the excitement could have led to a low cognitive load (Kothari, 2004).

6.3.4 Significance of findings for RQ7 and RQ8.

When a skill is gained, the speed in executing the task is increased (Taatgen, Huss, Dickison, & Anderson, 2008). It was this postulation that lead to this research question. No effect of the use of CS was found in the speed of writing the tests – in fact findings indicate that computer simulations increased the time of writing the test. A number of reasons could be offered such as when the performance in a test is higher it does not necessarily mean the learners wrote the test faster – information could be easy to retrieved and has nothing to do with speed. Another possible reason could be as the CS increased the performance one could indicate that the time they spent was through understanding the question and able to answer the questions correctly.

Research could be done especially with regard to the similar schools in Vhembe where active learning or a learner centred approach using CS for skills development could be used

6.4 Contribution of the Research

The findings indicate that despite the schools being in the rural areas they would benefit from the use of the computer simulations and the following reasons are presented:

The use of computer simulations leads to medium to large effect sizes with regard to learning in the domain of knowledge. Effect sizes of 0.4 are indicated as the cutoff where anything greater is very good (Hattie, 2003). In this study, an effect size of $d = 1.12$ and $d = 0.95$ were found for the female learners, which is an indication of a very good improvement through use of CS. The fact that the female learners benefitted more by using CS in the acquisition of knowledge compared to their male counterparts it could be used of address the need to encourage or motivate the female learners in the areas of science and mathematics (Hyde & Mertz, 2009).

The use of CS was not significant in the acquisition of the skill of describing relationships between variables in geometrical optics.

The findings support the importance of the educator in the classroom and the significance of a teacher centred approach.

The theoretical framework indicates three cognitive loads, the extraneous, intrinsic and germane. A reduction in the extraneous cognitive loads frees up space for the germane cognitive load and it is this that leads to positive, actual learning and the formation of schemas which eventually lead to long term memory (Sweller J. , 1988; Paas, Renkl, &

Sweller, 2003). This research has shown that CS indeed reduced the cognitive load of the learners but only initially. With time the CL increased.

No effect of the use of CS was found in the speed of writing the tests – in fact findings indicate that computer simulations increased the time of writing the test.

6.5 Suggestions for Further Research

Whereas knowledge items showed a great gain, the skills items showed very small or no gain. That indicates there was need for further research into learner centred approaches of using computer simulations in the acquisition of skills in physical science. It would be interesting that the research also considers how the male and female learners are affected by the intervention.

As an aside, these innovations can be undertaken by an individual, where a learner could learn from the use of the CS, practicing with them in the quiet of his room and computer or a mobile device. It could also be undertaken if a team of learners decide to use the CS in working on a topic (Adams, et al., 2008a; Adams, et al., 2008b). As the use of CS moves beyond the traditional approach, as this research has shown, it is important to determine how the educators are trained so that CS could be used in active environments. The implications of this go from the initial pre-service educator training and also to work on the existing educators in the profession which would lead to well defined professional development programmes.

Whereas teaching and learning was indicated with regard to how man can learn biologically primary knowledge (Paas & Sweller, 2012) (see Chapter 2 in this thesis) without a formal setting and that it was the biologically secondary knowledge that was taught in school situations, it would be necessary to study further how CS reduce cognitive load so as the biologically secondary knowledge to be easily learnt or assimilated. The importance of the biologically primary knowledge and letting biologically secondary knowledge be easily accessed wherein the CS could greatly lead to ease and great access to learning.

It would be necessary to measure the cognitive load for the learners as it is a fairly new thing in our current educational environment where different cognitive loads are indicated by the differing teaching approaches. Data would indicate what helps to reduce the loads and what does not.

6.6 Summary

The findings of the research have been looked from the starting points of the research questions 1 to 8. The findings have been discussed with regard to what they have added to the literature, most notably that the female learners greatly improved through the use of the computer simulations with regard to knowledge items. The females doing well did not mean the males did not improve they also showed great gain with regard to the use of computer simulations. The effect of the use of CS decreased the cognitive load initially and gradually increased with time.

With regard to areas of further research, it was suggested that the use of CS for acquisition of skills needs to be researched using learner-centred approaches.

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Appendices

Appendix A Matriculations pass rates according to the Provinces (Department of Basic Education, 2013)

Table 4: Overall performance of candidates in the 2013 NSC examination

Province	2013		
	Total Wrote	Total Achieved	% Achieved
Eastern Cape	72 138	46 840	64.9
Free State	27 105	23 689	87.4
Gauteng	97 897	85 122	87.0
KwaZulu-Natal	145 278	112 403	77.4
Limpopo	82 483	59 184	71.8
Mpumalanga	50 053	38 836	77.6
North West	29 140	25 414	87.2
Northern Cape	10 403	7 749	74.5
Western Cape	47 615	40 542	85.1
National	562 112	439 779	78.2

Appendix B NCS Content for Grade 11 geometrical optics

Geometrical optics:			
• lenses, image formation, gravitational lenses, spectacles, the eye;	• Describe the two general types of lenses, those that converge parallel beams of light (converging lenses), and those that diverge parallel beams of light (diverging lenses). • Describe all converging lenses as thicker in the middle than at the edge (convex), and all diverging lenses as thicker at the edge than in the middle (concave). • . • Define optic axis focal point and focal length (f). • Draw ray diagrams for converging and diverging lenses to locate the position of the image when the object is placed at distances from the lens greater than 2f, equal to 2f, between 2f and f, and less than f. • Describe the image in each of the cases mentioned above. • Describe how the human eye has a converging lens to create real, inverted, reduced images on the retina at the back of the eye. Focusing is achieved by muscles, which change the focal length of the lens. • Understand the meanings of long-sightedness, short-sightedness and astigmatism what causes these defects of vision. • Use simple diagrams to show how converging lenses can correct long-sightedness and diverging lenses can correct short-sightedness.	• State that the gravitational field of massive objects like galaxies, black holes and massive stars bend rays of light that pass close-by in accordance with predictions made by Einstein's Theory of General Relativity, and therefore act as a kind of gravitational lens, distorting, and altering the apparent position of, the image of a star. • Describe how astigmatism is corrected by a special lens, which has different focal lengths in the vertical and horizontal planes.	Learners should not try to memorise the ray diagrams for different lenses and object positions. The image of a point on an object can be located as follows: 1. For a converging lens, draw one ray from the point on the object straight through the centre of the lens. Draw a second ray from the object, parallel to the optic axis, and passing through the focal point on the other side of the lens. The image position is where these two lines cross. 2. For a diverging lens, draw one ray from the point on the object straight through the centre of the lens. Draw a second ray from the object, parallel to the optic axis that emerges on the other side of the lens at an angle that makes it look as if it came from the focal point on the same side of the lens as the object. Extend this ray back to this focal point using a dotted line. The image position is where the two lines cross.
• Telescopes, SALT;	• Draw ray-diagrams illustrating image formation by the refracting astronomical telescope and the reflecting telescope. • Know about the kinds of telescopes used at the Sutherland Observatory in the Western Cape and about the		Here is an excellent opportunity to contextualise the curriculum for South Africa. With the building of SALT, South Africa has become a world leader in optical telescopes.

Appendix C Grade 11 Pacesetter

LIMPOPO
PROVINCIAL GOVERNMENT
REPUBLIC OF SOUTH AFRICA

DEPARTMENT OF EDUCATION

PHYSICAL SCIENCES PACE SETTER GRADE 11 FOR 2012

Week number	Knowledge Area	Themes	Time-frame	Date		Comments
				started	completed	
3	Schools Re-Open: 16 January 2012 (Teaching starts on the 18th of January 2012)					
3 – 7	Matter & Materials	1. Electronic Properties of Matter 2. Atomic combinations: Molecular structure 3. Ideal gases and thermal properties	1.5 weeks 2.5 weeks 1 week			
8 – 12	Electricity & Magnetism	1. Electrostatics 2. Electric circuits 3. Electromagnetism	2 weeks 1.5 weeks 1.5 weeks			
13 -14	School holidays: 31 March 2012 – 09 April 2012					
Week number	Knowledge Area	Themes	Time-frame	Date		Comments
				started	completed	
15 – 19	Chemical Systems	1. Exploiting the Lithosphere/ Earth's crust 2. The atmosphere	3 weeks 1 week			
20-23	Waves, Sound & Light	1. Geometrical optics 2. Longitudinal waves	2 weeks 1 week			
24 – 25	**MID-YEAR EXAMINATION (± 2 WEEKS)**					
26 – 28	School holidays: 23 June 2012 – 15 July 2012					

Appendix D Ethical clearance UNISA

UNISA university of south africa

2 June, 2011

Mr. Sam Kaheru

South Africa

Dear Mr. Sam,

REQUEST FOR ETHICAL CLEARANCE: **Exploring the Use of Simulations in the Acquisition of Science Process Skills in High School Physical Sciences**

Your application for ethical clearance of the above study was considered by the ISTE sub-committee on behalf of the Unisa Research Ethics Review Committee on 20 January, 2011.

After careful consideration, your application is hereby **approved** and hence you can continue with the study at this stage.

Congratulations.

C E OCHONOGOR, *PhD*
CHAIR: ISTE SUB-COMMITTEE

cc. PROF T S MALULEKE
EXECUTIVE DIRECTOR: RESEARCH

PROF M N SLABBERT
CHAIR- UREC.

University of South Africa
Preller Street, Muckleneuk Ridge, City of Tshwane
PO Box 392 UNISA 0003 South Africa
Telephone +27 12 429 3111 Facsimile +27 12 429 4150
www.unisa.ac.za

Appendix E Permission from Vhembe District Manager to Conduct research

LIMPOPO
PROVINCIAL GOVERNMENT
REPUBLIC OF SOUTH AFRICA

Ref: 14/7/R
~~Enq: M.S. Matibe~~
Tel: 015 962 1029

DEPARTMENT OF
EDUCATION
VHEMBE DISTRICT

DEPARTMENT OF EDUCATION
VHEMBE DISTRICT
DSM'S OFFICE
2011 -02- 18
PRIVATE BAG X2250, SIBASA 0970
TEL: 015 962 1313/4
LIMPOPO PROVINCE

Mr. Sam J.M. Kaheru

P.O.BoX 6532

Thohoyandou

0950

APPLICATION TO CONDUCT RESEARCH IN SCHOOLS IN THE DISTRICT

1. The above-stated matter has reference
2. Your application for permission to conduct a research to investigate the effect of computer simulations in the acquisition of science process skills for the PHD degree at Unisa has been approved.
3. You are kindly requested to observe the following conditions:
   3.1 Inform the circuit Manager and principals of affected schools prior to your visits.
   3.2 Ensure that your interactions with teachers do not disrupt teaching and learning activities.

4. Wishing you the best in your endeavors for scholastic achievements.

DISTRICT SENIOR MANAGER

18/02/2011

DATE

Thohoyandou Government Building, Old Parliament, Block D, Private Bag X2250, SIBASA, 0970
Tel: (015) 962 1313 or (015) 962 1331, Fax: (015) 962 6039 or (015) 962 2288

The heartland of southern Africa - development is about people!

Appendix F Acknowledgement form from the Circuit Manager

Letter to the Educators

Acknowledgement form for the Circuit Manager

I ____ a Circuit Manager for ____ hereby **acknowledge that** Mr. Sam James Murungi Kaheru has informed me of the intention to do research in my circuit.

The data collected should only be used for research purposes and paper presentation at conferences or research related fora.

The data collected should be treated with confidentiality and the name of the participants (Teachers and learners) should not be mentioned in the analysis of the data. The Participants (teachers and learners) may withdraw from the study at any time.

Signature: ______________________________ Date: __________

Circuit Manager's stamp:

Appendix G Permission to conduct research from principal

Letter to the Principal

Contact: Cell: +2774 3747 111; +2778 220 6530
email: samkaheru@univen.ac.za

Kaheru SJM
P.O. Box 6532
Thohoyandou
0950

The principal
SCHOOL A

P.O.BOX A

XXXX

Dear Principal,

Re: Permission to conduct research in Physical science teaching in your school

I am Sam James Murungi Kaheru, a Lecturer at University of Venda and a PhD student at UNISA. As the studies are by research, I am Exploring the use of Computer Simulations in the acquisition of Science Process skills for Physical science learners in Physics.

I would like to humbly request your permission to use a computer simulation to teach learners in Grade 11 Physics, administer a pre-test, post-tests and questionnaires to collect data from the Grade 11 Physical Science learners by the help of the class educator(s).

There will be no interruption of your normal school programme, I will follow the normal school timetable and the Physical Science educator(s) will use the computer simulation to teach Geometrical optics in the normal classroom while a control group will be taught using the traditional (normal) teaching methods. After the intervention, I will collect data, by learners answering post-tests and a questionnaire. Educator(s) on the other hand will only answer a questionnaire. The data collected will be treated with confidentiality and the names of your school, educators and the learners will not be used in the analysis of the data.

The educator(s) may benefit from the research since they would be trained in the use of the simulations. The learners would also benefit from the method of instruction as it is hoped that this would enhance their acquisition of science process skills.

Please do not hesitate to contact me if you have any further queries or clarifications.

I look forward to your anticipated positive response.

Yours faithfully,

Sam James Murungi Kaheru 3 May 2011.

Appendix H Consent form from principal

Consent form for principal

I____ the principal of ____ (School) , hereby grant consent to Mr. Sam James Murungi Kaheru, to involve the Grade 11 learners and educator(s) in his research.

The data collected should be treated with confidentiality and the name of the participants (Educators and learners) should not be mentioned in the analysis of the data. The participants (educators and learners) may withdraw from the study at any time.

Signature: __________________________________ Date: ___________

And a school stamp:

Appendix I Request to participate in the research for the educator

Letter to the Educators

Contact: Cell: +2774 3747 111; +2778 220 6530

email: samkaheru@univen.ac.za

Kaheru SJM

P.O. Box 6532
Thohoyandou
0950

Dear Educator,

Re: Permission to be part of the research involving use of simulations in Physical science

I am Sam James Murungi Kaheru, a Lecturer at University of Venda and a PhD student at UNISA. As the studies are by research, I am Exploring the use of Computer Simulations in the acquisition of Science Process skills for Physical science learners in Physics.

I would like to request you to be part of my study. The study will involve the use a computer simulation programme to teach learners in Grade 11 Physical Science.

I will follow the normal school timetable and you will use the computer simulation programme to teach Geometrical optics in the computer lab while a control group will also be taught using the traditional (normal) teaching methods. After the intervention, I will collect data by asking the learners to complete post-tests and a questionnaire. You on the other hand will only respond to a questionnaire.

Participation in this research is voluntary and there will be no victimization whatsoever for refusal to participate. There would be no interruption of your normal school programme. The data collected will be treated with confidentiality and the names of your school, yourself and learners will not be divulged. It is hoped that you may benefit from the research since you would be trained in the use of the physics simulation programme. The learners would also benefit as it is hoped that this would enhance their acquisition of science process.

Please do not hesitate to contact me if you have any further queries or clarifications.

I look forward to your anticipated positive response.

Yours faithfully,

3 May 2011

Sam James Murungi Kaheru.

Appendix J Consent form from Educator

Letter to the Educators

Consent form for teachers to participate

I____ an educator at ____ (School) hereby grant consent to Mr. Sam James Murungi Kaheru to be part of his research.

The data that will be collected from me and my class should only be used for research purposes and paper presentation at conferences or research related fora.

The data collected should be treated with confidentiality and the name of the participants (Teachers and learners) should not be mentioned in the analysis of the data. The Participants (teachers and learners) may withdraw from the study at any time.

Signature: ___________________________________ Date: ____________

Appendix K Letter requesting consent from parents

Contact: Cell: +2774 3747 111; +2778 220 6530
email: samkaheru@univen.ac.za

Kaheru SJM
P.O. Box 6532
Thohoyandou
0950

The Parent / Guardian
Of a learner at

____

____

____

Dear Parent / Guardian,

Re: Consent for your child to be part of a research study

I am Sam James Murungi Kaheru, a Lecturer at University of Venda and a PhD student at UNISA. As the studies are by research, I am Exploring the use of Computer Simulations in the acquisition of Science Process skills for Physical science learners in Physics.

I will like to seek your consent for your child to be part of my study. The study will involve the use a computer simulation to teach learners in Grade 11 Physics. I will collect data by administering tests and observe lessons of your child.

Participation in this research is voluntary and there will be no victimization whatsoever for refusal to participate.

There will be no interruption of your child's normal school programme, the normal school schedule shall be followed and your child will be taught with the use of computer simulation in the computer laboratory. The data collected will be treated with confidentiality and the name of your child will not be mentioned in the analysis of the data. That is, the name and identity of your child will be protected in this study.

It is hoped that your child will benefit from the research since the computer simulation programme will be used for the acquisition of science process skills.

Please do not hesitate to contact me if you have any further queries or clarifications.

I look forward to your anticipated positive response.

Thank you.

Yours faithfully,

Date: 3 May 2011

Sam James Murungi Kaheru.

Appendix L Consent form from parents

Consent form for parents

Please indicate name of school: ....

I ____the parent of ____________________________________ hereby grant consent to Sam James Murungi Kaheru to allow my child to be part of his research. The data that will be collected from my child and his/her class should only be used for research purposes and paper presentation at conferences / seminars and other research related presentations.

The data collected should be treated with confidentiality and neither the name of the school, nor my child or the teacher may be mentioned in the analysis of the data. The participants (teachers and learners) may withdraw from the study at any time as the need may arise.

Parents Signature: _____________________________ Date: ______________

Child's name ________________________ Child's Signature: __________Date: __________

Consent form for learner participants in the study

I, ...,

of ....[school] have read and understood the procedures involved in the study and what is expected of me as a participant. I understand that my name and identity will be protected in the study. I willingly give the following consents:

Please put a tick in the appropriate box

☐ I am willing to participate in the study

☐ I give consent for being observed during my Physical Science lessons

☐ I give consent for my Physical Science notebook being checked

☐ I give consent for part(s) of my Physical Science notebook to be photocopied if necessary

The data collected shall be treated with confidentiality and the name of the participants (educators and learners) will not be mentioned in the analysis of the data. The participants (educators and learners) may withdraw from the study at any time. The extra copy of this form is for you to keep.

Thank you.

------------------------ --

Signature of learner and Date

Name (Please print)

Appendix N Consent to be videotaped

Video Release Form

I ………………………………………………………………………………………………… agree to participate in the study conducted and videotaped by Sam James Murungi Kaheru.

I understand and consent to the use and release of the videotape by Sam James Murungi Kaheru. I understand that the information and videotape is for research purposes only and that my name and image will not be used for any other purpose. I relinquish any rights to the videotape and understand the videotape may be copied and used by Sam James Murungi Kaheru without further permission.

I understand I can leave at any time.

I agree to immediately raise any concern or area of discomfort with the researcher.

Your signature: ____

Date: ____

Please print your name: ____

Thank you!

Your participation is hereby appreciated

Appendix O Cognitive Load Rating Scale

The Paas (1992) Cognitive Load rating scale
In solving or studying the preceding problem I invested

1. very, very low mental effort
2. very low mental effort
3. low mental effort
4. rather low mental effort
5. neither low nor high mental effort
6. rather high mental effort
7. high mental effort
8. very high mental effort
9. very, very high mental effort

Using it by permission from Paas, granted on 5th February 2011

Appendix P Cognitive Load Rating Scale as used in the study [14]

Date		School	
Surname:		Student no	

Cognitive Load rating scale*

In studying the work we have done in this week I invested

1. very, very low mental effort	(I found it very very easy)
2. very low mental effort	(I found it very easy)
3. low mental effort	(I found it easy)
4. rather low mental effort	(it was somehow easy)
5. neither low nor high mental effort	(it was not easy and not hard)
6. rather high mental effort	(it was quite hard)
7. high mental effort	(it was somehow hard)
8. very high mental effort	(it was very hard)
9. very, very high mental effort	(it was very very hard)

Indicate what you have felt: Indicate 1 or 2 or 3 or 4 ....or 9

**Cognitive load* *refers to how much pressure or thinking you felt in your mind as the educator was teaching you.*

Appendix Q The test TDRV-GO

Version 1.3.1

Instructions:

1. This is a test based on geometrical optics. Read the questions carefully and give the best answer from the given choices.
2. Indicate only one answer by a cross as indicated on the m answer sheet provided.
3. There are twenty six (26) questions, please attempt all of them.
4. Please return the question paper when you finish the test.

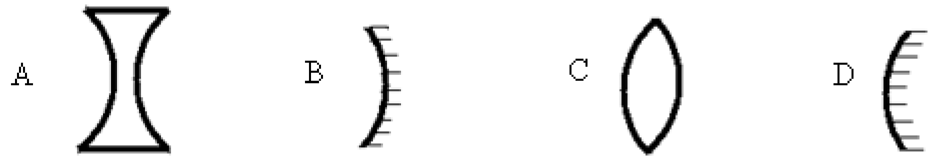
Kaheru SJM

Institute of Science and Technology Education

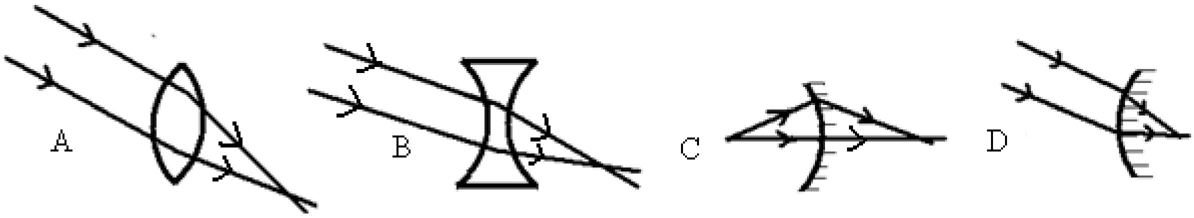
College of Science, Engineering and Technology

University of South Africa

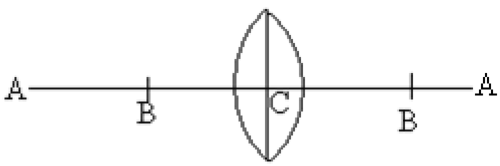
1. Which ONE of the following diagrams shows a converging lens



2. Which ONE of the following is a correct way of showing parallel rays passing through a given object?



For QUESTIONS 3, 4 and 5 refer to the following diagram:



3. What is AA most likely to be?

A Principal focus B Principal axis C Focal length D Optical centre

4. What is B most likely to be?

A Principal focus B Principal axis C Focal length D Optical centre

5. What is C most likely to be?

A Principal focus B Principal axis C Focal length D Optical centre

6. The image formed by the converging lens (convex) is real and smaller than the object. This means that the object is ...
   A. between the optical centre and the principal focus.
   B. between the principal focus and less than twice the focal length from the optical centre.
   C. greater than twice the focal length from the optical centre.
   D. at the principal focus.
7. Which ONE of the following is a property of an image formed by diverging (concave) lens?

A It is always bigger than the object B It is always virtual

C It is always beyond the principal focus D It is always upside down

8. An image formed by a converging lens is exactly the same size as the object. Which ONE of the following represents the object distance?

A f B 2f C $\frac{f}{2}$ D 3f

9. The ray which passes through the optical centre of a converging lens moves in such a way that ...

A. goes through without changing direction B. converges to the principal focus

C. converges to 2f D. moves out parallel to the principal axis.

The table below shows the results of an experiment where the object and image distances were taken.

Object distance d_o (cm)	Image distance d_i (cm)	$\frac{1}{do}$ (cm^{-1})	$\frac{1}{di}$ (cm^{-1})	$\frac{1}{do}+\frac{1}{di}$ (cm^{-1})
10	-59	0.100	-0.017	0.083
15	61	0.067	0.016	0.083
20	29.5	0.050	0.034	0.084
25	23.1	0.040	0.043	0.083
30	20.2	0.033	0.050	0.083

Use the given table to answer QUESTIONS 10, 11 and 12

10. If the object distance is 22 cm what will the image distance be?

A 32.4 cm B 21.2 cm C 25.5 cm D 26.6 cm

11. What type of lens was used during this experiment?

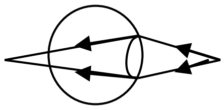
A Concave B Convex C Plane glass D Circular

12. The negative (-) number for the image in the first row with -59 means ...
    A. it is a mistake we cannot have a negative distance
    B. it is a vector quantity in the opposite direction
    C. the image is not real
    D. the image is real

13. The telescope used at the Sutherland in the Karoo uses .... for observing far off objects

A Convex Lens B parabolic reflectors C plane mirrors D spherical mirror

14. Which ONE of the defects of vision is shown below?



A Long-sightedness B Short-sightedness C Astigmatism D Blindness

15. In order to have a sharp image, it must be formed at the .... of the eye

A iris B pupil C cornea D retina

16. What type of lens is found in the human eye?

A Plane B Convex C Concave D Ciliary type

17. The image formed in the human eye is ...

A upside down B upright C virtual D same size as object

18. Which ONE of the following makes the human lens thick or thin at the centre

A Pupil B Cornea C Ciliary D Retina

19. If the lens is very thick at the centre, the image formed, compared to when the lens is thinner at the centre, will ...

A be closer B be further C not change D be wider

20. Which ONE of the following types of lenses must the person use in correcting short-sightedness?

A Concave B Plane C Direct D Convex

21. A lens that lets the light in from what is being observed in a telescope is called ...

A eye piece B plano concave C objective D tele lens

22. The image seen in a telescope of a far object is...

A bigger than the object B same size as the object

C thinner than the object D smaller than the object

23. The rays coming from a far object in a telescope are ...

A not parallel B through the principal focus

C through the optical centre D parallel

24. The image in a microscope is ...

A. smaller than the object

B. virtual

C. real

D. same size as the object

25. Which ONE of the following is the correct representation of the acronym "SALT" as used in Physics?

A Sodium chloride B South African Lens Telescope

C South African Large Telescope D South African Light Telescope

26 The image formed by the objective lens in a microscope is at a distance .... from the eye piece lens

A. greater than the focal length but less than twice the focal length

B. less than the focal length

C. greater than twice the focal length

D. exactly twice the focal length

Appendix R Blank Answer sheet of the TDRV-GO

Test of Describing relationships between variables in Geometric Optics

DATE OF TEST:..

SEX	MALE	FEMALE	SURNAME	
SCHOOL			STUDENT NO	

GRADE		Date of birth	dd_ _	m m _ _	19 _ _

Cross out the correct answer as indicated in the **example**: if your choice is C

1	A	B	~~C~~	D	Are you sure of your answer?	No	~~A bit~~	Yes!

In case of a mistake and you want to change to B

1	A	~~B~~	~~C~~	D	Are you sure of your answer?	No	~~A bit~~	~~Yes!~~

1	A	B	C	D	Are you sure of your answer?	No	~~A bit~~	Yes!
2	A	B	C	D	Are you sure of your answer?	No	A bit	Yes!
3	A	B	C	D	Are you sure of your answer?	No	A bit	Yes!
4	A	B	C	D	Are you sure of your answer?	No	A bit	Yes!
5	A	B	C	D	Are you sure of your answer?	No	A bit	Yes!
6	A	B	C	D	Are you sure of your answer?	No	A bit	Yes!
7	A	B	C	D	Are you sure of your answer?	No	A bit	Yes!
8	A	B	C	D	Are you sure of your answer?	No	A bit	Yes!
9	A	B	C	D	Are you sure of your answer?	No	A bit	Yes!
10	A	B	C	D	Are you sure of your answer?	No	A bit	Yes!
11	A	B	C	D	Are you sure of your answer?	No	A bit	Yes!

12	A	B	C	D	Are you sure of your answer?	No	A bit	Yes!
13	A	B	C	D	Are you sure of your answer?	No	A bit	Yes!
14	A	B	C	D	Are you sure of your answer?	No	A bit	Yes!
15	A	B	C	D	Are you sure of your answer?	No	A bit	Yes!
16	A	B	C	D	Are you sure of your answer?	No	A bit	Yes!
17	A	B	C	D	Are you sure of your answer?	No	A bit	Yes!
18	A	B	C	D	Are you sure of your answer?	No	A bit	Yes!
19	A	B	C	D	Are you sure of your answer?	No	A bit	Yes!
20	A	B	C	D	Are you sure of your answer?	No	A bit	Yes!
21	A	B	C	D	Are you sure of your answer?	No	A bit	Yes!
22	A	B	C	D	Are you sure of your answer?	No	A bit	Yes!
23	A	B	C	D	Are you sure of your answer?	No	A bit	Yes!
24	A	B	C	D	Are you sure of your answer?	No	A bit	Yes!
25	A	B	C	D	Are you sure of your answer?	No	A bit	Yes!
26	A	B	C	D	Are you sure of your answer?	No	A bit	Yes!

Appendix S Marking guide of TDRV-GO

DATE OF TEST:...

SEX	MALE	FEMALE	SURNAME	
SCHOOL			STUDENT NO	

GRADE		Date of birth	dd_	m m	19 _ _

Cross out the correct answer as indicated in the example: if your choice is C

1	A	B	~~C~~	D

In case of a mistake and you want to change to B

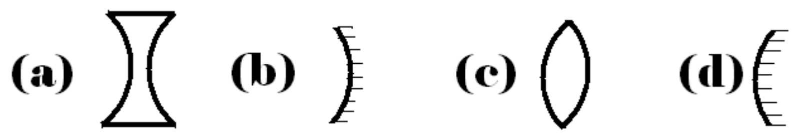
1	A	~~B~~	~~C~~	D

1	A	B	~~C~~	D
2	~~A~~	B	C	D
3	A	~~B~~	C	D
4	~~A~~	B	C	D
5	A	B	C	~~D~~
6	A	B	~~C~~	D
7	A	B	C	~~D~~
8	A	~~B~~	C	D
9	~~A~~	B	C	D
10	A	B	C	~~D~~
11	A	~~B~~	C	D
12	A	B	~~C~~	D
13	A	B	C	~~D~~

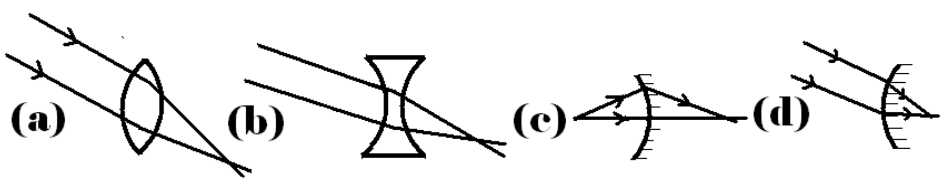
14	A	~~B~~	C	D
15	A	B	C	~~D~~
16	A	~~B~~	C	D
17	~~A~~	B	C	D
18	A	B	~~C~~	D
19	~~A~~	B	C	D
20	~~A~~	B	C	D
21	A	B	~~C~~	D
22	~~A~~	B	C	D
23	A	B	C	~~D~~
24	A	~~B~~	C	D
25	A	B	~~C~~	D
26	A	~~B~~	C	D

Appendix T Categorisation of questions TDRV-GO

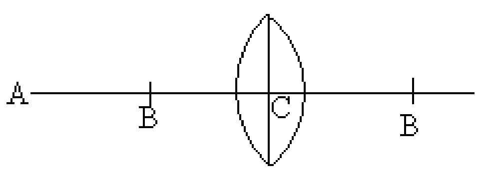
1. The following diagram shows a converging lens **Knowledge of converging lens**



2. Which of the following is a correct way showing parallel rays passing through: **Describing relationships**



Use this diagram for questions 3 to 5



3. What is A most likely to be **Knowledge of terms**
   (a) Principal focus B Principal axis C Focal length D Optical centre
4. What is B most likely to be **Knowledge of lens terms**
   (a) Principal focus B Principal axis C Focal length D Optical centre
5. What is C most likely to be **Knowledge of lens terms**
   (a) Principal focus B Principal axis C Focal length D Optical centre
6. The image formed by the converging lens is real and smaller than the object, it means the object was **Describing relationships**
   (a) between the optical centre and the principal focus.
   (b) between the principal focus and less than twice the focal length from the optical centre.
   (c) greater than twice the focal length from the optical centre.
   (d) at the principal focus.

7. What is special about the image formed by a real object for the diverging lens?

    Describing relationships

    (a) It is always bigger than the object

    (b) It is always virtual

    (c) It is always beyond the principal focus

    (d) It is always upside down

8. Where will the object be, if the image formed is exactly the same size as the image for the case of a converging lens? At the given distance from the lens **Describing relationships**

    (a) f B 2f C $\frac{f}{2}$ D 3f

9. The ray which passes through the optical centre of a converging lens moves in such a way that **Describing relationships**

    (a) goes through without changing direction

    (b) converges to the principal focus

    (c) converges to 2f

    (d) moves out parallel to the principal axis.

Use the table below for questions 10 – 14, the information is a result of an experiment where the object and image distances were taken. Answer the questions that follow:

Object distance d_o (cm)	Image distance d_i (cm)	$\frac{1}{do}$ (cm^{-1})	$\frac{1}{di}$ (cm^{-1})	$\frac{1}{do}+\frac{1}{di}$ (cm^{-1})
10	-59	0.100	-0.017	0.083
15	61	0.067	0.016	0.083
20	29.5	0.050	0.034	0.084
25	23.1	0.040	0.043	0.083
30	20.2	0.033	0.050	0.083

10. The focal length of the lens is **Describing relationships**

(a) 22 cm B 24 cm C 10 cm D 12 cm

11. The lens used is a Describing relationships

(a) Concave B convex C plane glass D circular

12. The negative (-) number for the image in the first row with -59 means **Describing relationships**

(a) It is a mistake we cannot have a negative distance

(b) It is a vector quantity in the opposite direction

(c) The image is not real

(d) The image is real

13. The sum of the reciprocals of object distance $\frac{1}{do}$ and the image distance $\frac{1}{di}$ is equal to 0.083, this means that **Describing relationships**

(a) The object and image distance when multiplied together must give us 0.083

(b) It is just a good coincidence that they all add up to 0.083

(c) Another lens will also be in such a way that the reciprocals of d_o and d_i add up to 0.083

(d) If d_o is 18, we can easily get d_i provided their reciprocals add to 0.083

14. If the object distance is negative it means the image distance will be **Describing relationships**

(a) Negative B positive C it cannot be predicted C there will be no image

15. In order to have a sharp image, it must be formed at the .... of the eye **Describing relationships**

(a) Iris B pupil C cornea D retina

16. The human eye has a .... lens **Application**

(a) Plane B convex C concave D ciliary type

17. The image formed in the human eye is .... **Describing relationships**

(a) Upside down B upright C virtual D same size as object

18. .... makes the human lens thick or thin at the centre **Knowledge**

(a) Pupil B cornea C ciliary D retina

19. If the lens is very thick at the centre it means the image will be ....than if it is thinner at the centre **Describing relationships**

(a) Closer B further C no change D wider

20. To correct short-sightedness the person must use .... lens **Describing relationships**

    (a) Concave B plane C direct D convex

21. The lens that lets in the light from what is being observed in a telescope is called **Knowledge**

    (a) Eye piece B observer C objective D tele lens

22. The image seen in a telescope of a far object is **Describing relationships**

    (a) Bigger than the object
    (b) Same size as the object
    (c) Thinner than the object
    (d) Smaller than the object

23. The rays coming from a far object in a telescope are parallel and the rays from the eye piece to the eye are **Describing relationships**

    (a) Not parallel
    (b) Pass through the principal focus
    (c) pass through the optical centre
    (d) parallel

24. The object in a magnifying lens is at a distance **Describing relationships**

    (a) greater than the focal length but less than twice the focal length
    (b) less than the focal length
    (c) greater than twice the focal length
    (d) exactly twice the focal length

25. SALT stands for **Knowledge**

    (a) Sodium chloride
    (b) South African Lens Telescope
    (c) South African Large Telescope
    (d) South African Light Telescope

26. The image formed by the objective lens in a microscope is at a distance of .... from the eye piece lens **Describing relationship**

    (a) greater than the focal length but less than twice the focal length
    (b) less than the focal length

(c) greater than twice the focal length

(d) exactly twice the focal length

No	What skill, knowledge item?	Explanation
1	Knowledge	Converging lens
2	Describing relationships between variables	Parallel rays through lens
3	Knowledge	Principal axis
4	Knowledge	Principal focus
5	Knowledge	Optical centre
6	Describing relationships between variables	Image size and relationship to where object was
7	Describing relationships between variables	Virtual images of concave lens
8	Describing relationships between variables	Image if object is at 2F
9	Describing relationships between variables	Rays through optical centre
10	Describing relationships between variables	$\frac{1}{do}+\frac{1}{di}$
11	Describing relationships between variables	Image distance and object distance for concave/convex lens
12	Describing relationships between variables	Meaning of negative distance
13	Describing relationships between variables	$\frac{1}{do}+\frac{1}{di}$
14	Describing relationships between variables	Interpreting $\frac{1}{do}+\frac{1}{di}$

15	Describing relationships between variables	For the case of the eye
16	Application	Lens of the eye
17	Describing relationships between variables	Image in the eye
18	Knowledge	Eye parts
19	Describing relationships between variables	Centre of curvature of lens and image distance
20	Describing relationships between variables	Correcting short-sightedness
21	Knowledge	Lens of telescope
22	Describing relationships between variables	Image of a telescope
23	Describing relationships between variables	Rays
24	Describing relationships between variables	Object in magnifying glass
25	Knowledge	What SALT stands for
26	Describing relationships between variables	Image in a microscope

Appendix U Multivariate tests for the TDRV-GO knowledge items

Effect		Value	F	Hypothesis df	Error df	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[c]
Intercept	Pillai's Trace	.922	328.659[b]	3.000	83.000	.000	.922	985.978	1.000
	Wilks' Lambda	.078	328.659[b]	3.000	83.000	.000	.922	985.978	1.000
	Hotelling's Trace	11.879	328.659[b]	3.000	83.000	.000	.922	985.978	1.000
	Roy's Largest Root	11.879	328.659[b]	3.000	83.000	.000	.922	985.978	1.000
Condition	Pillai's Trace	.203	7.068[b]	3.000	83.000	.000	.203	21.205	.976
	Wilks' Lambda	.797	7.068[b]	3.000	83.000	.000	.203	21.205	.976
	Hotelling's Trace	.255	7.068[b]	3.000	83.000	.000	.203	21.205	.976
	Roy's Largest Root	.255	7.068[b]	3.000	83.000	.000	.203	21.205	.976

a. Design: Intercept + Condition

b. Exact statistic

c. Computed using alpha = .05

Appendix V Tests of between subjects effects for TDRV knowledge items

Source	Dependent Variable	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[d]
Corrected Model	Test1K	7.607[a]	1	7.607	4.747	.032	.053	4.747	.577
	Test2K	23.334[b]	1	23.334	13.261	.000	.135	13.261	.950
	Test3K	36.598[c]	1	36.598	19.156	.000	.184	19.156	.991
Intercept	Test1K	846.228	1	846.228	528.082	.000	.861	528.082	1.000
	Test2K	1206.047	1	1206.047	685.427	.000	.890	685.427	1.000
	Test3K	1214.529	1	1214.529	635.720	.000	.882	635.720	1.000
Condition	Test1K	7.607	1	7.607	4.747	.032	.053	4.747	.577
	Test2K	23.334	1	23.334	13.261	.000	.135	13.261	.950
	Test3K	36.598	1	36.598	19.156	.000	.184	19.156	.991
Error	Test1K	136.209	85	1.602					
	Test2K	149.562	85	1.760					
	Test3K	162.391	85	1.910					
Total	Test1K	1084.000	87						
	Test2K	1541.000	87						
	Test3K	1599.000	87						
Corrected Total	Test1K	143.816	86						
	Test2K	172.897	86						
	Test3K	198.989	86						

a. R Squared = .053 (Adjusted R Squared = .042)

b. R Squared = .135 (Adjusted R Squared = .125)

c. R Squared = .184 (Adjusted R Squared = .174)

d. Computed using alpha = .05

Appendix W Tests between subjects for knowledge items TRDV-GO

Source	Dependent Variable	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[d]
Corrected Model	Test1K	7.607[a]	1	7.607	4.747	.032	.053	4.747	.577
	Test2K	23.334[b]	1	23.334	13.261	.000	.135	13.261	.950
	Test3K	36.598[c]	1	36.598	19.156	.000	.184	19.156	.991
Intercept	Test1K	846.228	1	846.228	528.082	.000	.861	528.082	1.000
	Test2K	1206.047	1	1206.047	685.427	.000	.890	685.427	1.000
	Test3K	1214.529	1	1214.529	635.720	.000	.882	635.720	1.000
Condition	Test1K	7.607	1	7.607	4.747	.032	.053	4.747	.577
	Test2K	23.334	1	23.334	13.261	.000	.135	13.261	.950
	Test3K	36.598	1	36.598	19.156	.000	.184	19.156	.991
Error	Test1K	136.209	85	1.602					
	Test2K	149.562	85	1.760					
	Test3K	162.391	85	1.910					
Total	Test1K	1084.000	87						
	Test2K	1541.000	87						
	Test3K	1599.000	87						
Corrected Total	Test1K	143.816	86						
	Test2K	172.897	86						
	Test3K	198.989	86						
a. R Squared = .053 (Adjusted R Squared = .042)									
b. R Squared = .135 (Adjusted R Squared = .125)									
c. R Squared = .184 (Adjusted R Squared = .174)									
d. Computed using alpha = .05C									

Appendix X Estimated Marginal means since they were unequal numbers of participants

Condition

Dependent Variable	Condition	Mean	Std. Error	95% Confidence Interval	
				Lower Bound	Upper Bound
Test1K	Without CS	2.909	.220	2.471	3.347
	With CS	3.519	.172	3.176	3.861
Test2K	Without CS	3.303	.231	2.844	3.762
	With CS	4.370	.181	4.011	4.729
Test3K	Without CS	3.182	.241	2.703	3.660
	With CS	4.519	.188	4.145	4.892

Appendix Y Tables showing analysis results for a paired samples t-test for the cognitive loads in the treatment and control conditions

Paired Samples Statistics

Experimental Conditions			Mean	N	Std. Deviation	Std. Error Mean
Control – Treatment	Pair 1	Cognitive_Load_week1	4.66	35	1.360	.230
		CLweek2	3.91	35	1.280	.216
Treatment – Control	Pair 1	Cognitive_Load_week1	3.74	21	1.480	.323
		CLweek2	3.38	21	1.404	.306

Paired Samples Correlations

Experimental Conditions			N	Correlation	Sig.
Control – Treatment	Pair 1	Cognitive_Load_week1 & CLweek2	35	.266	.123
Treatment – Control	Pair 1	Cognitive_Load_week1 & CLweek2	21	.225	.327

Paired Samples Test

Experimental Conditions			Paired Differences					t	df	Sig. (2-tailed)
			Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
						Lower	Upper			
Control - Treatment	Pair 1	Cognitive_Load_week1 - CLweek2	.743	1.601	.271	.193	1.293	2.744	34	.010
Treatment - Control	Pair 1	Cognitive_Load_week1 - CLweek2	.357	1.797	.392	-.461	1.175	.911	20	.373

Appendix Z of Independent t-tests for cognitive load analysis based on sex male or female

Experimental Conditions		Gender	N	Mean	Std. Deviation	Std. Error Mean
Control - Treatment	CLweek1	Male	21	4.3571	1.41548	.30888
		Female	21	4.6667	1.47761	.32244
	CLweek2	Male	17	3.7353	1.25147	.30353
		Female	18	4.0833	1.32009	.31115
Treatment - Control	CLweek1	Male	27	4.2593	1.53404	.29523
		Female	30	3.7333	1.25075	.22835
	CLweek2	Male	10	3.8500	1.35503	.42850
		Female	12	3.0417	1.33924	.38660

Independent Samples Test

Experimental Conditions			Levene's Test for Equality of Variances		t-test for Equality of Means						
			F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
										Lower	Upper
Control – Treatment	CLweek1	Equal variances assumed	.044	.836	-.693	40	.492	-.30952	.44652	-1.21197	.59292
		Equal variances not assumed			-.693	39.926	.492	-.30952	.44652	-1.21202	.59297
	CLweek2	Equal variances assumed	.114	.738	-.799	33	.430	-.34804	.43536	-1.23378	.53770
		Equal variances not assumed			-.801	32.999	.429	-.34804	.43467	-1.23239	.53631
Treatment – Control	CLweek1	Equal variances assumed	1.262	.266	1.424	55	.160	.52593	.36923	-.21402	1.26587
		Equal variances not assumed			1.409	50.281	.165	.52593	.37323	-.22363	1.27549
	CLweek2	Equal variances assumed	.030	.863	1.402	20	.176	.80833	.57648	-.39418	2.01085

	Equal variances not assumed			1.401	19.204	.177	.80833	.57713	-.39874	2.01540

Appendix AA Test for Writing time using multivariate analysis

Between-Subjects Factors

		Value Label	N
Condition	1	Without CS	35
	2	With CS	52
Name of school	1	SchoolA	11
	2	SchoolB	24
	3	SchoolC	21
	4	SchoolD	31
Gender	1	Male	42
	2	Female	45

Descriptive Statistics

	Condition	Name of school	Gender	Mean	Std. Deviation	N
Writing time1	Without CS	SchoolA	Male	0:21:47.33	0:03:12.467	7
			Female	0:22:45.79	0:03:50.160	4
			Total	0:22:08.59	0:03:17.454	11
		SchoolB	Male	0:27:59.11	0:05:33.204	10

		Female	0:25:14.24	0:05:40.918	14
		Total	0:26:22.93	0:05:40.633	24
	Total	Male	0:25:26.02	0:05:34.534	17
		Female	0:24:41.25	0:05:19.780	18
		Total	0:25:02.99	0:05:22.971	35
With CS	SchoolC	Male	0:23:44.47	0:03:30.499	10
		Female	0:23:52.72	0:04:08.509	11
		Total	0:23:48.79	0:03:45.467	21
	SchoolD	Male	0:20:51.66	0:03:38.601	15
		Female	0:23:16.17	0:06:20.844	16
		Total	0:22:06.25	0:05:16.562	31
	Total	Male	0:22:00.78	0:03:47.942	25
		Female	0:23:31.06	0:05:28.277	27
		Total	0:22:47.66	0:04:45.420	52
Total	SchoolA	Male	0:21:47.33	0:03:12.467	7
		Female	0:22:45.79	0:03:50.160	4
		Total	0:22:08.59	0:03:17.454	11
	SchoolB	Male	0:27:59.11	0:05:33.204	10
		Female	0:25:14.24	0:05:40.918	14
		Total	0:26:22.93	0:05:40.633	24

		SchoolC	Male	0:23:44.47	0:03:30.499	10
			Female	0:23:52.72	0:04:08.509	11
			Total	0:23:48.79	0:03:45.467	21
		SchoolD	Male	0:20:51.66	0:03:38.601	15
			Female	0:23:16.17	0:06:20.844	16
			Total	0:22:06.25	0:05:16.562	31
		Total	Male	0:23:23.86	0:04:50.662	42
			Female	0:23:59.14	0:05:23.107	45
			Total	0:23:42.10	0:05:06.602	87
Writing Time2	Without CS	SchoolA	Male	0:17:12.44	0:01:48.095	7
			Female	0:15:15.28	0:01:33.833	4
			Total	0:16:29.84	0:01:54.654	11
		SchoolB	Male	0:15:03.74	0:02:16.916	10
			Female	0:15:55.11	0:02:34.904	14
			Total	0:15:33.70	0:02:26.858	24
		Total	Male	0:15:56.73	0:02:18.524	17
			Female	0:15:46.26	0:02:22.103	18
			Total	0:15:51.35	0:02:18.401	35
	With CS	SchoolC	Male	0:19:26.36	0:02:20.817	10
			Female	0:21:01.83	0:03:52.686	11

		Total	0:20:16.37	0:03:15.913	21
	SchoolD	Male	0:14:22.67	0:03:10.914	15
		Female	0:16:58.68	0:04:12.246	16
		Total	0:15:43.19	0:03:54.743	31
	Total	Male	0:16:24.14	0:03:47.495	25
		Female	0:18:37.74	0:04:28.989	27
		Total	0:17:33.51	0:04:16.485	52
Total	SchoolA	Male	0:17:12.44	0:01:48.095	7
		Female	0:15:15.28	0:01:33.833	4
		Total	0:16:29.84	0:01:54.654	11
	SchoolB	Male	0:15:03.74	0:02:16.916	10
		Female	0:15:55.11	0:02:34.904	14
		Total	0:15:33.70	0:02:26.858	24
	SchoolC	Male	0:19:26.36	0:02:20.817	10
		Female	0:21:01.83	0:03:52.686	11
		Total	0:20:16.37	0:03:15.913	21
	SchoolD	Male	0:14:22.67	0:03:10.914	15
		Female	0:16:58.68	0:04:12.246	16
		Total	0:15:43.19	0:03:54.743	31
	Total	Male	0:16:13.05	0:03:14.856	42

			Female	0:17:29.15	0:04:00.364	45
			Total	0:16:52.41	0:03:41.639	87
Writing Time3	Without CS	SchoolA	Male	0:15:03.96	0:01:12.895	7
			Female	0:12:53.11	0:01:15.523	4
			Total	0:14:16.38	0:01:36.215	11
		SchoolB	Male	0:13:36.93	0:00:58.904	10
			Female	0:14:48.29	0:01:54.705	14
			Total	0:14:18.55	0:01:40.429	24
		Total	Male	0:14:12.76	0:01:16.770	17
			Female	0:14:22.69	0:01:56.171	18
			Total	0:14:17.87	0:01:37.707	35
	With CS	SchoolC	Male	0:16:49.26	0:02:48.288	10
			Female	0:14:36.63	0:03:46.488	11
			Total	0:15:39.79	0:03:27.366	21
		SchoolD	Male	0:10:02.40	0:02:05.378	15
			Female	0:11:21.94	0:03:15.860	16
			Total	0:10:43.45	0:02:47.776	31
		Total	Male	0:12:45.15	0:04:07.335	25
			Female	0:12:41.25	0:03:46.636	27
			Total	0:12:43.13	0:03:54.472	52

	SchoolA	Male	0:15:03.96	0:01:12.895	7
		Female	0:12:53.11	0:01:15.523	4
		Total	0:14:16.38	0:01:36.215	11
	SchoolB	Male	0:13:36.93	0:00:58.904	10
		Female	0:14:48.29	0:01:54.705	14
		Total	0:14:18.55	0:01:40.429	24
Total	SchoolC	Male	0:16:49.26	0:02:48.288	10
		Female	0:14:36.63	0:03:46.488	11
		Total	0:15:39.79	0:03:27.366	21
	SchoolD	Male	0:10:02.40	0:02:05.378	15
		Female	0:11:21.94	0:03:15.860	16
		Total	0:10:43.45	0:02:47.776	31
	Total	Male	0:13:20.61	0:03:20.010	42
		Female	0:13:21.83	0:03:15.170	45
		Total	0:13:21.24	0:03:16.369	87

Condition	Effect		Value	F	Hypothesis df	Error df	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[c]
Without CS	Intercept	Pillai's Trace	0.99	807.44[b]	3	29	0	0.99	2422.31	1
		Wilks' Lambda	0.01	807.44[b]	3	29	0	0.99	2422.31	1
		Hotelling's Trace	83.53	807.44[b]	3	29	0	0.99	2422.31	1
		Roy's Largest Root	83.53	807.44[b]	3	29	0	0.99	2422.31	1
	Condition	Pillai's Trace	0	.[b]	0	0	.	.	.	.
		Wilks' Lambda	1	.[b]	0	30	.	.	.	.
		Hotelling's Trace	0	.[b]	0	2	.	.	.	.
		Roy's Largest Root	0	.00[b]	3	28	1	0	0	0.05
	School	Pillai's Trace	0.38	5.91[b]	3	29	0.003	0.38	17.74	0.93
		Wilks' Lambda	0.62	5.91[b]	3	29	0.003	0.38	17.74	0.93
		Hotelling's Trace	0.61	5.91[b]	3	29	0.003	0.38	17.74	0.93
		Roy's Largest Root	0.61	5.91[b]	3	29	0.003	0.38	17.74	0.93
	Sex	Pillai's Trace	0.03	.25[b]	3	29	0.86	0.03	0.75	0.09
		Wilks' Lambda	0.98	.25[b]	3	29	0.86	0.03	0.75	0.09
		Hotelling's Trace	0.03	.25[b]	3	29	0.86	0.03	0.75	0.09
		Roy's Largest Root	0.03	.25[b]	3	29	0.86	0.03	0.75	0.09
	Condition * School	Pillai's Trace	0	.[b]	0	0	.	.	.	.
		Wilks' Lambda	1	.[b]	0	30	.	.	.	.
		Hotelling's Trace	0	.[b]	0	2	.	.	.	.
		Roy's Largest Root	0	.000[b]	3	28	1	0	0	0.05
	Condition * Sex	Pillai's Trace	0	.[b]	0	0	.	.	.	.
		Wilks' Lambda	1	.[b]	0	30	.	.	.	.

Condition	Effect		Value	F	Hypothesis df	Error df	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[c]
		Hotelling's Trace	0	.[b]	0	2	.	.	.	.
		Roy's Largest Root	0	.000[b]	3	28	1	0	0	0.05
	School * Sex	Pillai's Trace	0.35	5.14[b]	3	29	0.006	0.35	15.41	0.88
		Wilks' Lambda	0.65	5.14[b]	3	29	0.006	0.35	15.41	0.88
		Hotelling's Trace	0.53	5.14[b]	3	29	0.006	0.35	15.41	0.88
		Roy's Largest Root	0.53	5.14[b]	3	29	0.006	0.35	15.41	0.88
	Condition * School * Sex	Pillai's Trace	0	.[b]	0	0	.	.	.	.
		Wilks' Lambda	1	.[b]	0	30	.	.	.	.
		Hotelling's Trace	0	.[b]	0	2	.	.	.	.
		Roy's Largest Root	0	.000[b]	3	28	1	0	0	0.05
With CS	Intercept	Pillai's Trace	0.97	486.61[b]	3	46	0	0.97	1459.82	1
		Wilks' Lambda	0.03	486.61[b]	3	46	0	0.97	1459.82	1
		Hotelling's Trace	31.74	486.61[b]	3	46	0	0.97	1459.82	1
		Roy's Largest Root	31.74	486.61[b]	3	46	0	0.97	1459.82	1
	Condition	Pillai's Trace	0	.[b]	0	0	.	.	.	.
		Wilks' Lambda	1	.[b]	0	47	.	.	.	.
		Hotelling's Trace	0	.[b]	0	2	.	.	.	.
		Roy's Largest Root	0	.000[b]	3	45	1	0	0	0.05
	School	Pillai's Trace	0.5	15.32[b]	3	46	0	0.5	45.96	1
		Wilks' Lambda	0.5	15.32[b]	3	46	0	0.5	45.96	1
		Hotelling's Trace	1	15.32[b]	3	46	0	0.5	45.96	1
		Roy's Largest Root	1	15.32[b]	3	46	0	0.5	45.96	1

Condition	Effect		Value	F	Hypothesis df	Error df	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[c]
	Sex	Pillai's Trace	0.19	3.62[b]	3	46	0.02	0.19	10.87	0.76
		Wilks' Lambda	0.81	3.62[b]	3	46	0.02	0.19	10.87	0.76
		Hotelling's Trace	0.24	3.62[b]	3	46	0.02	0.19	10.87	0.76
		Roy's Largest Root	0.24	3.62[b]	3	46	0.02	0.19	10.87	0.76
	Condition * School	Pillai's Trace	0	.[b]	0	0	.	.	.	.
		Wilks' Lambda	1	.[b]	0	47	.	.	.	.
		Hotelling's Trace	0	.[b]	0	2	.	.	.	.
		Roy's Largest Root	0	.000[b]	3	45	1	0	0	0.05
	Condition * Sex	Pillai's Trace	0	.[b]	0	0	.	.	.	.
		Wilks' Lambda	1	.[b]	0	47	.	.	.	.
		Hotelling's Trace	0	.[b]	0	2	.	.	.	.
		Roy's Largest Root	0	.000[b]	3	45	1	0	0	0.05
	School * Sex	Pillai's Trace	0.11	1.86[b]	3	46	0.15	0.11	5.58	0.45
		Wilks' Lambda	0.89	1.86[b]	3	46	0.15	0.11	5.58	0.45
		Hotelling's Trace	0.12	1.86[b]	3	46	0.15	0.11	5.58	0.45
		Roy's Largest Root	0.12	1.86[b]	3	46	0.15	0.11	5.58	0.45
	Condition * School * Sex	Pillai's Trace	0	.[b]	0	0	.	.	.	.
		Wilks' Lambda	1	.[b]	0	47	.	.	.	.
		Hotelling's Trace	0	.[b]	0	2	.	.	.	.
		Roy's Largest Root	0	.00[b]	3	45	1	0	0	0.05

a. Design: Intercept + Condition + School + Sex + Condition * School + Condition * Sex + School * Sex + Condition * School * Sex

b. Exact statistic

Condition	Effect	Value	F	Hypothesis df	Error df	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[c]

c. Computed using alpha = .05

Multivariate Tests[a]

	Effect		Value	F	Hypothesis df	Error df	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[d]
	Intercept	Pillai's Trace	.972	877.926[b]	3.000	77.000	.000	.972	2633.779	1.000
		Wilks' Lambda	.028	877.926[b]	3.000	77.000	.000	.972	2633.779	1.000
		Hotelling's Trace	34.205	877.926[b]	3.000	77.000	.000	.972	2633.779	1.000
		Roy's Largest Root	34.205	877.926[b]	3.000	77.000	.000	.972	2633.779	1.000
	Condition	Pillai's Trace	.000	.[b]	.000	.000	.	.	.	.
		Wilks' Lambda	1.000	.[b]	.000	78.000	.	.	.	.
		Hotelling's Trace	.000	.[b]	.000	2.000	.	.	.	.
		Roy's Largest Root	.000	.000[b]	3.000	76.000	1.000	.000	.000	.050
	School	Pillai's Trace	.571	10.394	6.000	156.000	.000	.286	62.363	1.000

		Wilks' Lambda	.483	11.269[b]	6.000	154.000	.000	.305	67.617	1.000
		Hotelling's Trace	.959	12.147	6.000	152.000	.000	.324	72.881	1.000
		Roy's Largest Root	.823	21.395[c]	3.000	78.000	.000	.451	64.186	1.000
	Sex	Pillai's Trace	.061	1.654[b]	3.000	77.000	.184	.061	4.963	.418
		Wilks' Lambda	.939	1.654[b]	3.000	77.000	.184	.061	4.963	.418
		Hotelling's Trace	.064	1.654[b]	3.000	77.000	.184	.061	4.963	.418
		Roy's Largest Root	.064	1.654[b]	3.000	77.000	.184	.061	4.963	.418
	Condition * School	Pillai's Trace	.000	.[b]	.000	.000	.	.	.	.
		Wilks' Lambda	1.000	.[b]	.000	78.000	.	.	.	.
		Hotelling's Trace	.000	.[b]	.000	2.000	.	.	.	.
		Roy's Largest Root	.000	.000[b]	3.000	76.000	1.000	.000	.000	.050
	Condition * Sex	Pillai's Trace	.000	.[b]	.000	.000	.	.	.	.
		Wilks' Lambda	1.000	.[b]	.000	78.000	.	.	.	.
		Hotelling's Trace	.000	.[b]	.000	2.000	.	.	.	.
		Roy's Largest Root	.000	.000[b]	3.000	76.000	1.000	.000	.000	.050

	School * Sex	Pillai's Trace	.200	2.890	6.000	156.000	.011	.100	17.342	.884
		Wilks' Lambda	.808	2.886[b]	6.000	154.000	.011	.101	17.319	.884
		Hotelling's Trace	.228	2.882	6.000	152.000	.011	.102	17.291	.883
		Roy's Largest Root	.167	4.353[c]	3.000	78.000	.007	.143	13.058	.854
	Condition * School * Sex	Pillai's Trace	.000	.[b]	.000	.000	.	.	.	.
		Wilks' Lambda	1.000	.[b]	.000	78.000	.	.	.	.
		Hotelling's Trace	.000	.[b]	.000	2.000	.	.	.	.
		Roy's Largest Root	.000	.000[b]	3.000	76.000	1.000	.000	.000	.050

a. Design: Intercept + Condition + School + Sex + Condition * School + Condition * Sex + School * Sex + Condition * School * Sex

b. Exact statistic

c. The statistic is an upper bound on F that yields a lower bound on the significance level.

d. Computed using alpha = .05

Appendix BB Descriptive Statistics for the Test1K items for the with CS and without CS

	Condition	N	Mean	Std. Deviation	Std. Error Mean
Test1K	Without CS	43	2.95	1.25	0.19
	With CS	58	3.43	1.37	0.18

Appendix CC Descriptive statistics for Skills items in Test 1S

	Condition	N	Mean	Std. Deviation	Std. Error Mean
Test1S	Without CS	43	5.86	1.89	0.29
	With CS	58	6.09	1.80	0.24

Appendix DD Descriptive statistics for all items in Test1

	Condition	N	Mean	Std. Deviation	Std. Error Mean
Test1	Without CS	43	8.81	2.54	0.39
	With CS	58	9.52	2.36	0.31

Appendix EE Descriptive statistics for knowledge items Test1 based on gender

Gender		Condition	N	Mean	Std. Deviation	Std. Error Mean
Male	Test1K	Without CS	22	3.09	1.27	.27
		With CS	27	3.59	1.45	.28
Female	Test1K	Without CS	21	2.81	1.25	.27
		With CS	31	3.29	1.30	.23

Appendix FF Descriptive Statistics for Skills Items Test1 Based on Gender

Gender		Condition	N	Mean	Std. Deviation	Std. Error Mean
Male	Test1S	Without CS	22	6.09	2.02	.43
		With CS	27	6.67	1.36	.26
Female	Test1S	Without CS	21	5.62	1.75	.38
		With CS	31	5.58	2.00	.36

Appendix GG Descriptive Statistics for both knowledge and Skills Items Prestest1 Based on Gender

Gender		Condition	N	Mean	Std. Deviation	Std. Error Mean
Male	Test1	Without CS	22	9.18	2.72	.58
		With CS	27	10.26	1.77	.34
Female	Test1	Without CS	21	8.43	2.34	.51
		With CS	31	8.87	2.63	.47

Appendix HH Descriptive statistics for the post test1 for knowledge items for Test2K

	Condition	N	Mean	Std. Deviation	Std. Error Mean
Test2K	Without CS	46	3.35	1.57	0.23
	With CS	57	4.32	1.28	0.17

Appendix II Descriptive statistics for knowledge items Test2 based on gender

Gender		Condition	N	Mean	Std. Deviation	Std. Error Mean
Male	Test2K	Control-Treatment	23	4.00	1.51	.31
		Treatment-Control	27	4.37	1.12	.21
Female	Test2K	Control-Treatment	23	2.70	1.36	.28
		Treatment-Control	30	4.27	1.44	.26

Appendix JJ Descriptive statistics for Test 3 for knowledge items

	Condition	N	Mean	Std. Deviation	Std. Error Mean
Test3K	Without CS	35	3.23	1.35	0.23
	With CS	55	4.51	1.43	0.19

Appendix KK Descriptive statistics for knowledge items Test3 based on gender

Gender		Condition	N	Mean	Std. Deviation	Std. Error Mean
Male	Test3K	Control-Treatment	17	3.06	1.30	.32
		Treatment-Control	26	4.31	1.52	.30
Female	Test3K	Control-Treatment	18	3.39	1.42	.34
		Treatment-Control	29	4.69	1.34	.25

Appendix LL Descriptive statistics for paired samples of Test1K and Test2K

Condition			Mean	N	Std. Deviation	Std. Error Mean
Without CS	Pair 1	Test1K	2.95	43	1.25	0.19
		Test2K	3.51	43	1.47	0.22
With CS	Pair 1	Test1K	3.47	57	1.34	0.18
		Test2K	4.32	57	1.28	0.17

Appendix MM Descriptive statistics for paired samples of Test2K and Test3K

Condition			Mean	N	Std. Deviation	Std. Error Mean
Without CS	Pair 1	Test2K	3.14	35	1.50	0.25
		Test3K	3.23	35	1.35	0.23
With CS	Pair 1	Test2K	4.37	54	1.29	0.18
		Test3K	4.52	54	1.44	0.20

Appendix NN Descriptive statistics for paired samples with regard to gender Test1K and Test2

Condition	Gender			Mean	N	Std. Deviation	Std. Error Mean
Without CS	Male	Pair 1	Test1K	3.09	22	1.27	0.27
			Test2K	4.09	22	1.48	0.32
	Female	Pair 1	Test1K	2.81	21	1.25	0.27
			Test2K	2.90	21	1.22	0.27
With CS	Male	Pair 1	Test1K	3.59	27	1.45	0.28
			Test2K	4.37	27	1.12	0.21
	Female	Pair 1	Test1K	3.37	30	1.25	0.23

			Test2K	4.27	30	1.44	0.26

Appendix OO Descriptive statistics for paired samples with regard to gender Test2K and Test3K

Condition	Gender			Mean	N	Std. Deviation	Std. Error Mean
Without CS	Male	Pair 1	Test2K	3.76	17	1.48	0.36
			Test3K	3.06	17	1.30	0.32
	Female	Pair 1	Test2K	2.56	18	1.29	0.31
			Test3K	3.39	18	1.42	0.34
With CS	Male	Pair 1	Test2K	4.38	26	1.13	0.22
			Test3K	4.31	26	1.52	0.30
	Female	Pair 1	Test2K	4.36	28	1.45	0.27
			Test3K	4.71	28	1.36	0.26

Appendix PP Descriptive statistics for the Test2 for skills items

	Condition	N	Mean	Std. Deviation	Std. Error Mean
Test2S	Without CS	46	6.74	2.23	0.33
	With CS	57	6.28	2.02	0.27

Appendix QQ Descriptive statistics for Test 2S based on gender

Gender		Condition	N	Mean	Std. Deviation	Std. Error Mean
Male	Test2S	Without CS	23	6.65	2.42	.51
		With CS	27	6.11	1.81	.35
Female	Test2S	Without CS	23	6.83	2.06	.43
		With CS	30	6.43	2.22	.41

Appendix RR Descriptive statistics for Test 3 for skills items

	Condition	N	Mean	Std. Deviation	Std. Error Mean
Test3S	Without CS	35	6.66	1.92	0.33
	With CS	54	6.78	2.27	0.31

Appendix SS Descriptive statistics for paired samples with regard to gender Test1S and Test3S

Condition	Gender			Mean	N	Std. Deviation	Std. Error Mean
Without CS	Male	Pair 1	Test1S	5.65	17	1.90	0.46
			Test3S	6.65	17	1.77	0.43
	Female	Pair 1	Test1S	5.81	16	1.68	0.42
			Test3S	7.00	16	2.00	0.50
With CS	Male	Pair 1	Test1S	6.62	26	1.36	0.27
			Test3S	6.19	26	2.04	0.40
	Female	Pair 1	Test1S	5.75	28	1.97	0.37
			Test3S	7.32	28	2.37	0.45

Appendix TT Descriptive Statistics for Skills Items Test2 and Test 3 Based on Gender

Condition	Gender			Mean	N	Std. Deviation	Std. Error Mean
Without CS	Male	Pair 1	Test2S	6.12	17	2.32	.56
			Test3S	6.65	17	1.77	.43
	Female	Pair 1	Test2S	7.22	18	1.96	.46
			Test3S	6.67	18	2.11	.50
With CS	Male	Pair 1	Test2S	5.92	26	1.55	.30
			Test3S	6.19	26	2.04	.40
	Female	Pair 1	Test2S	6.41	27	2.33	.45
			Test3S	7.37	27	2.40	.46

Appendix UU Descriptive statistics for paired samples of Test1S and Test2S

Condition			Mean	N	Std. Deviation	Std. Error Mean
Without CS	Pair 1	Test1S	5.86	43	1.89	0.29
		Test2S	6.70	43	2.20	0.34
With CS	Pair 1	Test1S	6.12	57	1.79	0.24
		Test2S	6.28	57	2.02	0.27

Appendix VV Descriptive statistics for paired samples of Test2S and Test3S

Condition			Mean	N	Std. Deviation	Std. Error Mean
Without CS	Pair 1	Test2S	6.69	35	2.18	0.37
		Test3S	6.66	35	1.92	0.33
With CS	Pair 1	Test2S	6.17	53	1.98	0.27
		Test3S	6.79	53	2.29	0.32

Appendix WW Descriptive statistics for paired samples with regard to gender Test1S and Test2S

Condition	Gender			Mean	N	Std. Deviation	Std. Error Mean
Without CS	Male	Pair 1	Test1S	6.09	22	2.02	0.43
			Test2S	6.50	22	2.37	0.50
	Female	Pair 1	Test1S	5.62	21	1.75	0.38
			Test2S	6.90	21	2.05	0.45
With CS	Male	Pair 1	Test1S	6.67	27	1.36	0.26
			Test2S	6.11	27	1.81	0.35
	Female	Pair 1	Test1S	5.63	30	2.01	0.37
			Test2S	6.43	30	2.22	0.41

Appendix XX Descriptive statistics for paired samples with regard to gender Test2S and Test3S

Condition	Gender			Mean	N	Std. Deviation	Std. Error Mean
Without CS	Male	Pair 1	Test2S	6.12	17	2.32	0.56
			Test3S	6.65	17	1.77	0.43
	Female	Pair 1	Test2S	7.22	18	1.96	0.46
			Test3S	6.67	18	2.11	0.50
With CS	Male	Pair 1	Test2S	5.92	26	1.55	0.30
			Test3S	6.19	26	2.04	0.40
	Female	Pair 1	Test2S	6.41	27	2.33	0.45
			Test3S	7.37	27	2.40	0.46

Appendix YY A Mann-Whitney U test ranks for cognitive load 1

	Condition	N	Mean Rank	Sum of Ranks
Cognitive Load1	Without CS	42	56.08	2355.50
	With CS	56	44.56	2495.50
	Total	98		

Appendix ZZ Descriptive statistics for cognitive load for Without CS and With CS

						Percentiles		
	N	Mean	Std. Deviation	Minimum	Maximum	25th	50th (Median)	75th
Cognitive Load1	98	4.57	1.84	1	9	4.00	5.00	5.00
Condition	105	1.56	.50	1	2	1.00	2.00	2.00

Appendix AAA Mann-Whitney U test statistics for the cognitive load 1 based on male and female

Gender		Cognitive Load1
Male	Mann-Whitney U	263.00
	Wilcoxon W	641.00
	Z	-.46
	Asymp. Sig. (2-tailed)	.65
Female	Mann-Whitney U	199.00
	Wilcoxon W	634.00
	Z	-2.11
	Asymp. Sig. (2-tailed)	.04

a. Grouping Variable: Condition

Appendix BBB Descriptive Statistics for cognitive load 1 based on male and female learners

Gender		N	Mean	Std. Deviation	Minimum	Maximum	Percentiles		
							25th	50th (Median)	75th
Male	Cognitive Load1	48	4.67	1.63	1	9	4.00	5.00	5.00
	Condition	50	1.54	.50	1	2	1.00	2.00	2.00
Female	Cognitive Load1	50	4.48	2.03	1	9	3.00	4.50	5.00
	Condition	55	1.58	.50	1	2	1.00	2.00	2.00

Appendix CCC Mann-Whitney U test showing Ranks for the cognitive load 1 for male and female

Gender		Condition	N	Mean Rank	Sum of Ranks
Male	Cognitive Load1	Without CS	21	25.48	535.00
		With CS	27	23.74	641.00
		Total	48		
Female	Cognitive Load1	Without CS	21	30.52	641.00
		With CS	29	21.86	634.00
		Total	50		

Appendix DDD Mann-Whitney U Test Statistics for Cognitive load 3

	Cognitive Load3
Mann-Whitney U	342.00
Wilcoxon W	595.00
Z	-.72
Asymp. Sig. (2-tailed)	.47
Exact Sig. (2-tailed)	.48
Exact Sig. (1-tailed)	.24
Point Probability	.002

a. Grouping Variable: Condition

Appendix EEE Descriptive Statistics for Cognitive Load 3 for the Without CS and With CS for the Mann-Whitney U Test

						Percentiles		
	N	Mean	Std. Deviation	Minimum	Maximum	25th	50th (Median)	75th
Cognitive Load3	57	3.33	1.286	1	6	2.00	3.00	4.00
Condition	105	1.56	.499	1	2	1.00	2.00	2.00

Appendix FFF Mann-Whitney U Test showing ranks for Cognitive load 3 for the Without CS and With CS

	Condition	N	Mean Rank	Sum of Ranks
Cognitive Load3	Without CS	35	30.23	1058.00
	With CS	22	27.05	595.00
	Total	57		

Appendix GGG Mann-Whitney U test statistics for the cognitive load 3 based on male and female

Gender		Cognitive Load3
Male	Mann-Whitney U	74.00
	Wilcoxon W	227.00
	Z	-.58
	Asymp. Sig. (2-tailed)	.57
	Exact Sig. [2*(1-tailed Sig.)]	.60[b]
Female	Mann-Whitney U	78.50
	Wilcoxon W	156.50
	Z	-1.28
	Asymp. Sig. (2-tailed)	.20
	Exact Sig. [2*(1-tailed Sig.)]	.22[b]

a. Grouping Variable: Condition

b. Not corrected for ties.

Appendix HHH Descriptive Statistics for Cognitive load 3 based on male and female learners

Gender		N	Mean	Std. Deviation	Minimum	Maximum	Percentiles		
							25th	50th (Median)	75th
Male	Cognitive Load1	27	3.63	1.182	1	6	3.00	4.00	4.00
	Condition	50	1.54	.503	1	2	1.00	2.00	2.00
Female	Cognitive Load1	30	3.07	1.337	1	6	2.00	3.00	4.00
	Condition	55	1.58	.498	1	2	1.00	2.00	2.00

Appendix III Mann-Whitney U test showing Ranks for the cognitive load 3 for male and female

Gender		Condition	N	Mean Rank	Sum of Ranks
Male	Cognitive Load3	Without CS	17	13.35	227.00
		With CS	10	15.10	151.00
		Total	27		
Female	Cognitive Load3	Without CS	18	17.14	308.50
		With CS	12	13.04	156.50
		Total	30		

Appendix JJJ Tests of normality for the Cognitive loads 1 to 4

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Cognitive Load1	.220	89	.000	.924	89	.000
Cognitive Load2	.145	89	.000	.956	89	.004
Cognitive Load3	.240	89	.000	.859	89	.000
Cognitive Load4	.137	89	.000	.955	89	.004

a. Lilliefors Significance Correction

Appendix KKK Wilcoxon Signed Ranks for Cognitive load 1 and cognitive load 2

Condition			N	Mean Rank	Sum of Ranks
Without CS	Cognitive Load2 - Cognitive Load1	Negative Ranks	26[a]	21.13	549.50
		Positive Ranks	12[b]	15.96	191.50
		Ties	4[c]		
		Total	42		
With CS	Cognitive Load2 - Cognitive Load1	Negative Ranks	10[a]	8.25	82.50
		Positive Ranks	6[b]	8.92	53.50
		Ties	39[c]		
		Total	55		

a. Cognitive Load2 < Cognitive Load1

b. Cognitive Load2 > Cognitive Load1

c. Cognitive Load2 = Cognitive Load1

Appendix LLL Test Statistics for the Wilcoxon Signed Ranks Test for Cognitive load 1 and 2

Condition		Cognitive Load2 - Cognitive Load1	Cognitive Load4 - Cognitive Load3
Without CS	Z	-2.63[b]	-2.28[c]
	Asymp. Sig. (2-tailed)	.009	.02
	Exact Sig. (2-tailed)	.008	.02
	Exact Sig. (1-tailed)	.004	.01
	Point Probability	.000	.00
With CS	Z	-.76[b]	-1.70[c]
	Asymp. Sig. (2-tailed)	.45	.09

Condition		Cognitive Load2 - Cognitive Load1	Cognitive -Load4 - Cognitive Load3
	Exact Sig. (2-tailed)	.45	.10
	Exact Sig. (1-tailed)	.23	.05
	Point Probability	.007	.02

a. Wilcoxon Signed Ranks Test

b. Based on positive ranks.

c. Based on negative ranks.

Appendix MMM Descriptive statistics for the Wilcoxon dependent Samples test for Cognitive load 1 and 2 for Without CS and With CS

							Percentiles		
Condition		N	Mean	Std. Deviation	Minimum	Maximum	25th	50th (Median)	75th
Without CS	Cognitive Load1	42	5.07	1.97	1	9	4.00	5.00	6.00
	Cognitive Load2	42	3.95	1.87	1	8	2.75	4.00	5.00
With CS	Cognitive Load1	56	4.20	1.66	1	9	3.00	5.00	5.00
	Cognitive Load2	56	3.88	1.57	1	9	3.00	4.00	5.00

Appendix NNN Wilcoxon Signed Ranks for Cognitive load 3 and cognitive load 4

Condition			N	Mean Rank	Sum of Ranks
Without CS	Cognitive Load4 - Cognitive Load3	Negative Ranks	13[a]	10.23	133.00
		Positive Ranks	18[b]	20.17	363.00
		Ties	4[c]		
		Total	35		
With CS	Cognitive Load4 - Cognitive Load3	Negative Ranks	4[a]	4.50	18.00
		Positive Ranks	8[b]	7.50	60.00
		Ties	10[c]		
		Total	22		

a. Cognitive Load4 < Cognitive Load3

b. Cognitive Load4 > Cognitive Load3

c. Cognitive Load4 = Cognitive Load3

Appendix OOO Test statistics for the Wilcoxon dependent samples test for Cognitive Load 3 and 4

Condition		Cognitive Load4 - Cognitive Load3
Without CS	Z	-2.28[a]
	Asymp. Sig. (2-tailed)	.02
	Exact Sig. (2-tailed)	.02
	Exact Sig. (1-tailed)	.01
	Point Probability	.00
With CS	Z	-1.70[a]

Condition		Cognitive Load4 - Cognitive Load3
	Asymp. Sig. (2-tailed)	.09
	Exact Sig. (2-tailed)	.10
	Exact Sig. (1-tailed)	.05
	Point Probability	.02

a. Based on negative ranks.

Appendix PPP Descriptive Statistics for the Wilcoxon dependent Samples test for Cognitive Load 3 and Cognitive Load 4

Condition		N	Mean	Std. Deviation	Minimum	Maximum	Percentiles		
							25th	50th (Median)	75th
Without CS	Cognitive Load3	35	3.46	1.268	1	6	2.00	3.00	4.00
	Cognitive Load4	35	4.37	2.001	1	9	3.00	4.00	6.00
With CS	Cognitive Load3	22	3.14	1.320	1	5	2.00	3.00	4.00
	Cognitive Load4	22	3.68	1.756	1	7	2.75	3.50	5.00

Appendix QQQ Descriptive statistics for Wilcoxon U test for cognitive load 1 and 2 based on gender

Condition	Gender		N	Mean	Std. Deviation	Minimum	Maximum	Percentiles 25th	50th (Median)	75th
Without CS	Male	Cognitive Load1	21	4.90	1.578	1	8	4.00	5.00	5.50
		Cognitive Load2	21	3.81	1.965	1	8	2.50	4.00	5.00
	Female	Cognitive Load1	21	5.24	2.322	1	9	3.50	5.00	7.50
		Cognitive Load2	21	4.10	1.814	2	7	2.50	4.00	5.50
With CS	Male	Cognitive Load1	27	4.48	1.673	1	9	4.00	5.00	5.00
		Cognitive Load2	26	4.15	1.759	1	8	3.00	4.00	5.25
	Female	Cognitive Load1	29	3.93	1.624	1	8	3.00	4.00	5.00
		Cognitive Load2	30	3.63	1.377	1	6	3.00	4.00	5.00

Appendix RRR Descriptive statistics for Wilcoxon U test for cognitive load 3 and 4 based on gender

Condition	Gender		N	Mean	Std. Deviation	Minimum	Maximum	Percentiles 25th	50th (Median)	75th
Without CS	Male	Cognitive Load3	17	3.59	1.18	2	6	3.00	4.00	4.00
		Cognitive Load4	17	3.88	1.90	1	8	3.00	3.00	5.50
	Female	Cognitive Load3	18	3.33	1.37	1	6	2.00	3.00	4.25
		Cognitive Load4	18	4.83	2.04	1	9	3.00	5.00	7.00
With CS	Male	Cognitive Load3	10	3.70	1.25	1	5	3.00	4.00	5.00
		Cognitive Load4	10	4.00	1.56	1	7	3.00	4.00	5.00
	Female	Cognitive Load3	12	2.67	1.23	1	5	2.00	2.50	3.75
		Cognitive Load4	12	3.42	1.93	1	7	2.00	3.00	5.00

Appendix SSS Pearson Correlations Between the Cognitive Loads and the Tests Done Using CLRS and TDRV-GO respectively.

Condition			Cognitive Load1	Cognitive Load2	Cognitive Load3	Cognitive Load4	Test1	Test2	Test3
Without CS	Cognitive Load1	Pearson Correlation	1	.12	.47**	.03	-.08	-.02	-.11
		Sig. (2-tailed)		.45	.001	.85	.61	.89	.55
		N	46	42	46	35	43	46	35

Condition			Cognitive Load1	Cognitive Load2	Cognitive Load3	Cognitive Load4	Test1	Test2	Test3
	Cognitive Load2	Pearson Correlation	.12	1	.34*	.06	-.11	-.12	.05
		Sig. (2-tailed)	.45		.03	.75	.51	.44	.77
		N	42	42	42	35	39	42	35
	Cognitive Load3	Pearson Correlation	.47**	.34*	1	.19	-.07	-.03	.06
		Sig. (2-tailed)	.001	.03		.29	.64	.84	.72
		N	46	42	46	35	43	46	35
	Cognitive Load4	Pearson Correlation	.03	.06	.19	1	-.02	.05	.02
		Sig. (2-tailed)	.85	.75	.29		.91	.78	.91
		N	35	35	35	35	33	35	35
	Test1	Pearson Correlation	-.08	-.11	-.07	-.02	1	.50**	.10
		Sig. (2-tailed)	.61	.51	.64	.91		.001	.60
		N	43	39	43	33	43	43	33
	Test2	Pearson Correlation	-.02	-.12	-.03	.05	.50**	1	.53**
		Sig. (2-tailed)	.89	.44	.84	.78	.001		.001
		N	46	42	46	35	43	46	35
	Test3	Pearson Correlation	-.11	.05	.06	.02	.10	.53**	1
		Sig. (2-tailed)	.55	.77	.72	.91	.60	.001	
		N	35	35	35	35	33	35	35
With CS	Cognitive Load1	Pearson Correlation	1	.72**	-.11	.28*	-.02	-.08	-.15
		Sig. (2-tailed)		.00	.41	.04	.86	.56	.28
		N	58	56	58	56	57	56	53
	Cognitive Load2	Pearson Correlation	.72**	1	.01	.39**	-.06	-.04	-.12
		Sig. (2-tailed)	.00		.94	.004	.66	.80	.41

Condition			Cognitive Load1	Cognitive Load2	Cognitive Load3	Cognitive Load4	Test1	Test2	Test3
Treatment - Control		N	56	56	56	54	55	55	51
	Cognitive Load3	Pearson Correlation	-.11	.01	1	.09	-.39**	-.31*	-.26
		Sig. (2-tailed)	.41	.94		.49	.002	.02	.06
		N	58	56	59	56	58	57	54
	Cognitive Load4	Pearson Correlation	.28*	.39**	.09	1	-.35**	-.14	-.24
		Sig. (2-tailed)	.04	.004	.49		.008	.30	.09
		N	56	54	56	56	56	55	53
	Test1	Pearson Correlation	-.02	-.06	-.39**	-.35**	1	.34*	.25
		Sig. (2-tailed)	.86	.66	.002	.008		.01	.07
		N	57	55	58	56	58	57	54
	Test2	Pearson Correlation	-.08	-.04	-.31*	-.14	.34*	1	.56**
		Sig. (2-tailed)	.56	.80	.02	.30	.01		.00
		N	56	55	57	55	57	57	53
	Test3	Pearson Correlation	-.15	-.12	-.26	-.24	.25	.56**	1
		Sig. (2-tailed)	.28	.41	.06	.09	.07	.00	
		N	53	51	54	53	54	53	54

**. Correlation is significant at the .01 level (2-tailed).

*. Correlation is significant at the .05 level (2-tailed).

Appendix TTT Descriptive statistics for writing times 1,2 and 3

	Condition	N	Mean	Std. Deviation	Std. Error Mean
Writing time1	Without CS	45	24.23	5.18	0:00:46.33
	With CS	58	23.14	4.91	0:00:38.69
Writing Time2	Without CS	46	16.16	2.57	0:00:22.74
	With CS	55	17.58	4.28	0:00:34.63
Writing Time3	Without CS	35	14.30	1.63	0:00:16.52
	With CS	55	12.93	4.13	0:00:33.44

Appendix UUU Descriptive statistics for Writing times 1,2 and 3 based on gender

Gender		Condition	N	Mean	Std. Deviation	Std. Error Mean
Male	Writing time1	Without CS	22	24.67	5.30	1.13
		With CS	27	22.34	3.98	0.77
	Writing Time2	Without CS	23	16.63	2.73	0.57
		With CS	26	16.69	4.00	0.78
	Writing Time3	Without CS	17	14.21	1.28	0.31
		With CS	26	12.65	4.07	0.80
Female	Writing time1	Without CS	23	23.80	5.14	1.07
		With CS	31	23.84	5.57	1.00
	Writing Time2	Without CS	23	15.69	2.36	0.49
		With CS	29	18.38	4.43	0.82
	Writing Time3	Without CS	18	14.38	1.94	0.46
		With CS	29	13.17	4.25	0.79