

**THE IMPACT OF COMPUTER SIMULATIONS ON GRADE 11 LEARNERS’
CONCEPTUAL UNDERSTANDING OF PHOTOSYNTHESIS**

by

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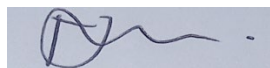
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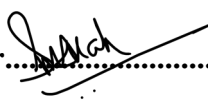
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ABSTRACT

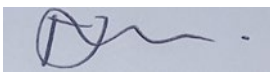
Conceptual understanding is fundamental in Life Sciences. Computer Simulations (CS) can be used to improve conceptual understanding. This study investigated the use of CS to enhance the conceptual knowledge of Grade 11 learners in photosynthesis compared to the traditional teaching method. The study used the Multimedia Learning Theory (MLT) as its theoretical model and the constructivist approach in MLT. The research paradigm used is positivism since it relies mainly on experimentation. A quantitative research design was used. The study used a quasi-experimental design to observe the relationship between the dependent and independent variables. The population was made up of secondary schools under Elim and Hlanganani Circuits. A purposive sampling procedure was used to sample participants. The sample was drawn from the grade 11 learners from four different schools under the two Circuits. Data was collected through tests and questionnaires. Validity and reliability were applied to ensure the quality and accuracy of research instruments. Data was analyzed and interpreted using the Statistical Package for the Social Sciences (SPSS) version 29 software.

The study investigated the effectiveness of CS in improving the conceptual understanding of grade 11 learners in photosynthesis. The quasi-experimental design involved a sample of 200 learners, 100 as the experimental and 100 as the control group. A pre-test was administered to all learners to assess their prior knowledge of photosynthesis. Thereafter, the experimental group was exposed to CS, while the control group used the traditional teaching method. Both groups were given the post-test to assess their understanding of photosynthesis. A questionnaire was also administered to gather the learner's views on simulations. The result displayed an important improvement in learners' understanding of photosynthesis after using CS and decreased misconceptions. The findings of this study were that CS can be used as a valuable tool in teaching and learning photosynthesis and deliver ideas for the application and design of a simulation-based learning environment.

Keywords: Computer simulations, conceptual understanding, photosynthesis, traditional teaching method

DECLARATION

I, Tinyiko Millicent Maluleke, student number 11617587, declare that my dissertation for the Master of Education in Science Education at the University of Venda is my work and has not been previously submitted for any degree at any institution. University of Venda Research Ethics Committee granted Ethical Clearance for this study with ethical clearance number FHSSE/24/CSEM/05/0107.

Signature : 

Date: 19/02/2025

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DEDICATION

This research is dedicated to my mother and sisters for their support. Most importantly, I dedicate this research to my children Lonene and Nkhaviso for their patience while I took time away from them to complete this research. I also want to mention my grandmother, Mamaila Maluleke (N’wamzamani), who supported me throughout my educational journe

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ABBREVIATIONS

ATP – Annual Teaching Plan

CAPS – Curriculum Assessment Policy Statement

CCTM - Cognitive Constructivist Theory of Multimedia

CS – Computer Simulations

FET – Further Education and Training

LFSC – Life Sciences

MLT - Multimedia Learning Theory

NCS – National Curriculum Statement

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CHAPTER 1

Introduction

1.1 Introduction

This chapter provides a summary of the study by outlining its background, problem statement, aims, research questions, and hypothesis. The key concepts relevant to the research are discussed as well as the significance, delimitations, and overall structure of the study. A brief discussion of the research methodology is included here, with full details presented in Chapter 4.

1.2 Background of the study

A simulation is a way of imitating and explaining what will happen in the real world and how it will happen (Duran, 2020). In its slightest logic, a computer simulation is a software package run on a computer that practices step-by-step approaches to discover the estimated behavior of a mathematical model (Duran, 2020). Computer simulations (CS) are essential to the mathematical modeling of natural systems in physics, chemistry, biology, and technology. The simulations may play significant roles in Life Sciences (LFSC) schoolrooms and science education since they promote experiential learning. CS provides learners the chance to witness real-world knowledge and interrelate with it. Learners who use simulations can understand and grasp challenging concepts in LFSC education.

Traditionally, classroom science learning focuses on transmitting and acquiring facts and rote learning. Learners do not actively participate in the classroom as the teacher delivers the content; they listen. Simulations are practical instructional techniques that teachers generate to replicate or duplicate real occasions, difficulties, measures, or skills to accomplish the anticipated instructional outcome (Sabus and Macauley, 2017). The goal of using CS is for learners to experience the condition from a valid viewpoint, apply or exercise new skills and information, think critically, and gather meaning from the situation (Jones and Barret, 2017).

In their study, Kolb and Kolb (2017) found that learners who were associated with an experiential learning atmosphere better understood their subject matter than learners in a traditional teaching class. Experiential learning activities can assist learners in engaging with their syllabus, expand learner enthusiasm and self-reliance, and develop proficient skills (Watkins and Poudyal, 2021). Learners participate in a substantial practice, duplicate that skill and other indications, support theories in order with experiences and facts, and

communicate a hypothesis or interpret a problem. Experiential learning gives learners more responsibility and actively involves them in learning. Boggu and Sundarsingh (2019) found that experiential learning is an effective teaching technique assisting vigorous learning by equipping real-world practices in which learners interact and critically evaluate the subject matter and become involved with a matter being taught.

The process of photosynthesis is critical to the production of food and fiber as it provides raw materials for all plant products. Since the agricultural land is limited and the human population is increasing, it is essential to understand the concept of photosynthesis and how it enhances productivity (Stirbet et al., 2020). The still-increasing population poses serious challenges to further strengthening the biomass production of crop plants. Photosynthesis begins with absorbing light and carbon dioxide and converting them into energy-rich carbohydrates such as glucose and starch, releasing energy and oxygen. It is the center of all life forms on earth, providing organic compounds and oxygen. A study by Marmaroti and Galanopoulou (2019) found that learners do not conceive of photosynthesis as a chemical reaction and do not understand the role of chlorophyll; they also found that learners misunderstood the concept of energy. The learner's misunderstanding of photosynthesis is based on misconceptions. Learners tend to confuse photosynthesis with cellular respiration, and they think that cellular respiration occurs when there is no photosynthesis.

Misconceptions about photosynthesis are sometimes passed from teachers to learners. Addressing the misconceptions will lead to a greater understanding of the concept of photosynthesis.

Photosynthesis is dealt with in the senior phase in Grades 8 and 9, but it is dealt with in detail in Grade 11 LFSC. It is one of the most challenging topics for both teachers and learners, simply because the concepts are difficult, which leads to a loss of interest and many misconceptions among learners. There are several limitations when it comes to the practical demonstration of photosynthesis because of the lack of laboratories and resources. The National Curriculum Statement (NCS) Grade R-12 is based on the principle that encourages an active and reflective learning method as a substitute for rote and unreflective learning of particular reality (Department of Education, 2010). The open-ended nature of CS encourages learners to consider the ramifications of a situation, which in turn encourages the application of critical and evaluative thinking. The learners become more involved since the scenario seems genuine.

This study focused on how CS will improve conceptual understanding of grade 11 learners in photosynthesis in Life Sciences. It investigated the understanding of learners' concepts when they were taught using traditional instruction in comparison with CS, as well as cultivating the learners' attitudes towards using CS. A quantitative method was used to gather the quantitative data.

1.3 Statement of the problem

Today, most teachers are concerned about learners getting high marks and making sure that they all pass. In order to do that, teachers need to bring new strategies into the teaching and learning environment. Some studies show the causes of poor performance in LFSC (Ngema, 2016), but they do not show how those weaknesses are being addressed. A study by Teane (2019) found that the use of English as the language of teaching and learning in teaching LFSC prevented learners from sufficiently understanding the subject and that learners seem to struggle with new terminology as implemented by the policy changes. According to Ndayambaje, Bikorimana and Nsanganwimana (2021), the reasons why learners performed poorly in the LFSC were: the use of English as the primary language of instruction; a lack of laboratory equipment; a lack of resources for instruction and learning; a poor teaching strategy; a lack of parental involvement in the learners' education; poverty; learner absenteeism; and the school environment.

A study by Panijpan, Ruenwongsa and Sriwattanarothai (2018) found that learners did not grasp the key concepts and could not apply simple knowledge to answer simple questions about photosynthesis even after numerous introductions to the topics. The main reason for the difficulty in understanding concepts might be because traditional instruction is dominant in the classroom. Traditional instruction is teacher-centred, the teacher talks and writes information on the board and learners copy notes and listen. In the traditional method, the teacher is seen as the wheel in the classroom, accountable for all activities and assuring that all communications go through him (Noreen and Rana, 2019). Learners are passively involved in the learning process. In classroom teaching periods, the principal physical activity done by the learners is either taking notes or answering questions asked by the teacher (Noreen and Rana, 2019). Learners become more active and interested in the learning process

when new approaches such as CS are introduced in the classroom, the pass rate may be increased because of such.

Another reason why learners find concepts difficult is because of the lack of innovation and creativity in the classroom (Aguilar and Turmo, 2019). In rural schools there are no laboratories, learners do experiments theoretically and are being told about the outcome of the investigation without performing the actual experiment. So, learners memorize facts rather than know and understand them. A study by Mtsi and Maphosa (2016) found that there were several encounters connected to the absence of necessary infrastructure and resources for teaching science such as the laboratory, lab equipment and computers. If those encounters are addressed, there will be meaningful learning and teaching of science. The problem to be investigated in this study is how simulations can be used to improve grade 11 learners' understanding of the photosynthesis concept.

1.4 Aims of the study

1. The main aim of this study is to investigate the effectiveness of using simulations to improve grade 11 learners' understanding of the photosynthesis concept. The following are the objectives of the study: To investigate the understanding of Grade 11 learners' photosynthesis concept using traditional method and CS.
2. To find out the attitudes of learners about the use of traditional method and CS in LFSC in the classroom environment.
3. To increase learners' motivation and interest in learning LFSC concepts.
4. To enhance learners' ability to recognize and correct misconceptions about photosynthesis.

1.5 Research questions

The main research question is; what is the effectiveness of using computer simulations in improving Grade 11 learners' conceptual understanding of the photosynthesis concept? The following are sub-questions of the research:

1. What is the difference in understanding of photosynthesis concepts between Grade 11 learners who receive traditional instruction compared to CS?

To answer this question, a pre-post-test was designed; it was administered before and after the use of CS in both groups (control and experimental).

2. What are the attitudes of learners towards the use of CS as compared to traditional methods in Life Sciences classrooms?

In order to answer this research question, a questionnaire was administered to the experimental group after the use of CS.

3. What is the impact of computer simulations on learners' motivation and interest in learning Life Sciences concepts?

This question was answered by the questionnaire that was administered after the use of CS.

4. To what extent do computer simulations improve learners' ability to recognize and correct misconceptions?

This question was answered by the use of a post-test in the experimental group.

1.6 Hypothesis

1. The use of CS is better than the traditional method for learners' understanding of photosynthesis.
2. Learners prefer the use of CS as compared to the traditional method for teaching and learning.

Based on previous studies, CS has been used to enhance traditional instruction, especially in laboratory activities. They also promote learner interest and involvement and provide opportunities for effective learning. Some studies indicate that CS serve as a powerful tool since learners learn by doing and knowledge is retained longer than learning by listening and reading.

1.7 Significance of the study

Life Sciences play a very important role in science education; it is concerned with plants, animals and microorganisms. LFSC allows us to understand our environment and the other living things found on earth. The knowledge of LFSC leads to conservation efforts and assists us in helping save our planet. The growing demand for graduates with a Life Sciences background justifies the necessity for an effective Life Sciences teaching style. Learners will receive superior instruction in schools that use the CS strategy. This study would improve learners' understanding of photosynthesis and performance. New strategies (computer simulations) are used in the classroom environment, which might improve teachers' creativity

in the learning environment. The study dealt with learners from rural areas with no laboratories; the simulations are going to give learners laboratory experience. The study would also help the Department of Basic Education to determine the strengths and weaknesses of using CS in the classroom and the ways of making them more useful and available in the school environment.

1.8 Delimitation of the study

This study was conducted using CS to improve the conceptual understanding of grade 11 learners in photosynthesis. It was conducted within the Vhembe-West District in Limpopo province, in Elim and Hlanganani Circuit. This study was conducted in a rural area because of the challenges learners face in Life Sciences. The challenges include limited access to quality education, resources and technology which can prevent them from producing good learning outcomes. The challenges faced by rural areas could be helped by implementing the CS and the quality of education can be improved. The study aims to get an understanding of various challenges and opportunities that exist in this context; and develop strategies to improve educational outcomes.

1.9 Outline of the study

This study is offered in six chapters, which are as follows:

Chapter 1: Introduction

This chapter presents the introduction which contains the research topic, background of the study, problem statement, aims and objectives, definition of key concepts, research paradigm, research approach and methods to be used in sampling, data collection, analysis of data, significance of the study, and delimitations of the study.

Chapter 2: Literature review

In this chapter, the researcher focuses on the literature review on the Impact of Computer Simulations on Grade 11 Learners' Conceptual Understanding of Photosynthesis

Chapter 3: Theoretical and conceptual framework

This chapter focuses on the theoretical and conceptual framework which is used to form theoretical background of the study.

Chapter 4: Research design and methodology

This chapter focuses on the research paradigm, research design and methodology as well as ethical considerations.

Chapter 5: Data presentation, analysis and interpretation

In this chapter, the researcher focuses on data presentation as well as data analysis and the interpretation.

Chapter 6: Summary of findings, conclusions, and recommendations

Chapter 6 presents the summary, conclusions from the findings, recommendations, and the need for further research. The main research questions and sub-questions are discussed.

1.10 Definition of key concepts

Cellular respiration – a metabolic process that converts glucose in the cell of the body into energy-rich adenosine triphosphate, or ATP (Bailey, 2020). It is an important process that occurs in the cells of all living organisms and can be defined as the metabolic process that converts chemical energy from the food we eat into ATP (Pamungkas, et al., 2019). The concept of cellular respiration will be used to address misconceptions learners have about photosynthesis since the two concepts are contrasting processes. CS can highlight the difference between photosynthesis and cellular respiration by giving clarity that photosynthesis produces oxygen and glucose while cellular respiration uses them. CS can also show how the two processes depend on each other. Common misconceptions can be overcome by using CS to connect the two processes.

Computer simulations (CS) - is a software package that is run on a computer and uses step-by-step procedures to discover the estimated behavior of a mathematical model (Smith, 2019). They allow for experimentation, analysis and prediction in a controlled digital environment (Hartmann, 2020). In simple terms, it refers to the visual imitation of a real-world situation or process that is created using a software model and it analyses and predicts the outcome or behaviour. CS were used to create visual labs for Life Sciences learners to learn the concept of photosynthesis. By using CS, the study enhanced learners' understanding of photosynthesis concepts, and their application in real life, as well as develop their critical and problem-solving skills.

Concepts - concepts have different meanings in the learning and teaching of science. Scientific concepts can be referred to as logical mental illustrations of the normal world, and they play an important role in science (Kampourakis, 2018). They are similar to something that can be observed (e.g. a plant) or something that cannot be observed (e.g. tissues) or they can be a process (e.g. photosynthesis). When we use concepts, they should be associated with their meaning; ideas or processes should be connected. This study investigates how CS enhance learners' existing concepts. Computer Simulations also involve the cognitive and learning processes that enhance the understanding of how learners develop and apply knowledge.

Conceptual understanding – is defined as grasping ideas in a way that is transferrable and can assist learners take what they learn in class and apply it in new situations (Moser and Chen, 2016). It means to grasp essential concepts and principles of Life Sciences such as photosynthesis, relate the concept to real-world phenomena and applications and then use this understanding to explain, predict, and analyse biological phenomena (Konicek-Moran and Keeley, 2015). Human ideas give rise to concepts (Konicek-Moran and Keeley, 2015). Concepts can also consist of a single word or a brief phrase (Konicek-Moran and Keeley, 2015). Examples of such concepts include the food chain, closed system, and digestive system. Conceptual understanding means that learners should be able to integrate new information into their present knowledge and context. In this study, conceptual understanding of photosynthesis is the variable being investigated or measured. Computer simulations are going to be used to improve that understanding.

Critical learning – refers to a learning situation in which learners experience effective and meaningful learning (Watkins and Poudyal, 2021). Critical learning aims to foster critical thinking and problem-solving skills as well as community engagement and participation (Robert, 2020). Critical learning is used to encourage learners to reflect on the CS experience and identify preconceptions, expectations and power dynamics that may inspire their decision-making. It is also used to foster critical thinking by using simulations that enable learners to question assumptions, evaluate evidence and develop well-supported environments. Encouraging critical learning together with the use of CS can make learners have a huge understanding of difficult issues promote critical thinking and reflection and prepare learners to solve real-world challenges.

Experiential learning – is an interactive learning process whereby learners reflect on their experiences learning by doing (Boggu and Sundarsingh, 2019). Experiential learning can also be defined as a process where learners gain knowledge and skills through direct experience and reflection (Kong, 2021). It enables learners to apply abstract ideas to actual circumstances through practical experiences, real-world applications, and hands-on activities (Yeo, 2020). Experiential learning is used in this research since it involves simulations; interactive simulations imitate real-world experiences, allowing learners to experience and experiment in a controlled and safe environment. Integration between simulations and experiential learning can create a powerful learning environment and raise deep understanding, develop learners' skills and enable them to transfer learning to real-life situations.

Meaningful learning - is a learning process where learners build their own understanding, make connections between concepts and be able to explain those concepts on their own. Meaningful learning is built on more than what is transmitted by teachers; it encourages the creation of information out of learners' experience, state of mind and interactions with other learners (Sharan, 2015). For meaningful learning to take place, information needs to be created by the learner, not the teacher transferring it to learners (Widiyatmoko, 2018). Learners who have a conceptual understanding of specific concepts create distinctive conceptual frameworks that are arranged hierarchically. When learners understand a concept, they can be able to think about it, use it in different situations, use their own words to define it, discover a representation or a comparison for it, or construct a mental or physical representation of it (Konicek-Moran and Keeley, 2015). Learners are able to formulate a concept on their own. When using CS, learners are encouraged to actively participate by interacting with simulations, making informed decisions and exploring concepts on their own. They use simulations that enable them to apply what they have learnt in new situations thus promote transfer of learning.

Misconception – is an opinion or understanding that is inappropriate based on incorrect thinking (Soeharto and Csapo, 2019). Misconceptions often lead to incorrect views or assumptions. Misconceptions can also lead to conceptual misunderstanding, which occurs when learners are taught scientific information in a way that does not inspire them to challenge ironies and conflicts in their own defined notions and non-scientific opinions (Fuschs and Arsenault, 2017). In this study, the misconceptions are used to identify knowledge gaps by analyzing learner misconceptions to recognize where they struggle with

the concept of photosynthesis. Simulations that address specific misconceptions are used to help learners correct their misunderstandings. By exploring misconceptions in CS, one can gain understanding of learners' cognitive processes, improve learning outcomes and develop more active instructional strategies.

Pacesetter – a document given to teachers from the Department of Education which contains work to be covered together with all the formal assessments to be given throughout the year (Department of Education, 2010). A pacesetter document is used to set standards for simulation design and inform the development of the CS learning environment, instructional materials and learning objectives. It is also be used to evaluate whether CS were effective by assessing their impact on learner performance. Using pacesetter documents in research can promote educational excellence and improve collaborative learning.

Photosynthesis – is the process by which producers convert radiant energy from the sun into chemical energy in the form of organic compounds, such as glucose (Alberts, et al., 2022). It is a process by which radiant energy is converted into chemical energy that cells can use. The concept of photosynthesis is used in CS to represent light-dependent and light-independent reactions (complex biological processes), allowing learners to explore and understand the details of photosynthesis. Computer simulations model the environmental factors affecting the rate of photosynthesis, such as light, temperature, and the amount of CO₂, allowing learners to alleviate these factors. Computer simulations are interactive and, therefore, promote a deeper understanding and appreciation of photosynthesis and its importance in biology and ecology (Mtsi and Maphosa, 2019).

Rote learning - The Oxford University Press (2020) defines rote learning as a type of learning where information is committed to memory without necessarily understanding its meaning or significance. It is a process of memorizing information based on repetition. While rote learning can be suitable in certain conditions, such as memorizing a phone number or a list of items, it is usually considered a less effective way of learning than other methods that emphasize understanding and application (Kewalramani and Turker, 2022). In this research, it is used to investigate the effectiveness of rote learning versus deeper learning strategies in CS and design instructional strategies such as CS that promote meaningful learning and mitigate rote learning.

1.11 Research design and methodology

This study used a quantitative research design to investigate the causal relationship between the use of CS and learners' conceptual understanding of photosynthesis. A quasi-experimental research design was used to collect data from a sample of 200 participants selected through a purposive sampling strategy. The data was collected through tests and questionnaires and analyzed using Statistical Package for the Social Sciences (SPSS) version 29 to determine the correlations and predictive relations between variables. This quantitative approach yielded a reliable and unbiased evaluation of the impact of CS, enabling generalisations to be made about the broader population and improving the field of education. The details of this methodology are discussed in detail in chapter 3.

1.12 Conclusion

Chapter 1 provides the study's background on the usage of computer simulation as a teaching method in the classroom. Along with the problem statement, the study's goals, objectives, research questions, and hypotheses were presented. A review of the literature and the theoretical framework that underpins the study are presented in the following chapter.

CHAPTER 2

Literature Review

2.1 Introduction

This chapter's goal is to review and summarize the body of research on how computer simulations affect 11th-grade learners' conceptual understanding of photosynthesis. The review looks at important aspects of this work, such as the use of CS, traditional teaching methods, conceptual comprehension in science education, and particular difficulties in teaching photosynthesis. The nature of conceptual comprehension and the variables influencing its development in learners are examined at the beginning of the chapter. After that, it looks at the empirical function of CS in science education, particularly how it affects learner engagement and conceptual transformation. The teaching of photosynthesis receives particular emphasis, with a focus on frequent misunderstandings and researched teaching methods to dispel them. The review also includes South African studies that are pertinent to teaching photosynthesis, using simulations, and teaching science in local settings.

2.2 Conceptual understanding

2.2.1 What does "conceptual understanding" mean?

According to Bransford et al (2013), learners who possess conceptual knowledge which arises when they are able to understand concepts in a transferable manner are able to apply what they learn in class to different domains. Conceptual understanding is a comprehension of the rules governing domains and the connections between different types of knowledge in a domain, both explicit and implicit (Rittle-John and Schnider, 2015). Understanding concepts is very similar to the difference between performing multiplication with and without a calculator. One does not have to consider the process and procedures when using a calculator. To obtain the solution, simply enter the values in the calculator. However, in order to multiply without a calculator, one needs to be familiar with the procedures and techniques. Individuals who comprehend multiplication acquire fluency and mental math abilities without the use of a calculator. According to Konicek-Moran and Keeley (2015), learners can better comprehend a topic by applying it in multiple contexts, defining or describing it in their own terms, creating a model of it, or choosing the right metaphor.

2.2.2 Conceptual Understanding in Science Education

Beyond merely remembering data or formulas, conceptual comprehension in science education refers to a learner's capacity to comprehend the underlying principles, linkages, and

systems that explain events. It entails creating logical mental models that enable learners to forecast results, explain novel circumstances, and critically apply their knowledge (Mills, 2016). Chabalengula, Sanders, and Mumba (2012) discovered that many first-year biology learners in South Africa had difficulty going beyond simple definitions of energy and were unable to relate what they had learned to biological situations like photosynthesis. Despite having a cursory awareness of the subject, this demonstrated a lack of conceptual understanding.

Learners must specifically comprehend how light energy is transformed into chemical energy, how chlorophyll works, and the reasons behind the common confusion between photosynthesis and respiration to have a conceptual grasp of photosynthesis. Learners who possess deep conceptual understanding are better equipped to identify and rectify mistakes, integrate new information with existing knowledge, and use scientific reasoning in a variety of situations (Duit and Treagust, 2012).

2.2.3 Importance of conceptual understanding

Conceptual understanding is a crucial objective in learning generally, but it is especially crucial in science education because it is necessary to make sense of phenomena (Tanitteerapan and Murphy, 2020). Conceptual understanding enables learners to solve problems without making numerous crucial mistakes (National Research Council, 2001). When learners multiply 9.83 and 7.65, for instance, and the result is 75119.5, they can quickly conclude that the answer is incorrect. Learning concepts stimulate additional learning (Chi, 2009). It has a strong foundation that promotes comprehension of other points of view. Thus, a learner needs to retain less information. For example, a learner who understands fractions mentally can easily work with percentages, decimals, ratios, and other mathematical concepts. He or she might consider these to be various depictions of the same theme. Learners who just know how to do certain things, on the other hand, will struggle since they have to remember a variety of processes.

It encourages participation (Chi, 2009). While procedural learning calls for the teacher to present information and provide examples, conceptual understanding necessitates learner participation. Without being made aware of the underlying dynamics, the learner is then expected to pay attention and practice the techniques. But when it comes to conceptual understanding, both the teacher and the learner play a significant part. The teacher gives learners tasks or difficulties that motivate them to fully develop an idea.

2.2.4 Conceptual understanding of Life Sciences concepts

According to Konicek-Moran and Keeley (2015), conceptual understanding is the one that is reliable and well-suited to scientific language or knowledge recognized by the community of science, it is not the language of inappropriate terminology, or the one used by non-scientists in everyday life with the meaning that is not the same. This includes the ability to identify new information, create interpretations and make links between scientific phenomena (Widiyatmoko, 2018). For example, in the photosynthesis and cellular respiration concept, learners have to be able to make the link between photosynthesis and cellular respiration, both are opposites of each other, on the other hand, they have a contrary relationship. Most learners come to school with interpretations that do not correspond with acceptable science ideas.

Teaching for conceptual knowledge is a crucial component of science education (Konicek-Moran and Keeley, 2015). Understanding the theories, models, and relationships that support facts or procedures in a field is known as conceptual knowledge (Anderson and Krathwohl, 2001). It enables learners to make sense of data, spot patterns, apply concepts to various situations, and explain why certain things operate in a particular way. Science is hard to understand conceptually. For example, it can combine single concepts such as glucose and oxygen for more complex concepts such as Adenosine triphosphate to form a new concept such as cellular respiration. Conceptual understanding is when learners can grasp ideas in a convertible way; it can help learners apply what they have learnt in the classroom in different situations (Hartmann, 2020). The increasing availability of scientific simulations in classrooms has brought about the study of their impact on practices of conceptual development and conceptual change (Widiyatmoko, 2018).

2.2.5 The effects of simulations on conceptual understanding

Computer simulations are used to investigate the active behaviour of objects or schemes in response to circumstances that cannot be effortlessly or securely applied in real life (Smith A., 2019). Learners can explore systems, change variables, and test hypotheses in learner-centred environments provided by computer simulations (Widiyatmoko, 2018). Computer simulations can be used by teachers to illustrate or by learners to investigate scenarios that are not feasible in everyday life. Additionally, computer simulations give learners real-world experiences from which to gather and alter data in order to better comprehend the connections between the ideas being studied. Computer simulations can be used in situations where there is no equipment; it is not easy to set them up. They can be used to do

experiments that are not easy or impossible to do in a classroom situation. Learners' questions can be answered by manipulating variables in situations where it is not always possible to do so with real instruments (Widiyatmoko, 2018).

According to numerous studies that have examined the employment of computer simulations with traditional instruction, CS can be used to enhance traditional training. In traditional instruction, CS can be useful extras, for example, aiding as pre-laboratory exercise or visualization tools (Widiyatmoko, 2018). Active and interactive CS that permit the learners to work together and become absorbed, in contrast to text and motionless pictures, have the same or more influence on the product of learning (Chen, Chang, Lai, and Tsai., 2014). A study by Rutten et al (2012) discovered that traditional teaching enhanced with CS assisted learners to perform better on short-term conceptual assessments.

2.3 Photosynthesis as a scientific concept

The Greek words "photo," which means light, and "synthesis," which means to create something, are the origin of the phrase photosynthesis. It is the most biochemical activity in life, and it is essential to all living things. Several studies have demonstrated that understanding photosynthesis is crucial to gaining a basic understanding of how the world functions as an ecosystem and how it connects the living and non-living worlds (Darja and Strgar, 2017). Thus, it makes sense that the idea of photosynthesis is covered in the school curriculum. One of the most fundamental ideas in biology is photosynthesis, which serves as the foundation for all of the energy sources required for life, from the consumption of food to the combustion of fossil fuels. Additionally, photosynthesising plants are extremely important for controlling climate since photosynthesis manages the balance of atmospheric gases like carbon dioxide. Overall, a comprehensive grasp of such a fundamental process as photosynthesis is a requirement for Life Science learners in this era of climatic, environmental, and societal changes (Södervik, Nousiainen, and Koponen, 2021)

2.3.1 South African curriculum in relation to photosynthesis

In South Africa, eighth-grade secondary school pupils begin learning the fundamentals of photosynthesis. The goal of the lesson is to demonstrate how plants need carbon dioxide from the atmosphere, water from the soil, and solar energy to produce glucose, or food, through a sequence of chemical processes. The Curriculum and Assessment Policy Statement paper

(Department of Basic Education, 2011) is in compliance with this. No other details are required. The material is then thoroughly covered in grade 11.

The CAPS document states that the main objectives for grade 11 are to comprehend the process of photosynthesis through the use of words and symbols, as well as the intake of raw materials, energy storage, the creation of food in chloroplasts, and the release of oxygen (Department of Basic Education, 2011). The significance of photosynthesis, including the production of food (which stores energy), the release of oxygen, the absorption of carbon dioxide from the atmosphere, and the effect of different levels of light, carbon dioxide, and temperature on the rate of photosynthesis (brief discussion along with graphs). In greenhouse systems, methods to boost agricultural output include carbon dioxide enrichment, ideal temperatures, and ideal light. The role of ATP as a crucial energy carrier in the cell and its potential to increase agricultural yields are also explored (Department of Basic Education, 2011).

2.3.2 Challenges with photosynthesis

According to research, learners enter science classes with a variety of prior knowledge that has a substantial impact on and can occasionally substantially hinder learning (Södervik et al., 2021).. There are misconceptions that make it difficult to understand photosynthesis. The majority of learners believe that plants do not require oxygen and that photosynthesis is the same as cellular respiration in plants. Because it is not addressed in the lower grades, learners carry these misconceptions into the higher grades. Learners also hold the misconception that plants continuously produce oxygen and that water and dissolved mineral compounds serve as the primary food source for plants. Other widespread fallacies include the notions that roots are the organs of feeding, that plants have a variety of food sources, that sunshine, carbon dioxide, water, and minerals are all food for plants and that food is created when plants absorb sunlight, and photosynthesis is a process that plants carry out for the benefit of humans and other creatures, especially in regard to the exchange of gases (Darja and Strgar, 2017).

Marmaroti and Galanopoulou (2018) conducted a study on learners' understanding of photosynthesis. Their study concentrated on six aspects of photosynthesis: physiology, energy and photosynthesis, photosynthesis as a chemical reaction, photosynthesis and respiration, photosynthesis and ecosystem function, and photosynthesis and plant feeding (autotrophy). They found that learners don't know how energy is converted and how

chlorophyll works in photosynthesis; they don't know that photosynthesis is a chemical reaction; they think that plants get their food from their environment; and they don't know the difference between photosynthesis and respiration. According to earlier research, learners have difficulty understanding important ecological concepts like photosynthesis, respiration, and energy transfer in ecosystems. Learners confuse sunlight with cellular respiration, according to a study by Svandova (2014).

As a vital biochemical process that generates energy for life on Earth, photosynthesis is a crucial biological concept. This chemical process provides energy for both producers and consumers. Although the concept they know does not fit into the current scientific paradigm, learners with misconceptions think it is true (Pamungkas, Saputro, and Mulyani, 2019). According to Pamungkas et al. (2019), misconceptions have an impact on learners' knowledge, which is then continuously transmitted to the next educational level and affects their learning achievement. When learners think on their own and expand their knowledge, misconceptions may arise.

There are major misconceptions that persist in learners' understanding of photosynthesis (Thomas, 2020):

- Plants get their food from the soil.
- The basic process of photosynthesis turns carbon dioxide and water into oxygen and carbohydrates.
- During the day, plants photosynthesise, and at night, they breathe.
- Because they absorb green light, plants are green.

A study by Svandova (2014) found that many learners mistake photosynthesis for plant respiration and that cellular respiration take place in special organs in the leaves called stomata. Learners also believe that plants produce oxygen during the day and they get their food from dissolved minerals and water (Svandova, 2014).

2.3.3 How challenges with photosynthesis are being addressed

Using inquiry-based science education as a teaching strategy that enables learners to achieve a conceptual change leading to scientifically accurate beliefs about photosynthesis and respiration in plants, Čipková, Karolčík and Vörösová (2017) conducted an investigation. A method of instruction known as inquiry-based learning (IBL) is focused on the questions and

natural curiosity of the pupils (Gholam, 2019). The results gained to support the assertion that by employing inquiry-based instruction in a science classroom, can prevent or minimize learners' misconceptions. Developing guided inquiry-based learning tools on photosynthesis and respiration matter that are feasible (valid, practical, and effective) to improve learners' science literacy was the subject of a separate study by Choirunnisak, Ibrahim, and Yuliani (2018). The results showed that it was possible to improve learners' science literacy skills.

Computer simulations were employed in several previous research to address difficulties with photosynthesis. Benya (2011) conducted a study in which the utilization of conventional lab exercises to teach the concepts of cell respiration and photosynthesis in an introductory high school biology course was compared with computer simulations of the same exercises. Learners who finished the task in a wet lab consistently performed much better than those who finished the activity in a virtual simulation. The study also showed that computer-assisted training provides feedback to learners so they can achieve mastery.

A network analysis method was used in a study by Södervik et al. (2021) to explore how to better understand how undergraduate Life Sciences learners perceive the function of photosynthesizing plants in the ecosystem. The findings revealed that there were significant differences between the tasks in the learners' use of macro-concepts and the depth of their concept networks. In the task pertaining to the role of plants from the perspective of the food chain, higher communicability measures were linked to a more abundant existence of macro-concepts.

2.4 Traditional teaching approaches

2.4.1 Definition of traditional teaching approach

Traditional teaching methods have been employed for a very long time. The traditional teaching methods are often teacher-directed, with lessons designed to encourage learners to sit still and listen (Tularam, 2008). In the past, teachers have been taught that a teacher-centred approach to learning is more effective since it makes the teacher the primary controller of the classroom and the learners merely the listeners and passive participants throughout the discussion. The method of training relies heavily on memorization and passive learning.

Teachers who employ traditional instruction believe that their learners will understand concepts more deeply if they simply hear the facts presented to them and will understand how

it is used in the real world. Traditional instruction uses textbooks and chalkboards/blackboards to explain concepts as teachers illustrate them for their learners. The instructor is the one with the expertise, the strategies, and the appropriate mix of learning capacity to impart the proper knowledge to the learner (Serrukh, 2020).

2.4.2 The importance of traditional instruction

Compared to other teaching strategies, traditional education is more structured and point learners in the appropriate direction. Teachers have a critical role in teaching discipline and providing pupils with a feeling of direction in a typical learning environment (Pant, 2020). It gives learners the chance to actively study, and it encourages them to work through academic issues under the teacher's supervision in the classroom. When learners experience challenges, the teacher can easily handle those difficulties because they will be monitoring.

Since it enables them to interact with both the teacher and their peers, most learners think that the traditional classroom environment is beneficial for learning (Paduraru, 2021). As the teacher outlines the principles to be enforced in class, how the learners should conduct themselves, and how they should do their homework, traditional instruction also promotes discipline. Communication skills among learners and teachers are improved through interaction. Because they do not have access to technological devices, some learners are unable to take online courses (Paduraru, 2021). Additionally, it pushes learners to be more competitive (Pant, 2020).

2.4.3 Challenges with traditional instruction

The direct instruction of learners is prioritized in traditional education, and learners learn through observation and listening (Sathish, Sornaganesh, Sudha and Chellama., 2020). The majority of learners respond well to traditional training, yet there are still some drawbacks to this kind of learning. The biggest drawback is that learners do not actively participate in the instructional environment because they merely listen to the teacher speak. Without understanding what is printed on the board or how it applies to real-world circumstances, they simply remember it. When they are perplexed or do not comprehend a certain topic, learners do not frequently ask inquiries. They do not pay attention to the lectures and adopt a passive attitude (Salim, 2019).

The ability to actively apply knowledge gained through experience and reason known as critical thinking skills is not promoted in traditional classroom instruction (Jaebi, 2021). Instead, traditional education emphasises the role of teachers as knowledge distributors and

learners as information repositories. The key sources of information are the teacher and textbooks. The knowledge of the pupils is limited to that which is offered by the textbooks and teachers because they are unable to learn new things (Salim, 2019). Public schools that strictly follow regulations risk impairing learners' capacity for critical and creative thought (Ponomarenko, 2019). Although a learner's performance and achievements are a good gauge of their growth, they also run the risk of undermining anything that is not strictly needed.

The emphasis on individual learner work and projects in traditional education is poor preparation for future endeavours, which are likely to involve working in teams and interacting with peers (Jaebi, 2021). Sometimes teachers assign learners a ton of homework each day, and learners do not work together to do it. Their social interactions are disrupted by their homework, which may have an impact on how they develop specific talents or personalities. Learners develop knowledge and skills that they may use in everyday life as they interact and socialize with one another. Another issue is that traditional education places more emphasis on memorization of information than practical application. It does not assist learners in comprehending the subject or using it in real-world situations, which is one among the most crucial aspects for learners.

2.5 Computer Simulations

2.5.1 Definition of computer simulations

A computer program known as a computer simulation employs step-by-step procedures to investigate the approximate behaviour of a mathematical model (Beisbart, 2017). In simpler terms, it is the use of a computer to simulate a system or process found in the actual world. Computer simulations can be used to research environmental behaviour that might be risky or impossible to apply in real life, such as a computer program designed to simulate a flying aircraft. Vehicle manufacturers utilize computational safety to test the safety features of new designs. By simulating a duplicate of the car in physics, they can potentially save more money than they would have needed to construct and test the new design. Speaking of simulations is speaking of a unique category of models called dynamic models, and speaking of models is speaking of deliberate representations of the target systems (Francois, 2018).

2.5.2 Advantages of computer simulations

Comparing computer simulations to traditional training, there are many benefits. Initially, computer simulation was employed as a supplement to the teacher's explanation of the theoretical notion to aid in learner comprehension (Hannel and Cuevas, 2018). They are able

to demonstrate how abstract ideas are implemented. Computer simulations enable communication between learners and the virtual tools. Additionally, they can offer comments to learners so that they can develop their abilities and knowledge. Numerous research have demonstrated how the use of CS has enhanced instruction and learning. The effectiveness of the simulation depends on how accurate it is.

Tools for simulation can measure learners' progress and give them standardized feedback to help them strengthen their skills (Anon, 2018). Under the guidance of teachers, learners can develop their talents by using CS. Learners can investigate systems, modify variables, explore systems, and evaluate hypotheses in a learner-centered environment provided by CS. Teachers can use these programs as demonstrations, or learners can use them directly to examine a variety of phenomena that are not readily accessible in everyday life (Widiyatmoko, 2018).

Using CS to perform tests that are difficult is another benefit. Variables can be changed by learners in response to their inquiries, which is not achievable in a real-world setting. Before performing actual laboratory experiments, learners can practice the necessary skills with the use of simulations, which also improves their comprehension of the experiments. Utilizing CS can assist prevent danger and fatalities. For instance, in a laboratory setting where harmful chemicals like acids are present. Simulations can be utilized to teach individuals how to drive safely.

Computer simulations can assist save money that was going to be spent on field trips as well as money that was going to be utilized to purchase chemicals and lab supplies. The behaviour that was supposed to be researched over a long period of time can be sped up through the use of simulations. In contrast to waiting for windy days, hot days, humid days, etc., environmental elements that influence the rate of photosynthesis, for instance, can be changed immediately. The behaviour can also be slowed down so that it can be thoroughly observed, as in the animal protein synthesis process.

Simulations help learners become more interested in learning science (Davies, 2019). For learners to be able to learn and be encouraged to be accountable for their own learning, they should be actively involved in the learning process. When learners are engaged, they should be encouraged to work in groups so that they can exchange knowledge and aid one another in better understanding complex ideas. Users can experience and engage with a setting that is similar to the actual world through simulation (Matveevskii and Gravenstein, 2020).

2.5.3 Challenges with Computer Simulations

Computer simulations have a lot of advantages, but there are still certain limitations. The greatest disadvantage of computer simulations is that they are not real (Widiyatmoko, 2018). People can feel and taste in a genuine world, but not in a simulation. When presented with real-life experience, many people respond differently. Unlike when utilizing computer simulations, learners become anxious when performing experiments in the actual world. Real-world facts, not ideal conditions, must be presented in simulation-based environments to guarantee that learners are getting the most out of the experience (Hannel and Cuevas, 2018).

Computer-based simulations may be difficult for learners with low computer literacy levels to use. Many computer-based simulations give learners with a number of modalities (text, images, and videos) that can be utilised to aid in the creation of hypotheses, the gathering of data, the inference of outcomes, and the drawing of conclusions (Hannel and Cuevas, 2018). Because they can navigate the computer-based simulation more readily, learners who are more comfortable and familiar with computers have the opportunity to learn more when they participate in it (Hannel and Cuevas, 2018). However, learners who are less computer-savvy are at a disadvantage. There may be a slower rate of knowledge gain.

Teachers must make sure that technology is used effectively as schools have more computers and simulations at their disposal. According to Renken and Nunez (2015), computer simulation is not the greatest method for experimentation when it lacks assistance. They discovered that when advice was not given along with the simulation, conceptual understanding was not positively impacted. Therefore, caution should be applied while using computer simulations. Computer simulations do little to improve lab equipment handling skills (Widiyatmoko, 2018).

They are pricey, which is another drawback of CS. Making a computer model can frequently be a costly approach to analysis (Pecaon, 2020). Even though there are cheaper simulation packages available, most large-scale modelling projects require a significant investment in time for study and development as well as in software, hardware, and training.

2.5.4 Previous research on the use of computer simulations

Kotoka and Kriek's 2014 study demonstrated the value of computer simulations in enhancing learners' conceptual comprehension. The study examined how Grade 11 learners' performance in electromagnetism was affected by CS as an interactive demonstration tool. An analysis of the test results prior to the implementation of computer simulations revealed that participants had a variety of alternative conceptions on the subject of electricity and direct current circuits, according to Gazikwa's (2019) study. This study examined the impact of CS on the conceptual understanding of Grade 10 learners in direct current circuits. A study of the results from the post-test revealed that the group that had access to computer simulations had a much higher average score than the group that continued to receive traditional teaching.

According to the research results of Feng (2018), computer simulation might be a viable substitute for conventional instruction that yields results that are equivalent. According to Aysheshim and Gebregziabher (2015), who looked at the use of computer simulations as a teaching tool for learners' comprehension of the ideas of electric fields and electric forces, learners who received instruction using computer simulations made better progress than the control group. Another study by Pfefferová (2015) to examine the impact of simulation use on learners' capacity to work with graphs and identify pertinent information revealed that experimental class learners do noticeably better than control class learners when simulation use is used in physics education.

2.5.5 The use of computer simulations in Life Sciences

For many years, dealing with pupils who performed poorly in biology was a challenge for biology professors. Then, computer simulation emerged as a powerful tool to support instruction and heighten learner focus (Niyigena and Nzabalirwa, 2022). Numerous studies demonstrated that teaching using technology was more successful than teaching without it, particularly when it came to science. As a result, it is the duty of scientific teachers to incorporate simulations into their instruction. By adapting and applying scientific information to real-world settings, computer simulation-based instruction improves learners' academic performance overall and in science-based courses in particular (Murugesan, 2019).

The biological sciences employ a wide range of traditional simulation techniques, such as finite-element simulations, cellular automata, agent-based modelling, Monte Carlo simulations, and artificial neural networks, to name a few (Wellmann, 2018). The use of computer simulations in the Life Sciences is easy to understand and could be a good example

of how technology could find its way into other fields of research once it is accessible (Wellmann, 2018). Learners could be engaged in critical, creative learning by using the extra time they would have had to experiment with accurate computer simulations. In biology labs, without access to lab equipment, CS can be utilized as a tool. In their 2018 study, Whitworth, Leupen, Rakes, Bustos, and Perez looked at interactive computer simulations as teaching aids in biology labs. Their research argues in favour of using computer simulations as teaching aids in more laboratory courses.

2.6 The attitudes of learners towards the use of simulations in the classroom

According to Salame and Makki's (2021) research, interactive computer simulations often encourages learners to increase their conceptual knowledge of chemistry topics and content while also having a progressive effect on their attitudes and opinions about learning.

According to Salame and Makki (2021), computer simulations seem to encourage and facilitate learning and comprehension of abstract concepts and offer learning possibilities that are not possible in a conventional laboratory setting. A study by Fatwa and Ismail (2017) indicated that learners provide a positive view towards the usage of CS and role-play in the classroom for the reason that they find it effective in refining their vocabulary as well as eliminating shyness, their confidence level to speak English increased as they explore other enjoyable ways to learn English which enhance their speaking skills. Most learners who have been exposed to simulations find them interesting and interactive.

Learners' attitudes toward Life Sciences

Attitudes are the emotional and mental units which motivate a person's action toward an object or subject (Perloff, 2016). Learners' attitudes towards a subject determine their ability and how well they are willing to learn. A study by Kabunga, Mohamed and Mnjokava (2016) discovered that attitude, age and gender had an important relationship with learners' achievement in science subjects. When teachers become aware of the learners' attitudes towards the subject they teach, it will help them to come up with strategies to improve teaching and learning of the subject matter. Some learners have a negative attitude towards LFSC simply because it is mainly theory and is the use of traditional instruction in the classroom.

Learners who have a negative attitude in the classrooms tend to become bored, uninterested and usually miss classes. Their achievement becomes low as a result. Learners' attitudes are very important; they have to be considered when understanding and explaining the

achievement of learners in science. Learners' perceptions of the learning environment or subject matter play a pivotal role in fostering learner-learning outcomes (Vereijken, van der Rijst, van Driel and Dekker., 2018). The way learners think, how they act, and how they behave can be affected by what they believe in and their perceptions and this can have several consequences for teaching and learning (Mensah, Okyene and Kuranchie., 2015). As learners grow older their positive attitude toward a subject can be improved by being actively engaged in the learning of science (Anwar and Bhutta, 2014).

Multiple academics have employed interactive computer simulations in the Life Sciences, and their findings demonstrate the effectiveness of CS in LFSC teaching and learning. In a study by Kibirige and Bodirwa (2021) on the impact of computer simulations on grade 11 learners' performance in South African plant biodiversity, they discovered that the use of CS positively influenced learners' attitudes toward the topic of plant biodiversity and was therefore effective in raising learners' performance. It has been demonstrated by Niyigena and Nzabairwa's subsequent study (2022) that the use of computer simulations in the teaching and learning of Life Sciences enhances learner performance.

2.7 South African context: photosynthesis, Simulations, and Conceptual understanding

The conceptual understanding of photosynthesis and the educational influence of CS have been the subject of much international research, but there are still very few studies conducted in the South African setting (Mnguni, 2014; Siswana and Armen, 2017). Given South Africa's distinct educational environment, which is marked by a variety of linguistic backgrounds, disparities in resource accessibility, and curriculum-specific teaching frameworks, this is noteworthy.

2.7.1 Misconceptions

According to Seswana and Armen (2017), a lot of learners in Grade 12 think that chlorophyll functions are the organelle that performs photosynthesis, and some people mix up inputs and outputs. Common language and disjointed education can contribute to these fallacies. Similar to this, Mghuni (2014) emphasized recurring alternative perceptions and photosynthesis linked to instructional deficiencies, pointing out that many learners find it difficult to integrate their understanding of the process at the microscopic and macroscopic levels.

2.7.2 Simulation-supported inquiry

Comparing simulations with inquiry-based frameworks to conventional teaching approaches, Dunn and Ramnarain (2020) showed that Grade 8 learners in South African schools greatly enhanced their comprehension of atomic and molecular structures. Comparing CS vs. lecture-based training, Tsamango and Kibiringe (2019) discovered similar benefits across Grade 10 learners, indicating that simulations can facilitate conceptual transformation by giving abstract scientific processes a more concrete form.

2.7.3 Teacher perspective and conceptual barriers

According to Singh-Pillay (2024), many science teachers in South Africa, especially those working in rural areas or under-resourced contexts, lack the infrastructure, training, and confidence necessary to successfully implement simulation-based pedagogy, even though simulations can improve conceptual learning and alleviate practical constraints. The impact of school socioeconomic status and experience on teacher self-efficacy in simulation integration was further investigated by Jere and Mpeta (2024), who came to the conclusion that institutional support and professional development are essential for adoption.

2.8 Conclusion

With an emphasis on the teaching of photosynthesis, conceptual comprehension in science education, and the use of CS as an instructional approach, this chapter has evaluated relevant material. According to the literature review, standard teaching approaches are effective at imparting factual knowledge, but they frequently fail to address learners' misconceptions and promote a thorough conceptual grasp of intricate biological processes like photosynthesis. Research on CS shows that by offering dynamic, interactive, and visual representations of abstract ideas, they can improve learning. However, careful instructional design, alignment with learning objectives, and consideration of learners' cognitive capacities are necessary for their efficacy.

A previously identified gap is filled by the inclusion of South African research in this review, which guarantees that the study is influenced by both global research and the realities of regional scientific education contexts. While highlighting the potential advantages of incorporating CS into the LFSC curriculum, the examined research also emphasizes the need for more empirical data in South African classrooms. The study's theoretical and conceptual framework, which integrates multimedia learning theory and cognitive constructivist

perspective to explain how CS may promote conceptual change and better comprehension of computer simulations, is presented in the following chapter, building on these insights.

CHAPTER 3

Theoretical and conceptual framework

3.1 Introduction

The theoretical and conceptual underpinnings of the current study, which examines the influence of computer simulations on grade 11 learners' conceptual understanding of photosynthesis, are presented in this chapter. This chapter concentrates on the guiding theoretical perspectives and conceptual frameworks that influence the study's design, interpretation, and conclusions, whereas the prior literature review looked at earlier research and contextual studies. Two related theoretical threads are incorporated into the study. The first is the Multimedia Learning Theory (MLT), which includes the Principles of Multimedia Learning and Cognitive Load Theory. Second, the Constructivist Approach to Multimedia Learning, Multiple Intelligence Theory, and Cognitive Theory of Multimedia Learning are all integrated into the Cognitive Constructivist Theory of Multimedia (CCTM). The relationship between the theoretical framework and the study background is also covered in the study.

3.2 Multimedia Learning Theory (MLT)

This study examines the theoretical underpinnings of multimedia learning and how CS might promote learning and learner growth. The principles for creating a multimedia learning environment were established by the multimedia MLT. The Cognitivism school of thought, which emphasises how the mind arranges, stores, and retrieves information, includes Multimedia Learning Theory. Like a computer, it uses the mind to process information. Richard Mayer invented the MLT for the first time in 1997. The framework for multimedia learning and the way the mind works are based on these three fundamental presumptions: channels, limited capacity, and active processing. These presumptions are listed as follows:

- **Dual-Channel:** Humans have distinct channels for processing visual and aural information, according to the dual-channel assumption (Mayer 2009). The first is the visual-pictorial channel, which interprets visual data, including words that are shown on a screen. The other channel is the auditory-verbal channel, which analyses spoken words.

- Limited Capacity:** People can only process so much information at once, according to the limited-capacity hypothesis (Mayer, 2009). This will probably be obvious to anyone who has tried to watch and listen to the news while conversing. Each channel has a maximum capacity for processing verbal and visual information. According to Mayer, the average person can only hold five to seven "chunks" of knowledge in working memory at once. Additionally, he suggests that those at the higher end of that spectrum may employ more effective metacognitive techniques that enable them to more effectively control their finite cognitive resources.
- Active-Processing:** The capacity of the learners' cognitive processing to choose, arrange, and integrate the information (verbal and visual) being presented with past knowledge is necessary for meaningful and deeper learning to take place (Mayer, 2008). The cognitive theory of multimedia learning essentially favours a learner-centred "knowledge building" model of instruction over a "knowledge transmission" approach. According to Mayer, pupils should aim to integrate words and images to produce information that can be stored in long-term memory rather than being "empty vessels" that are only waiting to be filled with knowledge.

How memory is stored and processed in multimedia learning

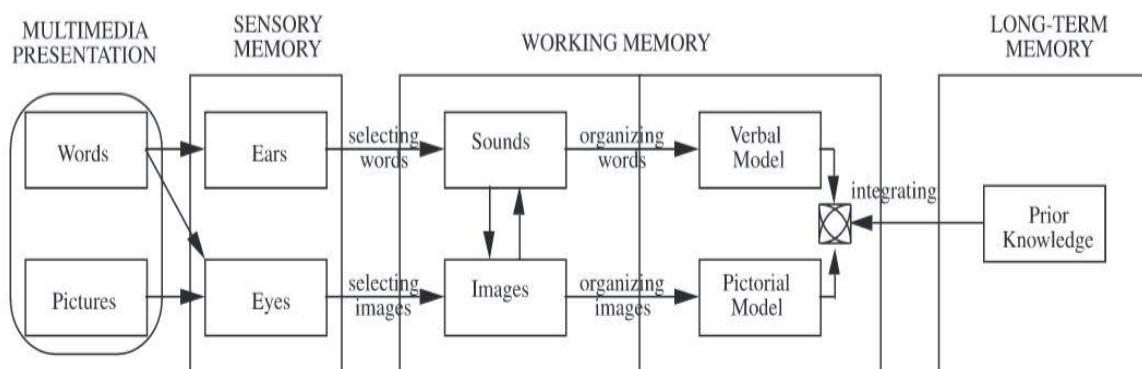


Figure 3.1: Cognitive model of multimedia learning (from *Multimedia Learning*, by R.E. Mayer, 2001).

The cognitive model of multimedia learning in **Figure 3.1** above illustrates how people process information. The sensory, working, and long-term memories are represented by the boxes as being stored. When learners view a multimedia presentation, their ears and eyes register it in their sensory memory. Words and images serve as tangible representations (Rudolph, 2017). Information is first processed in the sensory memory, where it is

temporarily retained. The sensory memory's function is to quickly analyse information before it is stored in the long-term memory. The auditory information and visual cues are then chosen by the learner and added to working memory. The learner picks and arranges the materials in working memory (words and pictures). Which knowledge gets stored in long-term memory is decided by the learner. Large amounts of information are kept in the long-term memory for a very long time. The chosen material is subsequently combined with past knowledge by a learner. Information must be moved from working memory to long-term memory before it can be used by the learner. Information is stored in working memory only momentarily.

3.2.1 Cognitive Load Theory

The cognitive load theory is the basic foundation of Mayer's MLT theory. The working memory, the area of the brain that processes what we are now doing, can only handle a certain amount of information at one time, according to the cognitive load theory, which was first investigated by Sweller (1998). Information supplied to learners shouldn't contain extraneous content because they can only process a certain amount of information at once (Rudolph, 2017). According to the theory, there are three types of cognitive load: germane, extraneous, and intrinsic.

- **Extraneous load** is the term for wasted mental energy on information or specifics that do not contribute to the learning objectives. By concentrating only on the crucial information and avoiding anything that can divert learners, instructors can reduce the amount of unnecessary content they present to learners (such as unnecessary animations, background music or irrelevant information).
- Based on the complexity or difficulty established in the learning materials, **intrinsic load** is the cognitive effort needed to represent the information in working memory. By breaking up their lessons into manageable chunks and defining any technical words beforehand, instructors should try to reduce intrinsic load.
- **Germane load**, which measures the effort learners must put up to comprehend the subject matter, is greatly influenced by their level of motivation. By structuring learning and using the right pace for the subject, instructors should minimize the germane load.

3.2.2 Principles of multimedia

Multimedia design principles were developed to assist designers of educational multimedia in finding a balance between the use of verbal and virtual content as well as how to actively engage learners in the learning process. To assist designers in balancing visual and verbal channels, Mayer developed the following twelve principles of multimedia design (Mayer, 2009):

- **Coherence Principle:** Excluding rather than including irrelevant words, images, and sounds improves learning. Designers are advised by the coherence principle to refrain from using extraneous words, noises, or pictures. The processing and application of cognitive resources will be unnecessary when there is extraneous or irrelevant text, sound, or pictures.
- **Signaling Principle:** When cues that emphasize how the key information is organized are introduced, people learn more effectively. Learners must understand what to focus on, where they are in the presentation, and how to integrate the information in order to create their own mental models. This is especially important when there are several bits of information on the screen. According to the signaling principle, important information might be highlighted to catch learners' attention. Signaling, which might take the form of highlighted text, bold or italic text, or images of a teacher pointing to a certain topic on a whiteboard, can be used to direct learners to significant content.
- The **Redundancy Principle** holds that narrative and graphics are more effective for teaching than narration, graphics, and on-screen text. A lot of multimedia presentations combine text on the screen with visuals, audio, and spoken phrases. According to the redundancy principle, using on-screen text along with audio and pictures might be distracting. When text is given with images and is read aloud by a narrator, the repetition of focusing and refocusing between the text and narrations can be distracting for learners. When a narrator does not read the words on the screen word for word, it is less distracting.

- People learn better when related text and images are placed next to one another rather than far apart on a page or screen, according to the **spatial contiguity principle**. The spatial contiguity concept suggests that when creating instructional message designs, text and graphics that connect to that text be placed close together. The classic example of text on one page of a book and the figure it is describing on a different page of that book results in additional processing that is not necessary.
- The simultaneous rather than sequential presentation of related words and visuals improves learning, according to the Temporal Contiguity Principle. The idea supports making presentations, audio and video synchronized. Learners become confused and distracted when audio is presented before video, video is presented before audio, or the timing of the two is off.
- The **segmenting principle** states that rather than presenting a multimedia lesson as one continuous piece, people learn better when it is broken up into manageable chunks. On memory and transfer tests, learners do better when they can set the speed of the course. A continuous complex presentation should be divided into smaller, easier to follow segments. By dividing difficult material into simpler parts, complex stuff can be made simpler.
- **Pre-training Principle:** When learners are familiar with the names and traits of the key ideas in a multimedia session, they learn the material more effectively. According to the pre-training concept, definitions and explanations of important, new terms should be supplied and addressed before an educational unit. Similar to segmenting, learners can be made ready for learning by first outlining and going over important definitions and concepts.
- The **modality principle** claims that animation and on-screen text are less effective teaching tools than pictures and narrations. Presenting text with images on screen primarily engages the learner's visual processing abilities, whereas using audio instead of text during presentations, animations, or videos better utilises the learner's visual and auditory processing abilities.
- **Multimedia Principle:** Words and pictures work better together to convey information than just words do. Displaying relevant images in addition to text

instead of just words. Static or dynamic images combined with text can often communicate ideas and concepts more effectively and efficiently than text alone by presenting them as a visual schema.

- **Personalization Principle:** People learn multimedia teachings more efficiently when the language used is conversational rather than formal. The personalizing principle advises using a conversational tone rather than a formal, academic one while narrating visuals. An approachable narrative voice encourages social presence, which heightens learning motivation.
- **The Voice Principle:** When a friendly human voice rather than a robotic one is used for narration in multimedia lessons, people learn more effectively. According to this notion, a human should narrate rather than a computer.
- The **image principle** states that adding the speaker's image to the screen in a multimedia lecture does not always provide for greater learning. It asserts that improving learning outcomes isn't always guaranteed by incorporating an image of an instructor's talking head during a multimedia presentation.

3.3 Cognitive Constructivist Theory of Multimedia (CCTM)

According to Mayer's (2009) constructivist theory of learning, multimedia is a cognitive tool for knowledge building rather than just a means of delivering information. Mayer's approach is consistent with current theories on successful learning, which emphasize a constructivist viewpoint: When learners are required to create their own knowledge structures and mental models, learning is most successful. Mayer (2009) asserts that effective instructional design encourages learners to engage in proper cognitive processing in addition to just delivering information. Instructors may be sure that their multimedia presentations will improve learner education by adhering to the cognitive theory of multimedia learning.

Bull (2009) developed the cognitive constructivist theory of multimedia (CCTM), which integrates concepts from multiple intelligences theory, constructivist theory, and cognitive theory of multimedia learning, to assist in the creation of interactive digital resources created by teachers. CCTM design incorporates multimedia (text, picture, animation, graphic, video, and audio) into a systematic design structure of visual thinking to lessen cognitive overload on the learner's memory (Bull, 2013). Additionally, CCTM uses the learner's many intelligences, learning preferences, and prior knowledge of multimedia material and content

metadata to build and refine knowledge using multimedia files. The following picture shows the CCTM developed by Bell (2013):

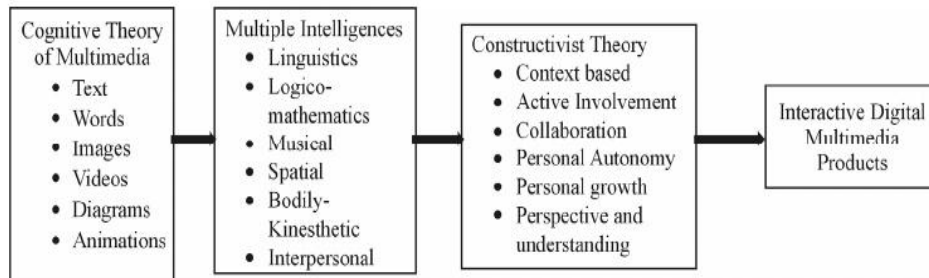


Figure 3.2: Cognitive Constructivist Theory of Multimedia (by Bell R.H, 2013).

3.3.1 Cognitive theory of multimedia

One of the underlying ideas for CCMT is the cognitive theory of multimedia learning. The learner uses both verbal and visual information processing systems when creating interactive digital learning materials. During this learning process, the verbal system processes all auditory information, while the visual system processes all visuals, pictures, and animations. In order to completely engage learners in the learning process, instructors should balance the verbal and visual repository systems of the learners when building interactive digital resources. Mayer's twelve principles of multimedia design are followed by the cognitive theory of multimedia.

3.3.2 Multiple intelligences

The Harvard professor, Howard Gardner put forth the notion of multiple intelligences in 1983. Instead of measuring intelligence as a single entry, many entries linking the intelligence that all humans possess should be used instead (Gardner, 1993). The principle of multiple intelligences enables multimedia designers to produce interactive learning resources that are in line with universal design for learning and learner differentiation (Bull, 2013). The theory of multiple intelligences rejects the idea of a single IQ and proposes that there are various forms of human intelligence, each of which stands for a unique method of information processing (Yüceda, 2018). The following is an overview of how numerous entries could be addressed in using CCTM as the theoretical framework to design interactive digital learning materials addressing verbal and visual systems:

- The term "**verbal-linguistic intelligence**" describes a person's capacity for information analysis and verbal or written language use.
- The capacity to create equations and proofs is referred to as **logical-mathematical intelligence**.
- The capacity to mentally visualize objects and spatial dimensions is referred to as **visual-spatial intelligence**.
- The capacity to master music, as well as rhythms, tones, and beats, is referred to as **musical intelligence**.
- The term "**naturalistic intelligence**" describes the capacity to recognize and classify many kinds of plants and animals.
- The term "**bodily-kinesthetic intelligence**" describes the capacity to regulate bodily motion.
- Possessing **interpersonal intelligence** is being able to identify and comprehend the feelings, desires, moods, and motives of others.
- Understanding one's own thoughts, feelings, and motivations is referred to as having **intrapersonal intelligence**.

By fusing Mayer's twelve principles of multimedia design with Gardner's theory of multiple intelligences, the CCMT promotes the creation of engaging, motivating, and learning-outcome-oriented interactive digital resources.

3.3.3 Constructivist theory

The constructivist approach utilised in the instructional design and delivery of CCTM multimedia content aims to build knowledge through prior verbal and visual experiences. A collection of learning principles derived from several branches of cognitive science form the basis of the constructivist philosophy of education (Bull, 2013). The idea of constructivist teaching makes appropriate use of learners' past knowledge and cognitive frameworks developed from such experiences. Bull (2013) asserts that in order to guarantee that instruction provided as a component of an interactive digital learning resource is consistent

with constructivism, teachers should ensure that the content, design, and presentations of interactive digital materials are in line with the following:

Digital learning resources must be based on context; the information supplied should be pertinent to the lesson's or presentation's goals; active participation should be encouraged in digital learning resources to encourage participation; learners should be actively involved in their education and encouraged to collaborate; the digital learning resources offered should establish the groundwork for learners to become independent and in charge of their own learning by producing new knowledge; by generating new information, digital learning materials should encourage learners' personal development; learning objectives should encourage perspective and comprehension rather than a predetermined result.

3.3.4 Constructivist approach in MLT

Constructivism states that people create their own understanding and knowledge of the world by going through things and reflecting on those experiences (Mungambi, 2018). Learners construct their own knowledge by being active participants in the classroom. The constructivist methodology stresses that the active building of knowledge by the learner is socially and culturally rooted (Fernando and Marikar, 2017). The popular technique of teaching is the traditional method which is the chalk-and-talk technique. Learners become passive since they play a minimal role in the learning process, and on the other hand, the constructivist approach requires learners to be active participants in the learning process. In constructivist-based learning, the role of the teacher becomes further complex as it involves the administration of the learning atmosphere, giving instruction and supporting activities, checking feedback and progress, and evaluating learners' performance (Tse-Kian, 2020).

Constructivism teaching methods together with multimedia create logical mental constructs from several perceptions such as the demonstration of words, pictures and auditory information (Zagade, 2017). The use of multimedia plays a very important role in the learning environment; it provides enough resources to make sure that the setting up of the learning environment is successful (Tse-Kian, 2020). Multimedia technology enables learners to be actively involved in their work. With the help of multimedia technologies, learners can be able to generate multimedia applications as part of their assignment requests and this would make them to be actively involved in their own learning process, rather than just being inactive learners of the educational content (Tse-Kian, 2020). **Figure**

3.2 below shows the relationship between the teacher, learners and multimedia in multimedia-mediated constructivist learning approaches.

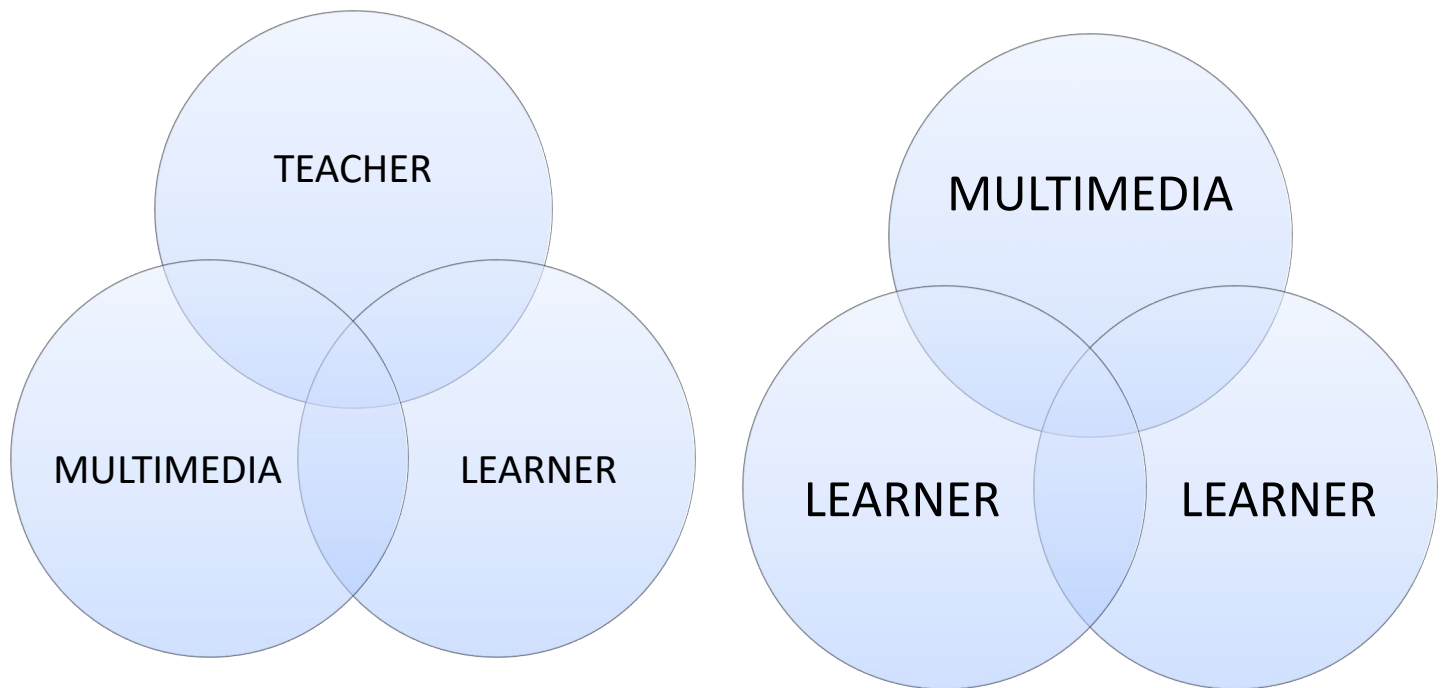


Figure 3.3: Multimedia-based learning process

In Figure 3.3 above, the role of the teacher is to provide instruction, manage the learning environment, provide multimedia, provide activities, assess learners and give feedback. The learners play a very active role in the learning process, they search for information and construct knowledge based on their past experiences and interact with each other to enhance the learning process, manipulate the multimedia and talk to each other. The technology provides them with sufficient resources for their learning process. Multimedia creates a constructivist environment whereby learners create their own knowledge.

The figure also shows learners interacting with each other while using multimedia. According to social constructivism, learning is a collaborative process, and when individuals interact with their society and culture, knowledge is developed (McLeod, 2019). According to Dewey, learning is a social activity; we do it together by interacting with each other rather than a mental concept. The person who developed social constructivism was Vygotsky (1978)

who proposed that every function in the cultural development of a child appears twice: it first appears on the social level, after that on the individual level. It first occurs between people and later on, occurs inside the child. The emphasis is based on learners who are active, learners who are able to seek information on their own so that they can be able to reach learning outcomes without relying on teachers for information. Here, learners learn to solve problems using multimedia by manipulating them and working collaboratively with each other. Learners who are more active and more knowledgeable assist the less knowledgeable ones. Learners are encouraged to find their own solutions based on their prior knowledge and experiences. With technology being integral to their learning, learners are able to develop critical thinking skills, problem-solving and teamwork skills. When working together, learners are able to construct knowledge by solving realistic problems.

3.4 Connection between Theoretical Framework and Study Background

The background of this study identifies key instructional challenges in teaching photosynthesis in South African Grade 11 Life Sciences classrooms: determined learner misconceptions, low engagement, limited opportunities for practical demonstration due to resource limitations, and an over-reliance on teacher-centred approaches. The selected theoretical perspectives directly address these issues and provide a strong foundation for the study's rationale and design.

Multimedia Learning Theory explains how people learn more effectively when instructional materials incorporate words and visuals meaningfully. Within the setting of this study, CS align with MLT by presenting photosynthesis concepts through joint text, narration, and dynamic visualisations. This multimodal presentation can reduce extraneous cognitive load (Cognitive Load Theory) caused by the mental and invisible nature of photosynthesis, allowing learners to focus their cognitive resources on building precise mental models of the process. For example, simulations can visually portray the transformation of light energy into chemical energy, helping learners overcome the difficulty of linking microscopic and macroscopic processes a challenge emphasized in the background.

The Cognitive Constructivist Theory holds that learners actively construct their own knowledge through commitment and reflection, rather than passively receiving information. The background of this study notes that traditional approaches often position learners as passive recipients of knowledge. In contrast, simulations invite active participation, hypothesis testing, and manipulation of variables, thereby endorsing deeper conceptual

understanding. The Constructivist Approach in Multimedia Learning emphasises that knowledge construction is reinforced when learners interact with representations, compare outcomes with prior beliefs, and resolve cognitive conflicts a process critical for addressing the misconceptions about photosynthesis described in the background.

Multiple Intelligences Theory recognises that learners have varied cognitive strengths. In the South African classroom context, where learners vary widely in language proficiency, prior knowledge, and preferred learning styles, simulations can cater to multiple intelligences by combining visual, linguistic, logical-mathematical, and even kinesthetic elements. This supports the broad and distinguished teaching approach called for by the National Curriculum Statement (NCS), aligning well with the background's emphasis on moving away from rote learning.

3.4 Conclusion

Drawing on MLT and CCTM, this chapter has presented the study's theoretical and conceptual framework. The conversations focused on how the principles of multimedia learning and cognitive load theory clarify the thought processes and design factors required for successful multimedia training. Additionally, it highlights how constructivist methods, multiple intelligences, and active learning strategies influence how learners interact with multimedia, including CS. The conceptual framework derived from these theories illustrates the expected connections among cognitive processes, instructional design, and conceptual knowledge of photosynthesis. While addressing the unique context and requirements of South African classrooms, this integrated perspective guarantees that the study is firmly based on recognized educational theory. The following chapter builds upon these foundations by outlining the research technique used to examine the study's research questions, making sure that theoretical presumptions, research design, and data interpretation are all in line.

CHAPTER 4:

Research Design and Methodology

4.1 Introduction

This study compared learners' conceptual understanding of photosynthesis when taught using CS and traditional methods. The positivist research paradigm was used as the background of this chapter. This study employed a quasi-experimental design and purposive sampling as the method for gathering data. Five schools took part, one of which was a pilot study. Computer simulations were used in two schools while traditional methods were used in the other two. Statistical Package for the Social Sciences (SPSS) version 29 was used to record and analyse the outcomes of a pre-post test given to all learners. This chapter's goal is to discuss the research approach, research design, research methodology, sampling technique, tools used for data collection and methods for data analysis. In this chapter, the ethical issues are also covered.

4.2 Research paradigm

A paradigm is described as a collection of presumptions or theories about basic aspects of reality that give rise to a particular worldview. It covers presumptions made with faith, including those about methods, ontological perspectives on reality, and epistemological perspectives on the relationship between the knower and the known (Maree, 2016). The research paradigm helps us decide which research methodology we are going to use in a research, based on a particular context and reasoning.

The type of research paradigm used in this research is positivism. The reason for choosing the positivist approach is that it relies mainly on experimentation. In the positivist approach, hypotheses are presented in propositional or question form about the contributory relation between phenomena (Adil and Khalid, 2016). After gathering empirical data, the vast majority of this data is examined and developed into a theory that clarifies how the independent variable affects the dependent variable. (Adil and Khalid, 2016). The positivist approach first proposes a hypothesis; the acceptance or rejection of a hypothesis is contingent upon statistical data analysis. The main reason is to measure, control, predict, create laws and assign causality (Cohen et al., 2018). If the hypothesis is accepted, the theory will be formulated.

The positivist approach states that good research should have internal validity, external validity, and reliability. To have internal validity, the independent variable must have an

impact on the dependent variable. The term "internal validity" refers to the degree to which the observed results represent the truth in the population we are studying and are therefore not the result of practical errors (Patino and Ferreira, 2018). Positivists use quantitative methodology and data to answer research questions. They collect data through experiments or less strictly quasi-experiments, standardised tests, large or small-scale surveys, and the use of closed-ended questionnaires (Adil and Khalid, 2016). The study will have external validity if the results can be generalised. The external validity of a treatment principally concerns the extent to which inferences hold across different operationalisations of the main explanatory variable of interest to a study (Findley, Kukuta and Danly, 2020). If different researchers find the same results when they do their research at different times, the results are considered to be reliable.

4.3 Research approach

In this study, the quantitative research approach was used. The quantitative research approach was used because the researcher was observing the situations that affect learners, based on the theory that explains the relationship between the independent and dependent variables. The systematic investigation of phenomena using numerical data gathering and the application of statistical, mathematical, or computational approaches is known as quantitative research (Adedoyin, 2020). Quantitative research is a technique for assessing objective hypotheses by looking at how variables relate to one another (Creswell and Creswell, 2018). Positivism paradigm is the source for quantitative research that promotes approaches rooted in statistics that involve strategies like testing of hypothesis, experimental and quasi-experimental design randomization, structured protocols, and questionnaires with a restricted variety of prearranged answers. Quantitative research objectives are measurable and cannot be separated from variables and hypotheses (Adedoyin, 2020).

4.4 The pilot study

4.4.1 Introduction and purpose of the study

The purpose of the pilot study was to investigate the effectiveness of using CS as a teaching tool to enhance grade 11 learners' conceptual understanding of photosynthesis. The aim of the study is to explore whether interactive CS can improve learners' understanding of difficult biological processes, such as photosynthesis. The pilot study aimed to determine how well grade 11 learners understood photosynthesis conceptually by using computer simulation as a

teaching tool. The study aims to investigate whether interactive digital simulations can help learners better understand intricate biological processes, like how sunlight is transformed into chemical energy. The pilot study also aims at ensuring the validity and reliability of the research instruments.

4.4.2 Method

A convenience sample of 20 grade 12 learners drawn from a population of 57 learners, from a local high school participated in the pilot study. A small sample size was used based on the fact that the purpose was not to test the hypothesis or generalize the results, but to test the feasibility of the research design, tools and procedures. The participants were randomly assigned to either the experimental group ($n=10$) or the control group ($n=10$) based on their availability and consent to participate in the study. Participants in both groups had a mean age of 17 years and were evenly distributed in terms of gender and academic performance.

The experimental group engaged with a series of CS that simulated the process of photosynthesis, allowing learners to interact with virtual modes of plant cells and explore the molecular mechanism of light-dependent and light-independent reactions. The control group received the traditional instruction on photosynthesis.

Pre-test and post-test assessments were administered to all participants to measure their baseline and final understanding of photosynthesis. The assessment consisted of 20 multiple-choice questions that assessed their knowledge of key concepts and processes in photosynthesis. Additionally, participants were given a questionnaire assessing their attitudes and motivation towards Life Sciences and the use of CS.

4.4.3 Results

The pre-test assessment revealed similar baseline levels of conceptual understanding of photosynthesis among participants in both experimental and control groups. The mean score of the pre-test for the experimental group was 50% ($SD=6.2$), while the control group scored 48% ($SD=5.8$).

After the intervention, the post-test assessment showed a significant improvement in conceptual understanding among learners in the experimental group. The mean score of the post-test in the experimental group increased to 75% ($SD=8.3$), while the control group only slightly improved to 51% ($SD=5.5$). A t-test comparison of the post-test scores revealed a

noteworthy distinction between the control and experimental groups ($t=3.82$, $p<0.05$), suggesting that learners who used CS improved their comprehension of photosynthesis more.

Quantitative analysis of the survey responses indicated positive attitudes towards using CS as a learning tool among learners in the experimental group. Themes identified in the responses included increased engagement, better visualization of complex concepts and a desire for more digital resources in their learning environment.

4.4.4 Discussion

The test instrument showed good validity and reliability, and learners' scores significantly improved after the CS intervention, suggesting that CS effectively improved learners' comprehension of photosynthetic principles. There was an alignment between the test questions and the learning objective; the results showed a significant correlation with the questionnaire responses. The questionnaire responses indicated that learners had positive experiences with CS intervention. The questionnaire instrument also demonstrated good validity and reliability—the questionnaire items aligned with the research objectives. The results of the test and questionnaire showed a significant positive correlation. Learners who performed well on the test also reported positive experiences with CS intervention.

4.4.5 Conclusion

This pilot study demonstrated the potential of CS to improve learners' conceptual understanding of photosynthesis and highlighted the benefits of utilizing innovative technology in science education. Through the use of interactive digital technologies, teachers may design successful and captivating lessons that let learners investigate and understand complex biological ideas like photosynthesis.

4.5 Research design

The study employed a quasi-experimental design, also known as the non-equivalent control group design (Campbell and Stanly, 1963). This design was chosen because it estimates the causal effect of a non-random assignment intervention on the target population. Quasi-experiments include assignment, but not random assignment of participants to groups (Creswell, Educational Research: Planning, Conducting, and Evaluating Quantitative and Qualitative Research, 2012). In all four schools that participated, the classes that were selected were based on the subjects that they were doing and in this case, Life Sciences. The

learners who participated were not divorced from their normal classes. The classes had different numbers of learners. The program did not interfere with the normal school system; it adhered to the normal school timetable.

The quasi-experimental design uses a pretest-posttest design (see Table 4. 1 below). In the pretest-posttest design, the dependent variable is measured once before the treatment and once after the treatment. All participants, both experimental and comparison (control) groups are first assessed on the pre-test. Thereafter, the experimental group receives the treatment (exposure to computer simulations) while the comparison group receives no intervention. Both groups are then assessed on the post-test. The answer to the question of whether the new treatment had an effect is obtained when comparing the two groups on the post-test results (Maree, First Steps in Research, 2016).

Select Control Group	Pre-test	No Treatment	Post-test
Select Experimental Group	Pre-test	Experimental Treatment	Post-test

Table 4.1: The quasi-experimental design – pre-and post-test design (Creswell, Educational Research: Planning, Conducting, and Evaluating Quantitative and Qualitative Research, 2012)

4.6 Research population and sample

The targeted population was Life Sciences learners from four secondary schools under the Vhembe-West district in Limpopo province. The schools were purposively selected (Creswell & Creswell, Research Design : Qualitative, Quantitative, and Mixed Methods Approaches, 2018) based on the ease of acceptance and that they are found in similar environments. Another reason for purposive selection is that learners were not exposed to simulations and that the researcher is teacher around the area and it was easy to collect data without having to travel a very long distance.

This research focused on grade 11 learners from four different schools who are doing Life Sciences. The sample had 50 learners from each school (a total of 200 learners) which was drawn from a population with a total of 433 learners (school A: 96, school B: 103, school C: 124, school D: 110). All the learners were selected based on the fact that they are all doing Life Sciences. The ages of the learners ranged from 15-18 years. Learners from two schools

were assigned experimental group and learners from the other two schools were assigned control group.

4.7 Instruments

Data collection instruments that were used were the pre-post tests and the questionnaires. They were both developed to gather quantitative data. The test consisted of 20 multiple-choice questions about photosynthesis. The questions were adapted from the grade 11 previous exam and controlled test question papers.

4.7.1 Tests

Creswell et al. (2018) define tests as a type of research instrument used to collect data in a systematic and objective way. Tests are often used in research to measure dependent variables and evaluate the effectiveness of the program. A test was used to assess learners' knowledge of photosynthesis. The test was administered before and after the use of CS. The test consisted of 20 multiple-choice questions which covered the photosynthesis topic. It was designed to assess learners' understanding of photosynthesis. The test was developed by the researcher using previous grade 11 question papers, and it was based on the curriculum requirements and literature review. It was also developed based on expert input from professionals. A small group of participants was used to pilot the question paper. The test was administered under controlled conditions and learners were given 30 minutes to complete it. The test was administered two times, as a pre-test and as a post-test.

4.7.2 Questionnaire

A questionnaire is a set of questions used to gather information, attitudes or beliefs of respondents, usually in a written format (Cohen, Manion, and Morrison, 2018). The questionnaire was used to gather information on the learners' attitudes and views on the use of CS. Two questionnaires were developed, the questionnaire before and after the use of CS. The one before the use of CS was developed to check the learners' attitude toward LFSC, how they felt about the method used for learning and what they thought about the introduction of new strategies in LFSC. The second one was about their views on the use of CS. The questionnaires were developed by the researcher based on the literature. They were also pilot-tested using a group of small learners. The first questionnaire had 7 items, and the second one had 3 items. These were designed using a Likert scale (strongly agree to strongly disagree). The questionnaires also covered demographic information such as age and gender. The first questionnaire was administered before the use of computer simulations and the

second one was administered after the use of computer simulations. Learners were instructed to answer the questionnaire honestly.

4.7.3 Validity of instruments

For content validity, the pre-post tests were given to two experts in Life Sciences in Limpopo district, Vhembe-West district. One of these experts holds a Bachelor's degree in Education and has been teaching Life Sciences for 30 years. The other one holds an Honours degree in Life Sciences Education and is a curriculum advisor for Life Sciences under Elim Circuit. They both agreed that the test measures the learning outcomes of the topic. A pilot study sample was also chosen to validate the instruments used. The sample comprised grade 12 LFSC learners in one of the schools in Limpopo province Vhembe-west district.

4.7.3 Reliability of instruments

The reliability of research instruments was ensured using the test-retest reliability (Creswell, 2012) using the reliability coefficient. It was obtained by repeating the same measure the second time. Learners were tested twice using the same pre-post test. The pilot study sample was also given the pre-post test to ensure the reliability of the instrument. The instruments' dependability was assessed using the Cronbach's Alpha coefficient instruments. The internal consistency or reliability of a collection of survey items is gauged by the Cronbach's alpha coefficient. The marks yielded a correlation coefficient of 0,7. The correlation coefficient ranges from a standardised on a scale of 0 to 1, higher values denote greater agreement between items. The zero correlation indicates that there is no relationship between the items, and one indicates that they are related perfectly. The reliability of the pre-and post-tests used in this research can be said to be established.

4.8 Training

On August 22, 2024, teachers received training at Muthuhadini Combined School Hall. An independent consultant with experience in simulation-based learning trained them. A crucial component of this study was teacher training, which ensured they had the tools to incorporate simulations into the classroom successfully. The aim was to familiarize the teachers with the simulation and improve their skills and ability to facilitate and provide feedback to learners. The training consisted of a two-hour module introducing the simulation platform and tools and a four-hour workshop on simulation-based lesson design and facilitation. The training activities included simulation trials, practice sessions, and peer feedback on simulation-based lesson plans. Teachers were provided with the user manual for the simulation platform and

access to online simulation resources. The effectiveness of the teacher training program was evaluated through observations of teacher practice in using simulations as well as feedback from teachers on the effectiveness of the training program. The training helped identify problems teachers had using CS; it also helped solve those problems to ensure that data collection was accurate. Teachers' training allowed them to properly incorporate CS into the classroom, which led to more accurate data collection. Teachers became more involved in the research due to the training, which increased learner participation. Teachers' classes became more structured and pleasurable once they had become acquainted with computer simulations.

4.9 Ethical considerations

Maree (2016) emphasises the importance of ethical considerations as it is the issue of the protection of participants' identities. Ethical considerations in research are principles that direct your research designs and practices (Bhandari, 2021). The following research guidelines were followed to guarantee that the participants are not placed at any risk by taking part of the study:

- **Informed consent:** is when participants are aware of the purpose, benefits, risks, and financing behind the study before they come to an agreement or disagree to join (Bhandari, 2021). Consent was requested from the guardians or parents of learners who were participating. The consent letter explained the goals of the research and its purpose. The letter explained to the parents/guardians that the learner's name will be kept a secret and no harm will come to them during and after the research. The letter also indicated that participants are permitted to decline participation at any stage, and their contribution is strictly voluntary.
- **Access and acceptance:** The significance of the principle of informed consent turns out to be apparent at the early stage of the research. There should be access to the institution or organisation where the research or study needs to take place, and there should be acceptance by those whose authorisation one requires before starting with the task (Cohen, et al., 2018). To collect data from the school, authorisation to carry out the study was requested from the Department of Education Head Office in addition to the principals of the schools where the research was conducted. Afterwards, the people who were responsible for or helping with the research such as the subject teachers were contacted.

- **Anonymity:** it simply means that one does not know who the participants are, and that they can not be linked to any data. Anonymity can be guaranteed by not collecting any personal information when collecting data. Any identifying information in the research data was separated from the research before reporting to ensure anonymity. The names of schools were kept anonymous when recording and publishing the results of the study. The records are kept safe through the use of password-secured files and placing all the research instruments and data in a locked drawer.
- **Maintaining confidentiality:** means that the participants are known, but all identifying information from the report is removed (Bhandari, 2021). All the data provided cannot be linked to any participant by name. The signed consent from parents is kept in a safe and locked place.
- **Member checking:** is ensuring that your work is free of plagiarism or research misconduct and that you accurately represent your results (Bhandari, 2021). All the results were communicated to the participants for confirmation and to avoid misinterpretation of the findings. Plagiarism, which is submitting other people's work as your own, was avoided at all costs.

Research ethical clearance: Research clearance usually includes an ethical review committee that examines the goals and methods of researchers to make certain that the research will be conducted in a way that safeguards the safety, rights, and dignity of research participants, as well as that the study design is morally complete and is expected to render the expected results (Henekom, 2018). The researcher followed the rules of ethics as specified by the University of Venda. Application for ethical clearance was granted by the University of Venda Research Ethics Committee (REC) as well the Limpopo Department of Education.

Measures were taken to guarantee that learners in the control group were not disadvantaged by their withdrawal from the intervention during the study period, by ethical research norms. The learners in the control group were given access to simulation-based teaching following the completion of data collection and analysis. This addressed fairness and equity in the study by giving them the same educational chances as the experimental group.

4.10 Conclusion

This study used a quantitative research design to investigate the causal relationship between the use of CS and learners' conceptual understanding of photosynthesis. A quasi-experimental research design was used to collect data from a sample of 200 participants selected through a purposive sampling strategy. The data was collected through tests and surveys, and SPSS version 29 (Statistical Package for the Social Sciences) was used for analysis to determine the correlations and predictive relations between variables. This quantitative approach advanced the field of education by providing a reliable and impartial evaluation of the impact of CS, enabling generalisations about the broader population. Additionally, ethical issues were discussed to make sure that the study's participants were not put in danger. The following chapter is going to discuss data presentation, analysis and interpretation.

CHAPTER 5

Data Presentation, Analysis and Interpretation

5.1 Introduction

The study results are presented in this chapter on The Impact of Computer Simulations on Grade 11 Learners' Conceptual Understanding of Photosynthesis. These findings are based on the data collected quantitatively using pre-post tests and questionnaires from 200 participants. All the participants' pre-test results were analyzed. Then, the post-test of the participants exposed to computer simulations (experimental group) was analyzed, followed by an analysis of the post-test results of the control group, which only received traditional instruction and was not exposed to CS. The control group aimed to provide a comparison to the experimental group. The Statistical Package for Social Sciences (SPSS) version 29 software thoroughly examines the data, including regression and comprehensive analyses, and uses the t-test. The means of the pre-test and post-test scores are compared to look for statistically significant differences between the two groups.

The goal is to use a quantitative approach to assess how computer simulations affect learners' conceptual understanding of photosynthesis and to find out if using simulations would improve learners' understanding in a way that is statistically significant. With an emphasis on the findings' implications, the data, analysis, and interpretation are presented in the sections that follow. The possible advantages and drawbacks of employing computer simulations as a teaching tool will thus be more clearly understood by researchers and teachers.

This chapter represents the analysed data gathered through the quantitative tools used in the study, specifically pre- and post- tests and questionnaire which was administered to total of 200 Grade 11 learners. The focus is on interpreting how the use of CS influenced the learners' conceptual understanding. The pre-test results of all the participants were analysed. Then the post-test of the participants who were exposed to computer simulations (experimental group) was analysed, followed by an analysis of the post-test results of the control group which only received traditional instruction and was not exposed to CS. The aim of the control group was to provide a comparison to the experimental group. The data analysis employs the t-test to compare the means of pre-test and post-test scores, examining the statistical significance difference between the two groups. Statistical Package for Social

Sciences (SSPS) version 29 software was used to conduct a comprehensive analysis of the data, including descriptive statistics, correlation analysis and regression analysis.

Through the use of a quantitative approach, the aim is to uncover the impact of CS on the conceptual understanding of learners on photosynthesis, exploring whether the use of simulations will result in statistically significant improvement in learners' understanding. The findings will provide insights into the effectiveness of computer simulations as a pedagogical tool, informing teachers and researchers on the potential benefits and limitations of this approach. The following sections present the data, analysis, and interpretation of the findings, highlighting the implications of the research for educational practice and future investigations.

5.2 Pre-test and post-test data analysis

The pre-and post-test analyses were done to assess the impact of CS on learners' understanding of photosynthesis concepts. The pre-and post-tests are usually used in educational research to measure the changes in learners' knowledge and abilities before and after the intervention. In this study, learners were given a pre-test intervention CS and traditional instruction, and then a post-test after intervention. The pre-test consisted of 20 multiple choice questions about photosynthesis which were adapted from previous grade 11 question papers. After the intervention, learners were provided with the same question paper to see if the use of CS simulations has an effect on learners understanding. Two hundred (200) learners participated and were all given the same question paper before and after the intervention, of which 100 were control and 100 experimental group. The pre-and post-tests were analysed using quantitative data analysis techniques to evaluate the impact of CS on learners' understanding of photosynthesis concepts. The paired t-test was used to determine if there were statistical differences in learners' understanding before and after the intervention. Descriptive statistics was also used to compare the mean differences between the pre-and post-tests in both control and experimental groups.

5.2.1 Group statistics

The hypothesis testing for means and proportions was used to analyse the pre-test and post-test data. The data analysis aimed to compare the mean scores of the experimental and control groups on the pre-test and post-test to ascertain whether there was a significant difference between them.

Group Statistics					
	Group	N	Mean	Std. Deviation	Std. Error Mean
Pre-test total	Experimental group	100	8,52	3,236	,324
	Control group	100	8,43	3,176	,318
Post-test total	Experimental group	100	17,46	1,861	,186
	Control group	100	8,54	3,277	,328

Table 5.1: Group statistics for pre- and post-test

The mean pre-test score in the experimental group was 8.52 (Std. Deviation = 3.236), and in the control group it was 8.43 (Std. Deviation=3.176). This indicates that the two groups' average scores did not differ significantly. The pre-test scores show that there is no statistically meaningful variation in the learners' baseline understanding of photosynthesis before the implementation of CS. The lack of difference suggests that the experimental and control groups had similar knowledge of photosynthesis prior to intervention. The study's internal validity was strengthened by the baseline similarity, which also shows that the groups were balanced with respect to factors like prior knowledge and educational background that might have profounded the results. The pre-test analysis's non-significant results made clear how crucial it is to use the CS intervention to clear up misconceptions and knowledge gaps about photosynthesis principles. Since there are no significant differences between the experimental and control groups' pre-test scores, it sets the stage for comparing the impact of CS on learning outcomes for post-tests.

The mean post-test score in the experimental group increased to 17.46 (Std. Deviation=1.861) after the intervention with CS (see table 5.1 above). A paired sample t-test revealed a noteworthy increase in the conceptual understanding within the experimental group. The t-test results showed a difference of 8.940 (Std. Deviation=2.898), t -value=30.845, and $p<0.001$ (see table 4.2 below). The mean difference of 8.940 indicates that on average the scores increased by 8.940 units from the pre-test to the post-test, this mean difference suggests an improvement in the scores on average. The standard deviation of 2,989 represents the variability differences between pre-test and post-test scores, which indicate more consistent results and increase the reliability of this study. The t -value of 30.845 is a measure of the difference between the mean difference and the expected difference, this suggests the

significant difference between the pre-test and post-test scores. A p-value of less than 0.001 suggests the highly significant results.

Paired Samples Test ^a										
		Paired Differences					Significance			
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference		t	df	One-Sided p	Two-Sided p
					Lower	Upper				
Pair 1	Pre-test total - Post-test total	-8,940	2,898	,290	-9,515	-8,365	-30,845	99	<,001	<,001

a. Group = Experimental group

Figure 5.2: paired sample t- test in an experimental group

These results indicate that the implementation of CS had an impact on improving learners' understanding of photosynthesis concepts. These results demonstrate the effectiveness of CS in helping learners comprehend the principles of photosynthesis. The experimental group's post-test results after the CS intervention have shown a noteworthy improvement, indicating that the use of simulations enhanced learners' comprehension of photosynthesis. The findings indicate that CS can help learners better understand the concepts of photosynthesis.

The mean post-test score in the control group was 8.54 (Std. Deviation =3.277) following traditional instruction without CS. A paired t-test revealed a slightly significant change in conceptual understanding within the control group. The t-test results showed a mean difference of 0.110 (Std. Deviation =4.266), t-value=0.258, and p=0.399). The control group's post-test scores showed a no significant change after the traditional instruction without CS. This highlights the potential of CS to drive improvements in conceptual understanding beyond traditional teaching methods.

Paired Samples Test ^a										
		Paired Differences					Significance			
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference		t	df	One-Sided p	Two-Sided p
					Lower	Upper				
Pair 1	Pre-test total - Post-test total	-,110	4,266	,427	-,956	,736	-,258	99	,399	,797

a. Group = Control group

Table 5.3: paired sample t-test in the control group

A paired samples t-test demonstrated a notable distinction significant disparity between the post-test outcomes of the experimental and control groups. The analysis suggests that the use of CS led to greater enhancement in conceptual understanding of photosynthesis compared to traditional instruction without CS. The comparison of post-test scores has shown that the experimental and control groups differed significantly in their scores, with the experimental group scoring better. This implies that the use of CS improved conceptual knowledge of photosynthesis more than standard training without simulations.

5.2.2 Addressing the misconceptions

As described in Chapter 2, previous research identified several misconceptions about photosynthesis among learners, including the conviction that the soil provides food for plants (Thomas, 2020), and the fact that learners mistake photosynthesis for cellular respiration (Svandova, 2014). The present study aimed at addressing some of these misconceptions using CS. Questions 1 and 15 we highly misconceived questions as according to the data analysis. The results of the pre-test revealed that 37,1% of the learners mistake photosynthesis for cellular respiration (as shown in the tables below). Furthermore, 62,4% of learners believe that the food in plants is prepared within the roots, this clearly tells us that the misconceptions about photosynthesis need to be seriously addressed. Learners learnt about photosynthesis in grade 9, meaning they came with the misconception from the previous grade.

What does this equation represent: $6\text{CO}_2 + 6\text{H}_2\text{O} \rightarrow \text{C}_6\text{H}_{12}\text{O}_6 + 6\text{O}_2$
?^a

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Cellular respiration	43	43,0	43,0	43,0
	Human respiration	11	11,0	11,0	54,0
	Photosynthesis	40	40,0	40,0	94,0
	Solar energy	6	6,0	6,0	100,0
	Total	100	100,0	100,0	

a. Group = Experimental group

Table 5.4: question 1 frequency table pre-test (experimental group)

What does this equation represent: $6\text{CO}_2 + 6\text{H}_2\text{O} \rightarrow \text{C}_6\text{H}_{12}\text{O}_6 + 6\text{O}_2$
?^a

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Cellular respiration	39	39,0	39,0	39,0
	Human respiration	10	10,0	10,0	49,0
	Photosynthesis	44	44,0	44,0	93,0
	Solar energy	7	7,0	7,0	100,0
	Total	100	100,0	100,0	

a. Group = Control group

Table 5.5: question 1 frequency table pre-test(control group)

Sweet potato is an underground structure which stores food. Where is the food prepared in this plant?^a

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Fruits	4	4,0	4,0	4,0
	Stem	10	10,0	10,0	14,0
	Leaves	18	18,0	18,0	32,0
	Root	68	68,0	68,0	100,0
	Total	100	100,0	100,0	

a. Group = Experimental group

Table 5.6: question 15 frequency table pre-test(experimental group)

Sweet potato is an underground structure which stores food. Where is the food prepared in this plant?^a

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Fruits	4	4,0	4,0	4,0
	Stem	13	13,0	13,0	17,0
	Leaves	13	13,0	13,0	30,0
	Root	70	70,0	70,0	100,0
	Total	100	100,0	100,0	

a. Group = Control group

Table 5.7: question 15 frequency table pre-test(control group)

The post-test results showed that after learners had participated in CS, there was a significant decrease in both misconceptions within the experimental group, and within a control group

there was a slight decrease in both misconceptions. These findings suggest that the CS were effective in addressing the misconception about photosynthesis and cellular respiration as well as about where the food is made in the plant. Furthermore, these results indicate that the CS improves overall learners' understanding of photosynthesis as indicated by the increase in the post-test responses by the experimental group. According to these findings, CS can be utilised as a valuable additional tool in teaching and can offer learners a dynamic and captivating way to learn about complex biological concepts.

What does this equation represent: $6\text{CO}_2 + 6\text{H}_2\text{O} \rightarrow \text{C}_6\text{H}_{12}\text{O}_6 + 6\text{O}_2$?^a

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Photosynthesis	100	100,0	100,0	100,0

a. Group = Experimental group

Table 5.8: question 1 frequency table post-test(experimental group)

What does this equation represent: $6\text{CO}_2 + 6\text{H}_2\text{O} \rightarrow \text{C}_6\text{H}_{12}\text{O}_6 + 6\text{O}_2$?^a

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Cellular respiration	38	38,0	38,0	38,0
	Human respiration	10	10,0	10,0	48,0
	Photosynthesis	45	45,0	45,0	93,0
	Solar energy	7	7,0	7,0	100,0
	Total	100	100,0	100,0	

a. Group = Control group

Table 5.9: question 1 frequency table post-test(control group)

Sweet potato is an underground structure which stores food. Where is the food prepared in this plant?^a

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Fruit	3	3,0	3,0	3,0
	Stem	14	14,0	14,0	17,0
	Leaves	14	14,0	14,0	31,0
	Root	69	69,0	69,0	100,0
	Total	100	100,0	100,0	

a. Group = Control group

Table 5.10: question 15 frequency table post-test(control group)

Sweet potato is an underground structure which stores food. Where is the food prepared in this plant?^a

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Stem	12	12,0	12,0	12,0
	Leaves	84	84,0	84,0	96,0
	Root	4	4,0	4,0	100,0
	Total	100	100,0	100,0	

a. Group = Experimental group

Table 5.11: question 15 frequency table posr-test(exerimental group)

$6 \text{ CO}_2 + 6 \text{ H}_2\text{O} + \text{light energy} \rightarrow \text{C}_6\text{H}_{12}\text{O}_6 + 6 \text{ O}_2$ is the equation for photosynthesis. This equation highlights the key reactants and products of photosynthesis, which is often misconceived for being similar to cellular respiration. However, in the diagram below (figure 4.1), photosynthesis produces glucose and oxygen, whereas cellular respiration produces carbon dioxide and water. The results of this study (table 4.7) show that learners who participated in the simulation-based learning activity demonstrated a significant improvement in their understanding of photosynthesis, including the ability to distinguish it from cellular respiration. Highlighting the distinctive features of photosynthesis that set it apart from cellular respiration, the equation in Figure 4.1 provides support for the results.

The study aimed to investigate the effectiveness of simulation-based learning in improving learners' understanding of photosynthesis. The findings of this study have significant

implications for Life Sciences education. These findings suggest that CS can be used as an effective tool for improving learners' understanding of biological concepts.

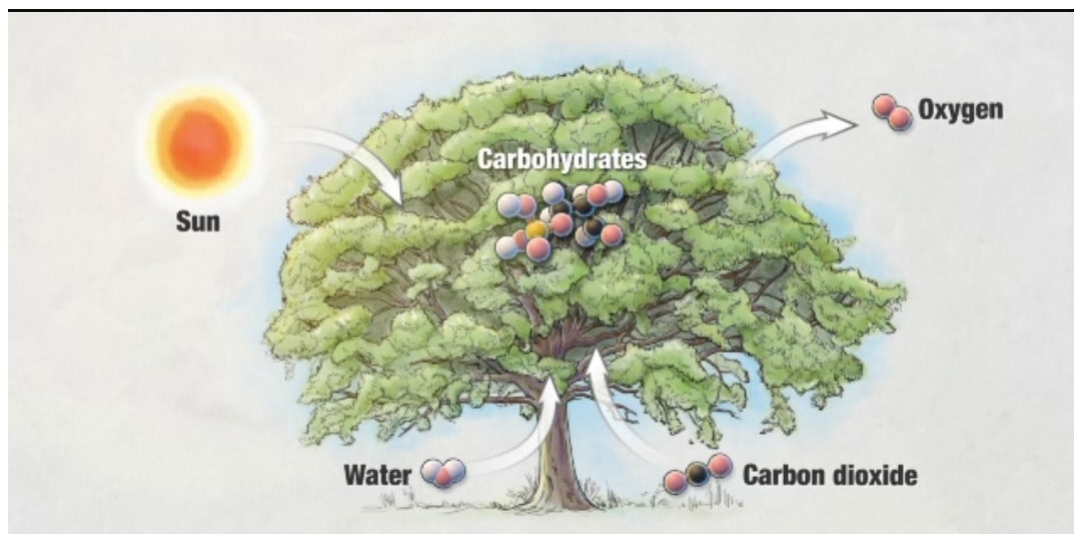


Figure 5.1: simulation on how photosynthesis takes place (BioInteractive simulation online lab)

Another common misconception is that plants get their food from the soil. However, as shown in Figure 4.1 above, plants produce their food through photosynthesis, using carbon dioxide, water, and light energy to produce glucose and oxygen. This process occurs in a unique organelle called chloroplast, which is found in plant cells. This process is essential for living on Earth as it provides energy and organic compounds needed to support the food chain. The results of this study have shown that the use of CS helped learners understand the concepts and addressed the misconception.

5.3 Analysis of questionnaire responses

In addition to analysing the pre and post-tests, the questionnaire was done to assess the impact of CS on learners' understanding of photosynthesis concepts. The questionnaire was given to all learners before the intervention, and then the experimental group was given a questionnaire after the implementation. The questionnaire before intervention consisted of learners' demographic information such as gender, age, and whether they were doing LFSC for the first time or not. It also had six questions which wanted information on their performance on LFSC, whether they enjoy LFSC or not, how they find the subject difficult, how they feel about the method used in LFSC, whether they are satisfied with the marks they

get, and what they think about the introduction of new strategies like technology in the classroom. The questionnaire after the intervention consisted of learners' demographic information as the one before the intervention. It had three questions which wanted to find out whether they enjoyed the method used while learning, whether they think the performance will be improved if they were to use CS daily, and whether the simulations can help them understand the LFCS concepts better. A Likert scale, with strongly agree and strongly disagree as the extremes, was used to assess the responses. The questionnaire before the use of CS was administered to a sample of 200 learners and the questionnaire after the use of CS was administered to a sample of 100 learners. The questionnaire responses were analysed using quantitative data analysis. Crosstabulation and frequency tables were used to summarize the overall responses and identify the trends or patterns.

5.3.1 Data analysis of the questionnaire before the use of CS

5.3.1.1 Frequency tables

Among 200 learners who participated, 44.5% were males and 55.5% were females. 70.5% of learners who participated were between the ages of 15-17 years and 29.5% were 18 years and above, there is a possibility that among those learners might have failed LFSC. The data also showed that 87.5% were doing grade 11 for the first time and 12.5% were repeating it. The tables below show the frequency tables based on gender, age and whether learners are doing LFSC for the first time or not.

		Gender			Cumulative Percent
		Frequency	Percent	Valid Percent	
Valid	Male	89	44,5	44,5	44,5
	Female	111	55,5	55,5	100,0
	Total	200	100,0	100,0	

Table 5.12: Gender frequency table

The gender frequency table was used to assess the study's male and female participant distribution. The frequency table revealed that out of 200 participants, 89 were males and 111 were females. There were more female participants in the study than male participants, according to the gender frequency table. This gender imbalance could potentially skew the results and limit the generalization of the findings to a larger population with equal gender

distribution. To investigate possible disparities in how male and female respondents viewed and profited from the CS intervention, the researcher chose to perform a gender-specific analysis to find gender-related patterns in the responses, given the unequal distribution of male and female participants.

		Age			Cumulative
		Frequency	Percent	Valid Percent	Percent
Valid	15-17	141	70,5	70,5	70,5
	18+	59	29,5	29,5	100,0
	Total	200	100,0	100,0	

Table 5.13: Age-frequency table

Important information about the distribution of participants across age categories was given via the age frequency table. The age frequency table above shows that among the learners who participated, 141 were between the age of 15-17 and 59 participants were 18 years and above. This age distribution provided insights into the participants of the study on the use of CS. The age frequency table directs the analysis of questionnaire responses regarding the use of CS in improving learners' performance in photosynthesis, and by knowing the distribution of participants, the researcher can customise the CS intervention to meet the needs and preferences of various age groups. The questionnaire responses indicated that participants between the age of 15-17 show greater satisfaction with the use of CS compared to the ones from 18 years and above.

Are you doing grade 11 for the first time?

		Frequency	Percent	Valid Percent	Cumulative
					Percent
Valid	Yes	175	87,5	87,5	87,5
	No	25	12,5	12,5	100,0
	Total	200	100,0	100,0	

Table 5.14: Frequency table

The frequency table above shows that 175 participants are taking grade 11 for the first time, and 25 are repeating the grade. This evidence is vital to understand the educational histories of the participants and whether the two groups' learning experiences differed. The questionnaire responses were used to learn more about the advantages of CS for both first-time and repeat grade 11 learners. The study's findings showed that CS use was beneficial for both first-time and repeat grade 11 learners.

5.3.1.2 Cross tabulations

The cross-tabulation was conducted based on age group; this is to allow the researcher to explore the relationships between different age groups.

First questionnaire: my performance in LFSC is very good.

This question aims to gauge the participants' self-assessment of their abilities and achievements in LFSC. This question relies on respondents' subjective perceptions of their own performance. The participants' responses varied based on their individual confidence levels, past experiences, and personal standards for what constitutes a good performance in LFSC. The participants were expected to compare their previous grade performance when answering the question. The table below shows how the participants responded to the above question based on different age groups.

Count

		My performance in Life Sciences is very good					Total
		I strongly disagree	I disagree	I partially agree	I agree	I strongly agree	
Age	15-17	11	23	60	38	9	141
	18+	11	15	9	21	3	59
Total		22	38	69	59	12	200

Table 5.15: Age performance crosstabulation

For participants between the ages of 15-17:

The majority of participants came within the group of 'somewhat agree', showing that a sizable proportion of participants aged 15-17 had mixed or indifferent feelings about their performance in LFSC. This shows that many individuals in this age range may not see their performance as very good. The combined number of learners who either 'strongly disagree' or 'disagree' (34 learners) outweighs those who 'agree' or 'strongly agree' (47 learners). This indicates a higher prevalence of negative or neutral perceptions of performance among the younger age group. Only 9 learners strongly agree that their performance in LFSC is very good. This shows that a minority of learners aged 15 to 17 have a very positive opinion of their performance in the subject. This suggests that a minority of learners in the 15-17 age bracket hold a highly positive view of their performance in the subject.

For learners aged 18 years and above:

The responses for learners aged 18 years and above exhibit a more evenly distributed pattern compared to the younger age group. There was a relatively balanced distribution across the 'disagree,' 'agree,' and 'partially agree' categories. The number of learners who strongly agree with the statement decreases in the older age group, with only three learners indicating strong agreement. This shows that a smaller proportion of older learners strongly consider their performance in LFSC as very good compared to younger learners. While the number of respondents in the 'agree' category is higher for learners aged 18 years and above compared to the younger group, the reduction in strong agreement implies a potential shift in perceptions of performance as per age.

In contrast, older learners (18 and above) show a greater variety of responses, suggesting a nuanced view of their performance. The data indicates that learners aged 15–17 are more likely to exhibit neutral or negative perceptions of their achievements in LFSC, with a higher number expressing disagreement. This indicates that a smaller percentage of older learners strongly view their achievement in LFSC as extremely good compared to younger learners. While the number of those who responded in the 'agree' category is higher for learners aged 18 years and above in contrast to the younger group, the decline in strong agreement signals a potential change in perceptions of performance as per age.

The thorough evaluation of the data shows that the two age groups' perceptions of their performance in LFSC differ, with older learners having a more varied perspective and younger learners exhibiting more negative or neutral views. These findings can guide focused interventions and support strategies to increase learners' opinions and self-confidence in their academic abilities.

Second questionnaire: Do you enjoy LFSC?

Count

		Do you enjoy Life Sciences?					Total
		I strongly disagree	I disagree	I partially agree	I agree	I strongly agree	
Age	15-17	3	8	33	53	44	141
	18+	10	14	11	18	6	59
Total		13	22	44	71	50	200

Table 5.16: Do you enjoy Life Sciences? Cross tabulation

For learners aged 15-17 years:

The majority of learners aged 15-17 exhibit positive attitudes towards enjoying LFSC, as indicated by the combined number of respondents in the ‘agree’ and ‘strongly agree’ categories (97 learners). This demonstrates a general inclination towards finding enjoyment in the subject among this age group. There is a strong positive sentiment regarding enjoying LFSC among learners aged 15-17, as evidenced by the large number of learners who either "agree" or "strongly agree" (97 learners) compared to those who disagree or only partially agree. A sizable portion of learners (44 learners) strongly agree that they enjoy LFSC. This suggests a considerable number of individuals in this age group have a strong affinity and enjoyment for the subject.

For learners aged 18 years and above:

The responses for learners aged 18 years and above show a more varied distribution than the younger age group. While the majority falls between the ‘agree’ and ‘disagree’ categories,

there is a spread across various levels of agreement and disagreement. Unlike the apparent positive inclination observed in the younger age group, the responses from older learners show a mix of agreement, with a relatively higher number of learners expressing partial agreement or disagreement. The number of learners who strongly agree that they enjoy LFSC decreases in the older age group, with only 6 learners indicating strong agreement. This suggests a lower proportion of stronger affinity toward the subject among older learners than their younger counterparts.

Younger learners (15-17) demonstrate a strong positive sentiment towards enjoying LFSC, with a high number expressing or strongly agreeing. The detailed data analysis shows that attitudes towards enjoying LFSC differ between the two age groups, with the younger learners displaying a more overwhelmingly positive attitude. Older learners (18 years and above) show more varied responses, with a mix of agreement, disagreement, and partial agreement, indicating a less uniform attitude toward enjoying LFSC.

Third questionnaire: Do you find LFSC concepts difficult?

Count

		Do you find Life Sciences topics difficult?					Total
		I strongly disagree	I disagree	I partially agree	I agree	I strongly agree	
Age	15-17	12	33	53	26	17	141
	18+	6	5	18	18	12	59
Total		18	38	71	44	29	200

Table 5.17: Age * Do you find Life Sciences topics difficult? Crosstabulation

For learners aged 15-17:

The responses from learners aged 15-17 demonstrate a range of perceptions regarding the difficulty in LFSC topics. There is no overwhelming consensus toward finding the topics easy or difficult. A higher number of respondents in the ‘partially agree’ and ‘agree’ categories (78 learners) compared to those in the ‘disagree’ categories (45 learners) suggest that a significant portion of learners in this age group find LFSC topics at least somewhat

challenging. The number of learners who strongly agree that they find LFSC topics difficult (17 learners) is substantial. This indicates that there is a portion of learners who perceive these topics as particularly challenging.

For learners aged 18 years and above:

There is a balance between agreement and disagreement in the responses from the learners who are 18 years of age and older. The responses are evenly distributed among the "partially agree," "agree," and "strongly agree" categories, indicating that these learners perceive the LFSC topic to be of a similar level of difficulty. A notable number of learners (30 combined in the 'agree' and 'strongly agree' categories) agree that they find LFSC topics difficult. This indicates a shared sentiment of challenge among a significant portion of older learners.

Both age groups show a balanced and varied range of responses towards the perceived difficulty of LFSC topics, with no clear consensus on whether the topics are easy or difficult. While learners aged 15-17 have a higher number of respondents in the 'partially agree' and 'disagree' categories, older learners aged 18 and above exhibit a more even distribution across agreement levels.

Both age groups' assessments of the difficulty of LFSC topics are mixed, according to a detailed analysis of the data; some learners find the subject tough. Teachers can adjust their teaching strategies and materials to better assist learners in overcoming any perceived challenges with LFSC topics by taking into account their perceptions.

Fourth questionnaire: does the method used in the teaching of LFSC make you understand it better

Count

		Does the method used in the teaching of Life Sciences make you understand it better?					Total
		I strongly disagree	I disagree	I partially agree	I agree	I strongly agree	
Age	15-17	11	9	37	47	37	141
	18+	6	12	18	19	4	59

Total	17	21	55	66	41	200
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Table 5.18: Does the method used in the teaching of Life Sciences make you understand it better? Cross tabulation

For learners aged 15 and 17:

The responses from learners aged 15-17 show a trend of increasing agreement with the effectiveness of the teaching methods used in LFSC, with a notable shift towards higher agreement levels. The combined number of learners in the ‘agree’ and ‘strongly agree’ categories (84 learners) significantly outweighs those in the ‘disagree’ and ‘strongly disagree’ categories (20 learners), indicating that a substantial majority of learners in this age group felt that the teaching methods enhance their understanding of LFCS. A considerable number of learners (in ‘strongly agree’) strongly believe that the methods in teaching LFSC are effective in facilitating their comprehension, highlighting a significant portion of highly satisfied learners within this age group.

For learners aged 18 and above:

The responses from learners aged 18 and above exhibit a more varied distribution across the Likert scale, with no single dominance in any single category. The number of respondents in the ‘disagree’ and ‘partially disagree’ categories are relatively balanced with those in the ‘agree’ and ‘strongly agree’ categories, suggesting diverse opinions on the effectiveness of teaching methods in enhancing understanding among older learners. The proportion of learners strongly agreeing that the teaching methods aid in comprehension is lower in this age group (4 learners) compared to the younger age group, indicating less strong conviction among older learners regarding the effectiveness of the teaching methods.

The findings show that learners between the ages of 15 and 17 are more likely to agree with a sizable percentage strongly endorsing that the teaching strategies employed in LFSC improve their comprehension of the material. learners who are 18 years of age and older, on the other hand, exhibit a wider range of views regarding the efficacy of instructional strategies, with no clear agreement regarding how these strategies affect their comprehension of LFSC.

According to a thorough analysis of the data, learners between the ages of 15 and 17 are more likely to believe that the LFSC teaching strategies have improved their comprehension of the material. On the other hand, learners who are 18 years of age or older exhibit a wider range

of opinions regarding the effectiveness of various instructional strategies. When teaching LFSC, teachers can use this knowledge to modify their methods to better suit the various requirements and preferences of learners in various age groups.

Fifth question: Are you satisfied with the marks you get in LFSC?

Count

		Are you satisfied with the marks you get on Life Sciences?					Total
		I strongly disagree	I disagree	I partially agree	I agree	I strongly agree	
Age	15-17	36	48	37	12	8	141
	18+	22	19	12	5	1	59
Total		58	67	49	17	9	200

Table 5.19: Age * Are you satisfied with the marks you get on Life Sciences? Cross tabulation

For learners aged 15-17:

The responses from learners aged 15-17 indicate that a significant number do not feel satisfied with the marks they receive in LFSC, with the majority falling into the ‘strongly disagree’ and ‘disagree’ categories. There is a lack of agreement among learners in this age group regarding their satisfaction with their grades, as evidenced by the higher numbers in the lower agreement categories compared to the ‘agree and strongly agree’ categories. A smaller portion of learners (20 in total) expressed some level of agreement or satisfaction with the marks they received in LFSC, suggesting that a minority of learners in this age group feel content with their academic performance in this subject.

For learners aged 18 years and above:

The responses from learners aged 18 and above also indicate a general lack of satisfaction with the marks received in LFS, with a significant number falling into the ‘strongly disagree’ and ‘disagree’ categories. A very small number of learners (6 in total) expressed some level of agreement or satisfaction with their marks in LFSC, indicating that overall, older learners in

this age group also have a low level of contentment with their academic performance in this subject.

The data from both age groups suggest that a significant portion of the learners do not feel satisfied with the marks they receive in LFSC, as evidenced by higher numbers in the ‘agree’ and ‘strongly agree’ categories. There is a trend of dissatisfaction and lack of agreement regarding academic performance in LFSC among both younger and older learners, with very few expressing high levels of satisfaction with their grades.

The detailed interpretation of data indicates that the majority of learners in both age groups do not feel satisfied with the marks they receive in LFSC. This highlights the potential need for teachers and educational institutions to provide additional support, feedback, and resources to address learners' concerns and enhance academic performance and satisfaction in the field of LFSC. Further discussions with learners and potential adjustments to teaching and assessment strategies could be beneficial in addressing the dissatisfaction expressed by learners in both age groups.

Sixth question: Do you think the introduction to new strategies such as technology in learning can help you understand it better?

Count

		Do you think the introduction of new strategies such as technology in learning can help you understand the subject better?					Total
		I strongly disagree	I disagree	I partially agree	I agree	I strongly agree	
Age	15-17	4	5	20	28	84	141
	18+	4	4	2	22	27	59
Total		8	9	22	50	111	200

Table 5.20: Age * Do you think the introduction of new strategies such as technology in learning can help you understand the subject better? Cross tabulation

For learners aged 15-17:

Learners between the ages of 15 and 17 who responded to the survey strongly agreed that using new teaching methods—specifically, technology—can significantly improve their understanding of LFSC. Compared to other replies, a notably greater proportion of learners fell into the "strongly agree" category, indicating this. With 84 percent saying they "strongly agree," the overwhelming majority of learners firmly believe that using technology in the classroom can improve their comprehension of the material. Younger learners strongly support the advantages of technological strategies, as evidenced by this high degree of agreement. The number of learners who disagree or who strongly disagree with the statement is very low, highlighting the widespread enthusiasm and openness among younger learners toward the idea that technology can play a significant role in improving their comprehension of the subject.

For learners aged 18 years and above:

The responses from learners aged 18 years and above show varied opinions regarding the effectiveness of new strategies, such as technology, in learning. While there is a sizeable number of learners in the 'strongly agree' and 'agree' categories, there are also respondents in the 'disagree' and 'partially agree' categories. There are comparatively more learners who agree or strongly agree with the statement than who disagree or strongly disagree, suggesting that older learners generally have a tendency to believe that technology can help them understand the material better. In this age group, there are slightly more learners (27 learners) who strongly agree with the statement than who only partially agree, indicating that older learners are becoming more aware of the possible advantages of using technology in the classroom.

According to the data, the vast majority of learners between the ages of 15 and 17 strongly agree that new tactics specifically, technology can improve their comprehension of LFSC. With a range of answers from different agreement levels, learners who are 18 years of age and older, on the other hand, show a more balanced viewpoint on how well technology can enhance comprehension. This suggests that different people have different views on how technology affects learning.

According to a thorough analysis of the data, younger learners (ages 15 to 17) are very certain of the advantages of using technology in the classroom to improve their comprehension of the material, and a sizable percentage strongly agree. . On the other hand,

older learners aged 18 and above show more varied opinions on the effectiveness of using new strategies such as technology in learning, with a mix of agreement and disagreement among this age group. This data can give teachers important information for creating and executing creative teaching strategies that suit the tastes and attitudes of learners across various age groups regarding the use of technology in the classroom.

5.3.2 Data analysis of the questionnaire after the use of CS

5.3.2.1 Frequency tables

Among 200 learners who participated, 44.5% were males and 55.5% were females. 70.5% of learners who participated were between the ages of 15-17 years and 29.5% were 18 years and above, there is a possibility that among those learners might have failed LFSC. The data also showed that 87.5% were doing grade 11 for the first time and 12.5% were repeating it. The tables below show the frequency tables based on gender, age and whether learners are doing LFSC for the first time or not.

		Gender			
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Male	48	48,0	48,0	48,0
	Female	52	52,0	52,0	100,0
	Total	100	100,0	100,0	

Table 5.21: Gender frequency table

		Age			
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	15-17	66	66,0	66,0	66,0

18+	34	34,0	34,0	100,0
Total	100	100,0	100,0	

Table 5.22: Age frequency table

Are you doing Life Sciences for the first time?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Yes	88	88,0	88,0	88,0
	No	12	12,0	12,0	100,0
	Total	100	100,0	100,0	

Table 5.23: Are you doing Life Sciences for the first time?-frequency table

5.3.2.2 Cross tabulations

The cross-tabulation was also conducted based on age group; this allowed the researcher to explore the relationships between different age groups.

First questionnaire: did you enjoy the method used when learning Life science?

Count

		Did you enjoy the method used when learning Life Sciences?					Total
		I strongly disagree	I disagree	I partially agree	I agree	I strongly agree	
Age	15-17	0	0	2	16	48	66
	18+	0	1	7	11	15	34
Total		0	1	9	27	63	100

Table 5.24: Did you enjoy the method used when learning Life Sciences? Cross tabulation

For learners aged 15-17:

The vast majority of learners highly agree with the statement, demonstrating high levels of engagement and appreciation for the teaching methodology. Responses from learners aged 15 to 17 demonstrate overwhelming enthusiasm with the usage of CS when learning LFSC. .

There are no responses in the 'disagree' and 'strongly disagree' categories from this age

group, signalling a complete absence of strong negative sentiments towards the method used for learning LFSC among these younger learners. Most learners in the age group (48 in 'strongly agree' and 16 in 'agree') express strong preference and enjoyment for the method employed in teaching LFSC, reflecting a positive learning experience for the majority of learners.

For learners aged 18 and above: The responses from learners aged 18 and above also indicate a generally positive sentiment towards using CS in learning LFSC, with the majority falling in the 'agree' and 'strongly agree' categories. Only a few learners (1 in 'disagree') disagreed with the method, suggesting that most older learners found the instructional approach enjoyable and effective. Many learners in this age group (15 in 'strongly agree' and 11 in 'agree') strongly endorse and enjoy the method employed for learning LFSC, reflecting positive perception and satisfaction with the instructional strategy.

Both age groups exhibit overall positive sentiments towards the method used when learning LFSC, with learners aged 15-17 showing a higher level of strong agreement and enjoyment than older learners aged 18 and above. The absence of strongly disagree and disagree responses in the younger age group suggests high satisfaction and engagement with the instructional approach. At the same time, older learners also strongly prefer and enjoy the method used in teaching LFSC.

A thorough data analysis shows learners in both age groups show positive satisfaction and enjoyment with the approach taken to teach LFSC. The high levels of agreement and engagement among younger and older learners with the instructional approach suggest that it is a successful and captivating teaching method that works for learners of all ages. Teachers can continue and improve their effective and engaging teaching methods with the help of this encouraging feedback.

Second questionnaire: Do you think your performance in Life Sciences can be improved if you were to use the same method every day?

Do you think your performance in Life Sciences can be improved if you were to use the same method every day?	Total
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		I strongly disagree	I disagree	I partially agree	I agree	I strongly agree	
Age	15-17	0	0	16	25	25	66
	18+	0	6	16	8	4	34
Total		0	1	9	27	63	100

Table 5.25: Do you think your performance in Life Sciences can be improved if you were to use the same method every day?

For learners aged 15-17:

The replies from learners aged 15-17 reveal a considerable agreement and positive attitude about the potential improvement in performance through the daily usage of CS. The statement is strongly agreed with by half of the respondents, while the remainder agree, indicating a high level of endorsement for this teaching method. There are no responses in the 'strongly agree' and 'agree' categories, indicating a complete absence of strong negative sentiments towards the use of CS every day among these younger learners. The majority of learners in this age range (25 who selected "strongly agree" and 25 who selected "agree") show a favourable attitude and expectations towards this teaching approach, expressing a high belief in the efficacy of everyday CS in improving their performance.

For learners aged 18 and above:

The responses from learners aged 18 years and above also indicate a generally positive sentiment towards the potential improvement in performance through daily use of CS, with learners falling in the 'agree' and 'strongly agree' categories. Although there are some learners who disagree with the statement (6 in 'disagree'), the overall sentiment leans towards agreement and strong agreement, suggesting that many older learners also perceive the benefits of incorporating daily CS in their learning routine. This learning approach is positively received and endorsed by older learners, as evidenced by the significant number of learners in this age group who strongly believe in the value of daily CS in improving their performance (4 in "strongly agree" and 8 in "agree").

The data suggest that learners in both age groups display a positive outlook and strong agreement towards the idea of improving their performance through daily use of CS, with stronger agreement observed among the younger age group (15-17). In both age groups, the

lack of strongly disagree and disagree replies suggests a high degree of openness and a positive attitude towards using CS as a useful learning tool to improve performance.

The thorough analysis of the data shows that both younger and older learners have favourable opinions and strongly concur that using CS on a daily basis will help them perform better. This feedback emphasises how using technology-enhanced learning methods to improve academic achievement across age groups is seen to be beneficial and successful. This information can inform teachers in the implementation and integration of impactful teaching tools and strategies that align with and cater to the positive attitudes and expectations of learners towards the use of CS for learning.

Question 3: Do you think the use of simulations can help you understand the concepts better?

Count

		Do you think the use of simulations can help you understand concepts better?				
		I strongly disagree	I disagree	I partially agree	I agree	I strongly agree
Age	15-17	1	3	10	24	28
	18+	1	9	13	8	3
Total		2	12	23	32	31

Table 5.26: Do you think the use of simulations can help you understand concepts better?

For learners aged 15-17:

For learners aged 15-17:

The responses from learners aged 15-17 demonstrate a high level of agreement with the idea that the use of CS can help them understand the concepts better. A significant majority of learners strongly agree with the statement, with very few indicating strong disagreement and disagreement. The absence of significant disagreement and the preponderance of responses in the 'agree' and 'strongly agree' categories among the young learners indicate a strong and unified belief in the positive impact of CS on improving understanding of concepts. The strong agreement among learners aged 15-17 reflects a high level of confidence in the benefits of incorporating CS as a learning tool to enhance understanding of concepts.

For learners aged 18 and above:

The responses from learners aged 18 and above display a wider distribution across the Likert scale, with varied opinions regarding the effectiveness of CS in enhancing understanding of concepts. While some learners in this age group strongly disagree or disagree with the statement, others partially agree, agree, or strongly agree, pointing to differing perspectives on the role of CS in improving comprehension of concepts. Though there is some disagreement, the fact that both agreement and strong agreement responses were found indicates that some older learners recognise the potential advantages of using CS to comprehend concepts, albeit to differing degrees.

The data indicates that learners aged 15-17 demonstrate strong agreement and belief in the effectiveness of CS for improving understanding of concepts, with minimal disagreement or dissenting opinions. Conversely, learners who are 18 years of age and older show a wider range of ideas, including a number of disagreement replies, highlighting varying views on the value of CS in improving conceptual understanding in this age group.

According to a thorough analysis of the data, learners between the ages of 15 and 17 strongly agree and have a favourable opinion of CS's ability to help them grasp concepts. However, older learners (18 years of age and up) exhibit a wider range of views, expressing both agreement and disagreement about the advantages of using CS to improve comprehension. This knowledge can guide instructors in evaluating and maximising the potential benefits of technology-enhanced educational methods to support learners' understanding of concepts across different age groups

5.4 Research questions and data analysis integration

Main research question:

'What is the effectiveness of using computer simulations in improving Grade 11 learners' conceptual understanding of the photosynthesis concept?'

In order to answer the primary research question, the comparison of pre-test and post-test scores between the experimental and control groups evaluated how CS affected conceptual understanding. The experimental group's post-test scores significantly increased when compared to the control group, suggesting that CS improved learners' comprehension of photosynthesis. The results of the study suggest that using CS is effective in improving Grade 11 learners' conceptual understanding of photosynthesis. The experimental group showed a great increase in mean scores between the pre-test and post-test, while the control group it

showed no improvement. The findings of this study shows support the hypothesis that CS are effective in improving learners' understanding of complex biological concepts.

Sub-question (a):

'What is the difference in understanding of photosynthesis concepts between Grade 11 learners who receive traditional instruction compared to CS?'

Using descriptive statistics and t-tests, the impact of traditional instruction versus CS on learners' understanding of photosynthesis concepts was assessed, and the results showed a significant difference in the effectiveness of traditional instruction versus CS in improving understanding of photosynthesis. The comparison between the traditional instruction group (control) and the CS group (experimental) involved evaluating the differences in pre-test and post-test scores as well as analysing the questionnaire responses before and after intervention. Pre-test comparison indicated that both groups had similar baseline knowledge, indicating the initial equivalence of understanding. Results from post-tests showed that the experimental group that received computer simulations (CS) significantly improved, demonstrating the beneficial effects of immersive and interactive learning experiences on learners' comprehension and retention of information. In contrast, the control group that received traditional instruction showed little improvement in post-test performance, highlighting the limitations of traditional teaching methods in producing significant gains in conceptual understanding. underscoring the superiority of computer simulations in promoting deeper engagement, critical thinking and overall conceptual mastery of grade 11 learners in the context of studying photosynthesis. The questionnaire responses further reinforced the preference and positive attitudes of learners towards CS over traditional instructional approaches.

Sub-question (b):

'What are the attitudes of learners towards the use of CS as compared to traditional method in Life Sciences classroom?'

The questionnaire analysis revealed that learners in the experimental group exhibited more positive attitudes toward CS than those in the control group. The descriptive statistics indicated greater engagement and satisfaction with the interactive learning experiences facilitated by CS. The analysis of test scores also show that learners have more positive attitude towards the use of CS compared to traditional methods in Life Sciences classrooms.

There was a significant increase in positive attitudes toward pre-test and post-test in experimental group, while control group showed no change. The result of this study indicates that CS are more effective in promoting positive attitudes towards learning of Life Sciences in the classroom.

Sub-question (c):

‘What is the impact of computer simulations on learners’ motivation and interest in learning Life Sciences concepts?’

The analysis of questionnaire responses highlighted a significant increase in motivation and interest among learners who engaged with CS. The results of this study indicate that CS have positive impact on learners’ motivations and interest on learning Life Sciences concepts.

Comparison of pre-test and post-test scores in the experimental group suggests that the use of CS positively influences learners’ motivation and interest in learning Life Sciences concepts.

Sub-question (d):

‘To what extent do computer simulations improve learners’ ability to recognize and correct misconceptions?’

The evaluation of questionnaire data indicated that exposure to CS improved learners’ ability to recognize and correct misconceptions related to photosynthesis. The significant improvement in post-test scores within the experimental groups demonstrated the effectiveness of CS in addressing misconceptions and enhancing conceptual understanding.

5.7 Conclusion

Data analysis was done using quantitative data analysis. Cresswell (2007) defines quantitative data analysis as a systematic process of both collecting and evaluating measurable and verifiable data. The scores obtained from pre-and post-tests were quantitatively recorded and analysed using the Statistical Package for Social Sciences (SPSS) version 29. It used the t-test to compare the experimental group and the control group in order to determine whether the scores of the pre-post test were statistically significant from each other. The test only considered multiple-choice questions. The questionnaire provided was also analysed using SPSS.

CHAPTER 6

Summary of Findings, Conclusions and Recommendations

6.1 Introduction

Because of its complexity, photosynthesis—a vital biological process—is frequently regarded as a complex subject for learners in grade 11. This study examined CS as a teaching tool to improve learners' conceptual grasp of photosynthesis. The study adopted a quantitative research approach, comprising pre and post-tests as well as a questionnaire administered before and after the implementation of CS.

This chapter offers an in-depth overview of the findings from the study, drawing conclusions based on the results obtained and offering practical recommendations for teachers and curriculum developers. The results show how CS affects grade 11 learners' comprehension of photosynthesis and how these simulations can improve learners' attitudes toward studying this vital biological process.

6.2 Summary of the findings

The purpose of the study was to look into how computer simulations (CS) might help learners in Grade 11 better comprehend the photosynthesis conceptually. Using a quantitative quasi-experimental design, the study used questionnaires before and after the CS intervention was implemented, as well as pre- and post-tests. The findings showed that after being exposed to the CS, learners' conceptual understanding significantly improved.

According to the pre-test findings, many learners initially had trouble correctly understanding important ideas of photosynthesis, including the function of chlorophyll, how light is absorbed, and how carbon dioxide and water are converted into glucose. Post-test results, however, showed a noticeable improvement, suggesting that the CS intervention successfully improved learners' understanding of these challenging subjects. The decrease in widespread misunderstandings, especially the one that confused photosynthesis with cellular respiration, further reinforced this development.

Additionally, the answers to the questionnaire showed that learners' attitudes towards understanding photosynthesis had improved. Many learners indicated anxiety and disinterest in the subject before the intervention, frequently finding it difficult and abstract. The majority of them reported feeling more interested, confident, and motivated to learn after

using the CS, indicating that the simulation technique not only enhanced cognitive knowledge but also encouraged more engagement and excitement for the material.

These results support the usefulness of computer simulations as teaching aids in the Life Sciences and are consistent with previous studies that support interactive, technologically enhanced learning environments. Furthermore, by offering learners immersive and interactive learning experiences that foster a stronger conceptual understanding, the study highlights how CS may help overcome real-world limitations like scarce laboratory resources.

6.3 Conclusions

According to the study's results, it can be said that the use of CS is an effective tool in improving the conceptual understanding of grade 11 learners in photosynthesis. The interactive and visual nature of the simulations proves to be engaging and impactful leading to a better comprehension of the complex processes involved in photosynthesis. Furthermore, the improvement in the learners' attitudes towards studying photosynthesis suggests that CS might potentially raise learners' enthusiasm and interest in the topic. Better learning outcomes and academic achievement may follow from this.

6.4 Recommendations

The study's conclusions lead to the following suggestions being made for curriculum designers and teachers:

1. Increase learner comprehension and engagement by incorporating computer simulations (CS) into the curriculum. Teachers should think about incorporating CS into the teaching of photosynthesis and other difficult scientific subjects.
2. Give teachers training: teachers should be trained on how to integrate CS into their lessons in a way that will optimise learners' learning.
3. Research on the long-term impacts of computer simulation use on learners' conceptual knowledge and academic achievement in photosynthesis and other science courses should be the main focus of future studies.

4. Cooperation between teachers and simulation developers: To make sure that the simulations satisfy learner needs and complement the curriculum, teachers should work together with simulation developers.
5. Evaluation: additional investigation is required to create instruments capable of accurately assessing the learning results of simulation-based learning.

Overall, by implementing the above suggestions, policymakers and teachers may maximise the potential of CS to improve teaching and learning in sciences education.

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Appendices

APPENDIX A: Questionnaire for collecting data before the implementation of Computer Simulations

Please make a cross (X) in the appropriate box

Gender	Male		Female	
Age	15-17		18 +	
Are you doing grade 11 for the first time?	Yes		No	

	I strongly agree	I agree	I partially agree	I disagree	I strongly disagree
My performance in Life Sciences is very good.					
Do you enjoy Life Sciences?					
Do you find Life Sciences topics difficult?					
Does the method used in teaching Life Sciences make you understand it better?					
Are you satisfied with the marks you get in Life Sciences?					

Do you think the introduction to new strategies such as technology in learning can help you understand the subject better?					
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APPENDIX B: Questionnaire for collecting data after the implementation of computer simulations

Please make a cross (X) in the appropriate box

Gender	Male		Female	
Age	15-17		18 +	
Are you doing grade 11 for the first time?	Yes		No	

	I strongly agree	I agree	I partially agree	I disagree	I strongly disagree
Did you enjoy the method used when learning Life Sciences?					
Do you think your performance in Life Sciences can be improved if you were to use the same method every day?					
Do you think the use of simulations can help you understand concepts better?					

APPENDIX C: Pre-post test

SCHOOL NAME :.....
CIRCUIT :.....
DISTRICT :.....
DATE :.....

INSTRUCTIONS:

Answer all questions

QUESTION 1

Various options are provided as answers to the following questions. Choose the correct answer by circling the correct answer in the options provided.

1. What does this equation represent: $6\text{CO}_2 + 6\text{H}_2\text{O} \rightarrow \text{C}_6\text{H}_{12}\text{O}_6 + 6\text{O}_2$?
 - A. Cellular respiration
 - B. Human respiration
 - C. Photosynthesis
 - D. Solar energy (1)

2. Energy is never created nor destroyed, it is only transferred from one form to another.
 - A. The first law of thermodynamics
 - B. Second law of thermodynamics
 - C. Law of energy
 - D. Energy dynamics (1)

3. What is an autotroph?
- A. An animal that feeds on plants
 - B. An organism that makes its own food
 - C. An organism that cannot make its own food
 - D. An animal that feeds on both plants and animals (1)
4. Which of the following is NOT a raw material of photosynthesis?
- A. Carbon dioxide
 - B. Oxygen
 - C. Water
 - D. Sunlight (1)
5. Where in the cell does photosynthesis take place?
- A. Nucleus
 - B. Chloroplast
 - C. Mitochondria
 - D. Cytoplasm (1)
6. A by-product of photosynthesis that becomes a useful substance in cellular respiration.
- A. Carbon dioxide
 - B. Energy-rich hydrogen atoms
 - C. Oxygen
 - D. Water (1)
7. Which one of the following characteristics makes the leaf suitable for photosynthesis to take place?
- A. The spongy mesophyll is elongated.
 - B. The leaf has many stomata in the lower epidermis for gaseous exchange to take place.
 - C. The upper epidermis is the white cuticle

- D. Xylem is present in the products of photosynthesis (1)
8. Which reagent is used to test for the presence of starch in a leaf?
- A. Millon's reagent
 - B. Iodine solution
 - C. Biuret test
 - D. Benedict's test (1)
9. Where does the dark phase of photosynthesis take place?
- A. In the chlorophyll
 - B. In the grana of chloroplast
 - C. In the stroma of chloroplast
 - D. In the nucleus (1)
10. Which one of the following statements is NOT true about photosynthesis?
- A. Needs chlorophyll before it takes place
 - B. Requires light for each step to take place
 - C. A process which has many steps
 - D. Uses up carbon dioxide (1)
11. The matrix of the chloroplast where the dark phase occurs
- A. Mesophyll
 - B. Grana
 - C. Starch grain
 - D. Stroma (1)
12. Removal of starch from the leaf
- A. Iodine
 - B. Starching
 - C. Destarch
 - D. Light (1)
13. Transparent and allow sunlight to pass through
- A. Cuticle
 - B. Epidermis
 - C. Spongy mesophyll

- D. Stomata (1)
14. Which of the following factors affects the rate of photosynthesis
- A. Water
 - B. Soil
 - C. Light intensity
 - D. Nutrients (1)
15. Sweet potato is an underground structure which stores food. Where is the food prepared in this plant?
- A. Fruit
 - B. Stem
 - C. Leaves
 - D. Root (1)
16. Photosynthesis in plants converts light energy to
Energy.
- A. Thermal
 - B. Chemical
 - C. Kinetic
 - D. Physical (1)
17. Which part of the plant takes in carbon dioxide from the air for photosynthesis?
- A. Root hair
 - B. Stomata
 - C. Leaf veins
 - D. Petals (1)
18. The final product of photosynthesis
- A. Hydrocarbon
 - B. Carbon dioxide
 - C. Oxygen
 - D. Water (1)
19. Chlorophyll in a leaf is required for:
- A. Trapping light energy
 - B. Emitting green light
 - C. Storing starch in leaves
 - D. Attracting water (1)
20. What are the requirements for photosynthesis?

- A. Carbon dioxide
- B. Water and light
- C. Chlorophyll only
- D. All of the above

(1)

TOTAL

[20]

APPENDIX D: Permission letter to principals

PERMISSION LETTER TO THE PRINCIPAL

Muthuhadini Combined School
P O Box 2118
Elim Hospital
0960

Contact numbers: 072 063 4892/081 447 3891

Email: tinyikomillicent@gmail.com

The Principal

Request for permission to conduct research in Life Sciences in your school

Dear principal,

I am Maluleke Tinyiko Millicent, an educator at Muthuhadini Combined School and a Masters Student at the University of Venda. I am doing research titled: “The Impact of Computer Simulations on Grade 11 Learners’ Conceptual Understanding of Photosynthesis”

I hereby request permission to conduct a research study within your school by teaching Grade 11 learners Life Sciences using simulations, data will be collected in the form of tests (pre and post-test), questionnaires, interviews and observation.

I promise that my research will not interfere with the normal school programme, I will follow the normal school timetable and content as per Pacesetter and Annual Teaching Plan (ATP). The data collected will be treated with confidentiality and the names of learners, educators and your school will not be published.

This study is going to improve learners’ understanding of Photosynthesis and improve their performance since they will be exposed to the new learning environment. Teachers will also benefit because they will be trained in the use of simulations and it will improve their creativity in the classroom.

If you require any further information, please do not hesitate to contact me.

I will be patiently looking forward to your response.

Yours sincerely,

Maluleke Tinyiko Millicent

Signature..... Date.....

APPENDIX E: Informed consent form

LETTER OF INFORMATION

Title of the Research Study: The Impact of Computer Simulations on Grade 11 Learners' Conceptual Understanding of Photosynthesis

Principal Investigator/s/ researcher: Maluleke Tinyiko Millicent, Bachelor of Science Honours in Life Sciences Education

Co-Investigator/s/supervisor/s : Dr Kaheru S.J.M, Phd
Dr Muthambi S.K Phd

Brief Introduction and Purpose of the Study:

Outline of the Procedures: This study is going to use a quantitative research design and the type of quantitative research design is quasi-experimental. There will be experimental and comparison groups which will be tested on the use of simulations as compared to traditional teaching methods. Data will be collected using the pre-post tests and questionnaires. Purposive sampling is going to be used in this study and the four schools from the two

circuits will form the population of the study and this is where the sample will be drawn from.

The research methodology to be used is quantitative. Two schools are going to be used as experimental and the other two schools as the control. All the four groups will be given a pre-test. Thereafter two schools are going to be exposed to Computer Simulations and the other two schools will be taught using traditional methods. After that, all four schools will be given a post-test. All the results will be recorded and analysed using quantitative data analysis. All learners will be given a questionnaire before and after the treatment to reflect on their feelings about the two types of teaching methods used. All ethical considerations will be observed and participants will be fully informed about their rights, their information will only be used for this study and they will remain anonymous to protect their identity.

Risks or Discomforts to the Participant: No foreseeable risks

Benefits : This study will be conducted in rural areas because of the challenges learners face in Life Sciences. Some of the challenges are limited access to quality education, resources and technology which can prevent them from producing good learning outcomes. The implementation of CS in rural areas can help address these challenges and provide quality education to learners. By conducting CS in rural areas, this study aims to gain an understanding of different challenges and opportunities that exist in these contexts, developing tailored interventions to improve educational outcomes. The findings of this study will help the Department of Education to come up with strategies on how to integrate technology into education to help learners from rural schools

Reason/s why the Participant May Be Withdrawn from the Study: participants will be allowed to withdraw from the study anytime should they wish not to participate for any reason. There will be no consequences for the participant should they choose to withdraw.

Remuneration : No remuneration will be received by participants

Costs of the Study : None

Confidentiality : To maintain confidentiality, all the data provided cannot be linked to any participant by name. The signed consent from parents will be kept in a safe and locked place.

Research-related Injury : The research has no risks at all, there will not be compensation if anyone gets injured.

Persons to Contact in the Event of Any Problems or Queries:

(Dr Kaheru S.J.M,) Please contact the researcher (0720634892.), my supervisor (0727092626). University Research Ethics Committee Secretariat on 015 962 9058 / Vanecia.Khoza@univen.ac.za

Complaints can be reported to the University Research Ethics Committee Secretariat on 015 962 9058 / Vanecia.Khoza@univen.ac.za or Whistleblowing Ethics Hotline Tollfree Telephone number: 0800212755 Email.univenhotline@tipoffs.com

Certificate of Assent

Title of the study : The Impact of Computer Simulations on Grade 11
Learners' Conceptual Understanding of Photosynthesis

Participant's name

:

Participant's signature

:

.....

Date

:

I, (**Baloyi Dumisani Justice**), have witnessed the above-named participant voluntarily agree to participate in the research study The Impact of Computer Simulations on Grade 11 Learners' Conceptual Understanding of Photosynthesis. I confirm that the participant has been informed of the study procedures, risks, benefits, and rights, and has provided their assent to participate.

Witness's name

: Baloyi Dumisani Justice

Witness's signature

:



Date

: 05 October 2025

By signing below, I attest that I observed the participant's assent and can verify its voluntary nature.



.....

CONSENT FORM FOR PARTICIPANT:

General:

Potential participants must be assured that participation is voluntary and the approximate number of participants to be included should be disclosed. A copy of the information letter should be issued to participants. The information letter and consent form must be translated and provided in the primary spoken language of the research population.

CONSENT

Statement of Agreement to Participate in the Research Study:

- I hereby confirm that I have been informed by the researcher, (**MALULEKE TINYIKO MILLICENT**), about the nature, conduct, benefits and risks of this study - Research Ethics Clearance Number: FHSSE/24/CSEM/05/0107 ,
- I have also received, read and understood the above-written information (Participant Letter of Information) regarding the study.
- I am aware that the results of the study, including personal details regarding my sex, age, date of birth, initials and diagnosis will be anonymously processed into a study report.
- In view of the requirements of research, I agree that the data collected during this study can be processed in a computerized system by the researcher.
- I may, at any stage, without prejudice, withdraw my consent and participation in the study.
- I have had sufficient opportunity to ask questions and (of my own free will) declare myself prepared to participate in the study.
- I understand that significant new findings developed during the course of this research which may relate to my participation will be made available to me.

Full Name of Participant	Date	Time	Signature
.....			

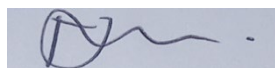
I, (**MALULEKE TINYIKO MILLICENT**) herewith confirm that the above participant has been fully informed about the nature, conduct and risks of the above study.

Full Name of Researcher

MALULEKE TINYIKO MILLICENT

Date: **2024/07/03**

Signature:



Full Name of Witness (If applicable)

BALOYI DUMISANI JUSTICE

Date: 2024/07/03

Signature:



Full Name of Legal Guardian (If applicable)

.....

Date.....

Signature.....

PAPILA RA VUXOKOXOKO

Nhloko-mhaka ya dyondzo : Ku tirhisa swifaniso swa khompyuta ku antswisa ka miehleketso ya vadyondzi va giredi ya 11 eka photosynthesis

Mulavisisi : Maluleke Tinyiko Millicent, Bachelor of Science Honours in Life Sciences Education

Valavisisi-kulobye/valanguteri : Dr Kaheru S.J.M, Phd
Dr Muthambi S.K Phd

Xingheniso xo koma ni xikongomelo dyondzo

:

Xivumbeko xa maendlelo : dyondzo ley iyi ta tirhisa ndzavisiso wa nhlayo na swona vuxaka bya dizayini ya ndzavisiso wa nhlayo i 'quasi-expeirimental'. Ku ta va na mintlawo ya ku ringeta naku pimanisa leyi ngata kamberiwa eka matirhidelo ya swifaniso loko ku pimanisiwa na ndlela ya ndhavuko yo ndondzisa. Data yi ta hlengeleriwa hiku tirhisa swikambelo swa le ndzhaku-mahlweni na swivutiso. Ku tekeriwa seikombiso hi xikongomelo swi ta tirhisiwa eka dyondzo yoleyo naswona swikolo swa mune ku suka eka swifundzha swimbiri swi ta vumba vaaki va dyondzo naswona laha hi laha xikombiso xi nga ta tekiwa kona.

Maendlelo ma ndzavisiso lama nga ta tirhisiwa I ya nhlayo. Swikolo swimbirhi swita tirhisiwa tanihi swa ku ringeta kasi leswin'wana swimbirhi tanihi vulawuri. Swikolo hinkwaswo swa mune swita nyikiwa xikambelo xale ndzhaku. Endzhaku ka sweswo swikolo swimbirhi swi ta dyodzha hi swifaniso swa khompyuta naswona swikolo leswin'nana swimbirhi seita dyondziwiwa hi ku tirhisa ndlela ya ndzhavuko. Endzhaku ka sweswo swikolo hinkwaswo swa mune swi ta nyikiwa xikambelo xa le ndzhaku. Mimbuyelo hinkwayo yi ta rhekhodiwa no xopaxopiwa hi ku thirhisa nxopaxopo wa datha ya nhlayo. Vadyondzi hinkwavo vata nyikiwa phepha ra swivutiso emahlweni na le ndzhaku ka loko vutshunguri ku anakanyisisa hi matwelo ya vona eka tinxaka timbirhi ta maendleko yo dyondzisa lama tirhisiweke. Ku tekeriwa nhlokweni hinkwako ka mahanyelo ku ta langutiwa naswona vatekaxiave va ta tivisiwa hi ki hetiseka hi timfanelo ta vona, mahungu ya vona ya ta tirhisiwa ntsena eka ndzavisiso lowu naswona va ta tshama va nga tiviwi hiku sirhelela vumunhu bya vona.

Khombo kumbe ku nga tsaki eka mutekaxiave: vatekaxiave ava nge vekiwi ekhombyeni

Mimbuyelo : Dyondzo leyi yi ta endliwa etindhawini ta le makaya hikwalaho ka mintlhontlho leyi vadyondzi va langutaneke na yona eka Sayense ya Vutomi. Mintlhontlho yin'wana i ku fikelela loku nga nyawuriki eka dyondzo ya xiyimo xa le henhla, switirhisiwa na thekinoloji leswi nga va sivela ku humesa mimbuyelo ya kahle ya dyondzo. Ku tirhisiwa ka swifaniso swa Khomphyuta etindhawini ta le makaya swi nga pfuna ku lulamisa mintlhontlho leyi na ku nyika dyondzo ya xiyimo xa le henhla eka vadyondzi. Hi ku endla swifaniso swa Khomphyuta etindhawini ta le makaya, ndzavisiso lowu wu kongomisa ku kuma ku twisisa ka mintlhontlho yo hambana na minkarhi leyi nga kona eka swiyimo leswi, ku hluvukisa ku nghenelela loku lulamisiweke ku antswisa mimbuyelo ya dyondzo. Swikumiwa swa ndzavisiso lowu swi ta pfuna Ndzawulo ya Dyondzo ku ta na maqhinga ya ndlela yo hlanganisa thekinoloji eka dyondzo ku pfuna vadyondzi lava humaka eswikolweni swa le makaya.

Swivangelo/swivangelo leswi endlaka leswaku Mutekaxiave a nga Susiwa eka Dyondzo: participants will be allowed to withdraw from the study anytime should they wish not to participate for any reason. There will be no consequences for the participant should they choose to withdraw.

Ku hakeriwa : aku nge hakeriwi munhu

Ntsengo wa ndzavisiso lowu : ku hava

Ku hlayisa xihundla : ku hlayisa xihundla, datara hinkwayo leyi nga ta kumeka yinge hlanganisiwi na vatekaxiave hi vito. Fomo leyi nga mfunghiwa hi vatswari ya mpfumelelo yita vekiwa laha yinga tava yi hlayisekili na swona ku khiyiwilie.

Ku vaviseka loku fambelenaka na ndzavisiso lowu : ndzavisiso lowu vu hava khombo, loko munhu o vaviseka ange hakeriwi mali.

Vanhu lava minga ti hlanganisaka na vona loko kova na swiphiqo kumbe swivutiso:

(Dr Kaheru S.J.M) hi kombela mi ti hlanganisa na mulavisisi (0720634892), mulanguteri {0727092626}. Vumatsalani bya komiti ha mahanyelo ya ndzhavisiso wa le yunivhesiti eka 015 962 9058 / vanecia.khoza@univen.ac.za

Swivilelo swi nga vikiwa eka Vumatsalani bya Komiti ya Mahanyelo ya Vulavisisi bya Yunivhesiti eka 015 962 9058 / Vanecia.Khoza@univen.ac.za kumbe Nomboro ya Riqingho ya Mahala ya Mahanyelo ya Mahanyelo yo pfurhetela nomboro: 0800212755 Imeyili.univenhotline@tipoffs.com

FOMO YA PFUMELO YA VATEKAXIAVE

Hi ku angarhela:

Lava nga ta nghenela va fanele ku tiyisisiwa leswaku ku nghenelela i ka ku tirhandzela naswona nhlayo leyi ringanyetiweke ya vatekaxiave lava nga ta katsiwa yi fanele ku paluxiwa. Khopi ya papila ra vuxokoxoko yi fanele ku nyikiwa vatekaxiave. Papila ra mahungu na fomo ya mpfumelelo swi fanele ku hundzuluxeriwa no nyikiwa hi ririmi ro sungula leri vulavuriwaka ra vaaki va ndzavisiso

PFUMELELO

Xitatimende xa Ntwanano wo Nghenelela eka Dyondzo ya Ndzavisiso:

- Ndzi tiyisisa leswaku ndzi tivisiwile hi mulavisisi, (MALULEKE TINYIKO MILLICENT), hi muxaka, mahanyelo, mimbuyelo na makhombo ya ndzavisiso lowu - Nomboro ya Mpfumelelo wa Mahanyelo ya Ndzavisiso: FHSSE/24/CSEM/05/0107_,
- Ndzi tlhele ndzi kuma, ndzi hlaya no twisisa mahungu lama tsariweke laha henhla (Papila ra Mahungu ya Mutekaxiave) mayelana na dyondzo.
- Ndza swi tiva leswaku mbuyelo wa ndzavisiso, ku katsa na vuxokoxoko bya munhu hi xiyexe mayelana na rimbewu ra mina, malembe, siku ra ku velekiwa, mavito yo sungula na ku kumiwa ka vuvabyi swi ta phurosesiwa swi nga tiviwi eka xiviko xa dyondzo.
- Hi ku languta swilaveko swa ndzavisiso, ndza pfumela leswaku datha leyi hlengeletiweke hi nkarhi wa dyondzo leyi yi nga tirhisiwa eka sisiteme ya khompyuta hi mulavisisi.
- Ndzi nga, eka xiteji xin'wana na xin'wana, handle ka xihlawuhlawu, hoxa mpfumelelo wa mina na ku nghenelela eka dyondzo.

- Ndzi vile na nkarhi lowu eneleke wo vutisa swivutiso na (hi ku tihlawulela ka mina) ku tivula leswaku ndzi lunghekele ku nghenelela eka dyondzo.
- Ndza swi twisisa leswaku swikumiwa leswintshwa swa nkoka leswi tumbuluxiweke hi nkarhi wa ndzavisiso lowu leswi nga fambelanaka na ku nghenelela ka mina swi ta endliwa swi kumeka eka mina.

Vito leri heleleke ra Mutekaxiave

Siku

Nkharhi

Mfungho

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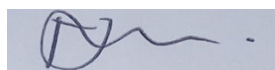
Mina, (MALULEKE TINYIKO MILLICENT) hi ku tiyisisa leswaku mutekaxiave loyi a nga laha henhla u Tivisiwe hi ku hetiseka hi muxaka, mahanyelo na makhombo ya dyondzo leyi nga laha henhla.

Vito leri heleleke ra Mulavisisi

MALULEKE TINYIKO MILLICENT

Siku: **2024/07/03**

Mfungho:



Vito leri heleleke ra Mbhoni (Loko swi fanerile) .

BALOYI DUMISANI JUSTICE

Siku: 2024/07/03

Mfungho:



Vito leri heleleke ra Muhlayisi wa swa Nawu (Loko swi fanerile) .

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Siku.....

Mfungho.....

LETTER OF INFORMATION

Title of the Research Study : The Impact of Computer Simulations on Grade 11 Learners' Conceptual Understanding of Photosynthesis

Principal Investigator/s/ researcher : Maluleke Tinyiko Millicent, Bachelor of Science Honours in Life Sciences Education

Co-Investigator/s/supervisor/s : Dr Kaheru S.J.M, Phd
Dr Muthambi S.K Phd

Brief Introduction and Purpose of the Study:

Outline of the Procedures : This study is going to use a quantitative research design and the type of quantitative research design is quasi-experimental. There will be experimental and comparison groups which will be tested on the use of simulations as compared to the traditional teaching methods. Data will be collected using the pre-post tests and questionnaires. Purposive sampling is going to be used in this study and the four schools from the two circuits will form the population of the study and this is where the sample will be drawn from.

The research methodology to be used is quantitative. Two schools are going to be used as experimental and the other two schools as the control. All the four groups will be given a pre-test. Thereafter two schools are going to be exposed to Computer Simulations and the other two schools will be taught using traditional methods. After that, all four schools will be given a post-test. All the results will be recorded and analysed using quantitative data analysis. All learners will be given a questionnaire before and after the treatment to reflect on their feelings on the two types of teaching methods used. All ethical considerations will be observed and participants will be fully informed about their rights, their information will only be used for this study and they will remain anonymous to protect their identity.

Risks or Discomforts to the Participant: No foreseeable risks

Benefits : This study will be conducted in rural areas because of the challenges learners face in Life Sciences. Some of the challenges are limited access to quality education, resources and technology which can prevent them from producing good learning outcomes. The implementation of CS in rural areas can help address these challenges and provide quality education to learners. By conducting CS in rural areas, this study aims to gain an understanding of different challenges and opportunities that exist in these contexts, developing tailored interventions to improve educational outcomes. The findings of this study will help the Department of Education to come up with strategies on how to integrate technology into education to help learners from rural schools

Reason/s why the Participant May Be Withdrawn from the Study: participants will be allowed to withdraw from the study anytime should they wish not to participate for any reason. There will be no consequences for the participant should they choose to withdraw.

Remuneration : No remuneration will be received by participants

Costs of the Study : None

Confidentiality : To maintain confidentiality, all the data provided cannot be linked to any participant by name. The signed consent from parents will be kept in a safe and locked place.

Research-related Injury : The research has no risks at all, there will not be compensation if anyone gets injured.

Persons to Contact in the Event of Any Problems or Queries:

(Dr Kaheru S.J.M,) Please contact the researcher (0720634892.), my supervisor (0727092626). University Research Ethics Committee Secretariat on 015 962 9058 / Vanecia.Khoza@univen.ac.za

Complaints can be reported to the University Research Ethics Committee Secretariat on 015 962 9058 / Vanecia.Khoza@univen.ac.za or Whistleblowing Ethics Hotline Tollfree Telephone number: 0800212755 Email.univenhotline@tipoffs.com

CONSENT FORM FOR PARENTS

General:

Potential participants must be assured that participation is voluntary and the approximate number of participants to be included should be disclosed. A copy of the information letter should be issued to participants. The information letter and consent form must be translated and provided in the primary spoken language of the research population.

CONSENT

Statement of Agreement to Allow My Child to Participate in the Research Study:

- I hereby confirm that I have been informed by the researcher, (**MALULEKE TINYIKO MILLICENT**), about the nature, conduct, benefits and risks of this study - Research Ethics Clearance Number: FHSSE/24/CSEM/05/0107 ,
- I have also received, read and understood the above-written information (Participant Letter of Information) regarding the study.
- I am aware that the results of the study, including my child's personal details regarding his/her sex, age, date of birth, initials and diagnosis will be anonymously processed into a study report.
- In view of the requirements of research, I agree that the data collected during this study can be processed in a computerized system by the researcher.
- I may, at any stage, without prejudice, withdraw my consent and my child's participation in the study.
- I have had sufficient opportunity to ask questions and (of my child's free will) declare my child to be prepared to participate in the study.
- I understand that significant new findings developed during the course of this research which may relate to my child's participation will be made available to me.

Full Name of Parent/Guardian Date Time Signature

.....
.....

I, (**MALULEKE TINYIKO MILLICENT**) herewith confirm that the above parent/guardian has been fully.

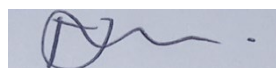
Informed about the nature, conduct and risks of the above study.

Full Name of Researcher

MALULEKE TINYIKO MILLICENT

Date: **2024/07/03**

Signature:



Full Name of Witness (If applicable)

BALOYI DUMISANI JUSTICE

Date: 2024/07/03

Signature:



Full Name of Legal Guardian (If applicable)

.....

Date.....

Signature.....

PAPILA RA VUXOKOXOKO

Nhloko-mhaka ya dyondzo : Ku tirhisa swifaniso swa khompyuta ku antswisa ka miehleketo ya vadyondzi va giredi ya 11 eka photosynthesis

Mulavisisi : Maluleke Tinyiko Millicent, Bachelor of Science Honours in Life Sciences Education

Valavisisi-kulobye/valanguteri : Dr Kaheru S.J.M, Phd
Dr Muthambi S.K Phd

Xingheniso xo koma ni xikongomelo dyondzo

:

Xivumbeko xa maendlelo : dyondzo ley iyi ta tirhisa ndzavisiso wa nhlayo na swona vuxaka bya dizayini ya ndzavisiso wa nhlayo i ‘quasi-expeirimental’. Ku ta va na mintlawwa ya ku ringeta naku pimanisa leyi ngata kamberiwa eka matirhidelo ya swifaniso loko ku pimanisiwa na ndlela ya ndhavuko yo ndondzisa. Data yi ta hlengeletwa hiku tirhisa swikambelo swa le ndzhaku-mahlweni na swivutiso. Ku tekeriwa seikombiso hi xikongomelo swi ta tirhisiwa eka dyondzo yoleyo naswona swikolo swa mune ku suka eka swifundzha swimbirhi swi ta vumba vaaki va dyondzo naswona laha hi laha xikombiso xi nga ta tekiwa kona.

Maendlelo ma ndzavisiso lama nga ta tirhisiwa I ya nhlayo. Swikolo swimbirhi swita tirhisiwa tanihi swa ku ringeta kasi leswin’wana swimbirhi tanihi vulawuri. Swikolo hinkwaswo swa mune swita nyikiwa xikambelo xale ndzhaku. Endzhaku ka sweswo swikolo swimbirhi swi ta dyodzha hi swifaniso swa khompyuta naswona swikolo leswin’nana swimbirhi seita dyondziwiwa hi ku tirhisa ndlela ya ndzhavuko. Endzhaku ka sweswo swikolo hinkwaswo swa mune swi ta nyikiwa xikambelo xa le ndzhaku. Mimbuyelo hinkwayo yi ta rhekhodiwa no xopaxopiwa hi ku thirhisa nxopaxopo wa datha ya nhlayo. Vadyondzi hinkwavo vata nyikiwa phepha ra swivutiso emahlweni na le ndzhaku ka loko vutshunguri ku anakanyisisa hi matwelo ya vona eka tinxaka timbirhi ta maendleko yo dyondzisa lama tirhisiweke. Ku tekeriwa nhlokweni hinkwako ka mahanyelo ku ta langutiwa naswona vatekaxiave va ta tivisiwa hi ki hetiseka hi timfanelo ta vona, mahungu ya vona ya

ta tirhisiwa ntsena eka ndzavisiso lowu naswona va ta tshama va nga tiviwi hiku sirhelela vumunhu bya vona.

Khombo kumbe ku nga tsaki eka mutekaxiave: vatekaxiave ava nge vekiwi ekhombyeni

Mimbuyelo : Dyondzo leyi yi ta endliwa etindhawini ta le makaya hikwalaho ka mintlhontlho leyi vadyondzi va langutaneke na yona eka Sayense ya Vutomi. Mintlhontlho yin'wana i ku fikelela loku nga nyawuriki eka dyondzo ya xiyimo xa le henhla, switirhisiwa na thekinoloji leswi nga va sivela ku humesa mimbuyelo ya kahle ya dyondzo. Ku tirhisiwa ka swifaniso swa Khomphyuta etindhawini ta le makaya swi nga pfuna ku lulamisa mintlhontlho leyi na ku nyika dyondzo ya xiyimo xa le henhla eka vadyondzi. Hi ku endla swifaniso swa Khomphyuta etindhawini ta le makaya, ndzavisiso lowu wu kongomisa ku kuma ku twisisa ka mintlhontlho yo hambana na minkarhi leyi nga kona eka swiyimo leswi, ku hluvukisa ku nghenelela loku lulamisiweke ku antswisa mimbuyelo ya dyondzo. Swikumiwa swa ndzavisiso lowu swi ta pfuna Ndzawulo ya Dyondzo ku ta na maqhinga ya ndlela yo hlanganisa thekinoloji eka dyondzo ku pfuna vadyondzi lava humaka eswikolweni swa le makaya.

Swivangelo/swivangelo leswi endlaka leswaku Mutekaxiave a nga Susiwa eka Dyondzo: participants will be allowed to withdraw from the study anytime should they wish not to participate for any reason. There will be no consequences for the participant should they choose to withdraw.

Ku hakeriwa : aku nge hakeriwi munhu

Ntsengo wa ndzavisiso lowu : ku hava

Ku hlayisa xihundla : ku hlayisa xihundla, data hinkwayo leyi nga ta kumeka yinge hlanganisiwi na vatekaxiave hi vito. Fomo leyi nga mfunghiwa hi vatswari ya mpfumelelo yita vekiwa laha yinga tava yi hlayisekili na swona ku khiyiwilie.

Ku vaviseka loku fambelenaka na ndzavisiso lowu : ndzavisiso lowu vu hava khombo, loko munhu o vaviseka ange hakeriwi mali.

Vanhu lava minga ti hlanganisaka na vona loko kova na swiphiqo kumbe swivutiso:

(Dr Kaheru S.J.M) hi kombela mi ti hlanganisa na mulavisisi (0720634892), mulanguteri {0727092626}. Vumatsalani bya komiti ha mahanyelo ya ndzhavisiso wa le yunivhesiti eka 015 962 9058 / vanecia.khoza@univen.ac.za

Swivilelo swi nga vikiwa eka Vumatsalani bya Komiti ya Mahanyelo ya Vulavisisi bya Yunivhesiti eka 015 962 9058 / Vanecia.Khoza@univen.ac.za kumbe Nomboro ya Riqingho ya Mahala ya Mahanyelo ya Mahanyelo yo pfurhetela nomboro: 0800212755
Imeyili.univenhotline@tipoffs.com

FOMO YA PFUMELO YA VADYONDZI

Hi ku angarhela:

Lava nga ta nghenela va fanele ku tiyisisiwa leswaku ku nghenelela i ka ku tirhandzela naswona nhlayo leyi ringanyetiweke ya vatekaxiave lava nga ta katsiwa yi fanele ku paluxiwa. Khopi ya papila ra vuxokoxoko yi fanele ku nyikiwa vatekaxiave. Papila ra mahungu na fomo ya mpfumelelo swi fanele ku hundzuluxeriwa no nyikiwa hi ririmi ro sungula leri vulavuriwaka ra vaaki va ndzavisiso

PFUMELELO

Xitatimende xa Ntwanano wo Nghenelela eka Dyondzo ya Ndzavisiso:

- Ndzi tiyisisa leswaku ndzi tivisiwile hi mulavisisi, (MALULEKE TINYIKO MILLICENT), hi muxaka, mahanyelo, mimbuyelo na makhombo ya ndzavisiso lowu - Nomboro ya Mpfumelelo wa Mahanyelo ya Ndzavisiso: FHSSE/24/CSEM/05/0107_,
- Ndzi tlhele ndzi kuma, ndzi hlala no twisisa mahungu lama tsariweke laha henhla (Papila ra Mahungu ya Mutekaxiave) mayelana na dyondzo.
- Ndza swi tiva leswaku mbuyelo wa ndzavisiso, ku katsa na vuxokoxoko bya munhu hi xiyexe mayelana na rimbewu ra n'wana wa mina, malembe, siku ra ku velekiwa, mavito yo sungula na ku kumiwa ka vuvabyi swi ta phurosesiwa swi nga tiviwi eka xiviko xa dyondzo.
- Hi ku languta swilaveko swa ndzavisiso, ndza pfumela leswaku datha leyi hlengeletaweke hi nkarhi wa dyondzo leyi yi nga tirhisiwa eka sisiteme ya khompyuta hi mulavisisi.
- Ndzi nga, eka xiteji xin'wana na xin'wana, handle ka xihlawuhlawu, hoxa mpfumelelo wa n'wana wa mina na ku nghenelela eka dyondzo.
- Ndzi vile na nkarhi lowu eneleke wo vutisa swivutiso na (hi ku hlawula ka n'wana wa mina) ku vula leswaku u lunghekele ku nghenelela eka dyondzo.

- Ndza swi twisisa leswaku swikumiwa leswintshwa swa nkoka leswi tumbuluxiweke hi nkarhi wa ndzavisiso lowu leswi nga fambelanaka na ku nghenelela ka n'wana wa mina swi ta endliwa swi kumeka eka mina.

Vito leri hebeleke ra Mutswari/ muhlayisi wa n'wana
Mfungho

Siku

Nkharhi

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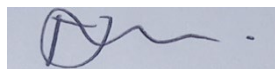
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Mina, (MALULEKE TINYIKO MILLICENT) hi ku tiyisisa leswaku mutekaxiave loyi a nga laha henhla u Tivisiwe hi ku hetiseka hi muxaka, mahanyelo na makhombo ya dyondzo leyi nga laha henhla.

Vito leri hebeleke ra Mulavisisi

MALULEKE TINYIKO MILLICENT

Siku: **2024/07/03** Mfungho:



Vito leri hebeleke ra Mbhoni (Loko swi fanerile) .

BALOYI DUMISANI JUSTICE

Siku: 2024/07/03

Mfungho.....

Vito leri hebeleke ra Muhlayisi wa swa Nawu (Loko swi fanerile) .

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Siku.....

Mfungho.....

Luñwalo lwa vhuṭanzi

Ṭhoho ya ngudo dza ṭhoḍisiso : u shumisa khomphutha lwa u edzisela u khwaṭhisa lu sa hanedzei kupfesesele kha vhana vha gireidi 11 nga ha

Mune wa ṭhoḍisiso : Maluleke Tinyiko Millicent, Bachelor of Science Honours in Life Sciences Education

Muthusi kha ṭhoḍisiso: Dr Kaheru S.J.M, PhD

Dr Muthambi S.K PhD

Marangaphanda na tshipikwa tsha ṭhoḍisiso

Ṭhalutshedzo ya kushumele/ : ṭhoḍisiso iyi I khou ḍo vha itshi khou shumisa ndila ya ṭhoḍisiso ino vhidzwa uri quantitative, kha iyi ṭhoḍisiso ya qualitative hu ḍo shumiswa quasi-experimental. Hu ḍovha na u lingwa nga zwigwada na u vhambedzwa ha e zwi zwigwada, vhana vha ḍo lingwa kha ku shumisele kwa u edzisela/ fanyisa hu tshi vhambedzwa na Kufunzele kwo ḍowealeho. Mawanwa a ḍo kuvhanganyiswa hu tshi shumiswa Mulingo wa u rangela na Bammbiri ḽa dzi mbudziso. Kunangele kwo livhanyiswaho na vhathu vhane vha khou ṭodea ndi kwone kwu no ḍo shumiswa kha heyi ṭhoḍisiso, zwikolo zwina zwa sekhethe mbili zwi ḍo vhumba zwigwada zwa vhathu vha no ḍo shumiswa kha ngudo idzi, ndi henefho hune tsumbo dza ḍo va hone.

Ṭhoḍisiso I do shumisa kuitele ku no vhidzwa uri quantitative. Zwikolo zwivhili zwi ḍo shumisiwa kha u linga ngeno zwivhili zwi tshi ḍo shumiswa kha control. Zwikolo zwoṭhe zwina zwi ḍo newa Mulingo wa u rangela. U bva afho zwikolo zwivhili zwi ḍo pfumbudzwa nga ndila ya u edzisela nga khomphyutha, ngeno zwivhili zwi tshi ḍo funzwa nga ndila ya kale. Nga murahu ha afho, zwikolo izwo vhuna hazwo zwi ḍo newa Mulingo wa u tevhela ngudo. Mawanwa oṭhe a ḍo ṇwalwa a dovha a sedzuluswa hu tshi khou shumiswa tshisedzulusi tsha mawanwa tsha quantitative. Nwana muṇwe na muṇwe u ḍo newa Bammbiri ḽa dzi mbudziso dza u rangela na dzo no ḍoda murahu ha u lingedza ngudo idzi, uri a sedze Vhuḍipfi hawe ho sedzwa tshakha idzi mbili dza u guda dzo shumiswaho. Vhathu vho nangwaho vha ḍo vha vho bviselwa khagala nga ha milayo na kushumele, pfanelo

dzavho, na uri mafhungo othe o shumiswaho kana e vha amba a do vha tshiphiri nahone a do shumiswa kha iyi Bammbiri u itela u tsireledza vhona vhane.

Khombo kana u sa farea zwavhuḏi ha vhadzheneleli: a huna khombo dzivhonalaho dzi tshi dovha hone

Benefits

Idzi ngudo dzi do itwa kha mashango kana mivhundu ire mahayani vhukuma, ngauri vhana vhanzhi vha khou tanga na vhuleme musi ho sedzwa thero ya Life Science. Huṅwe ha vhuleme ndi u sa vha na Zwishumiswa zwo linganelaho zwine vha nga zwi swikelela, pfunzo ine vha khou I wana ndi ya fhasi, na zwi shumiswa zwa thekholodzhi, zwine zwi nga ita uri vhana vha kone u vha na mvelele dzavhuḏi. U shumisiwa ha heyi CS kha mashango are mahayani zwi do thusa u bvisa khagala zwickundisi na u disa pfunzo yo teaho kha vhana. U shumisa heyi CS kha mivhundu ya mahayani, zwi do thusa kha u bvisa khagala Thaidzo na Zwickhala zwine zwa vha hone kha heyi Nyimele, na u thusa u kona u disa na u fhaṭa ndila dzo teaho u alusa mvelelo dza ngudo idzi.

Mawanwa a ngudo idzi a do thusa muhasho wa zwa pfunzo u da na dziṅwe ndila dza u panga mawanwa a thekholodzhi kha zwa pfunzo u thusa vhana vha re zwickoloni zwa mahayani.

Zwivhanga zwino do ita uri muthu a bvisa kha ngudo idzi

Vhanangiwa vha do tendelwa u di bvisa kha ngudo idzi tshifhinga tshinwe na tshinwe tshine vha toḁa, arali vha si tsha toḁa u dzhenelela nga mavhanga manwe na manwe. A huna a noḁo vhone mulandu kha u di bvisa havho.

Mbadelo : a hunga dovha na mbadelo kha vathu vho dzhenelaho

Mbadelo dzi no do shumiswa kha ngudo idzi : a huna mbadelo

Tshidzumbo: uri hu vhe na zwidzumbo, zwothe zwo wanwaho a zwi nga do livhanywa na dzina la muthu. Fomo dza thendelo dzo sainwaho nga vhabebi dzi do vhewa fhethu ho dzumbamaho dza dovha dza khielelwa.

Khuvhabvu dzi no do wanala vhukati ha ngudo idzi: thoḁisiso idzi a dzi ngavhi na kuvhabvu, dzi do vha dzo tsireledzeaho, a hunga do vha na mbadelo kha vathu vho huvhalaho

Muthu ane atea u kwamiwa arali hu na Zwiñwe kana dziñwe Thaidzo kana mbudziso

(Dr Kaheru S.J.M,) Please contact the researcher (0720634892.), my supervisor (0727092626). University Research Ethics Committee Secretariat on 015 962 9058 / Vanecia.Khoza@univen.ac.za

Mbilahelo dzi nga livhiswa kha University Research Ethics Committee Secretariat on 015 962 9058 / Vanecia.Khoza@univen.ac.za or Whistle blowing Ethics Hotline Toll-free Telephone number: 0800212755 [Email.univenhotline@tipoffs.com](mailto:univenhotline@tipoffs.com)

CONSENT FORM FOR PARENTS

General:

Vhathu vho dzhenelelaho vha tea u khwaṭhisedzelwa uri u dzhenelela havho a vha kombetshedzwi, vha tou nanga/ funa, a zwi kombetshedzwi, mbalo ya vhathu vho dzhenelelaho I tea u vha yo vhudzwa vhathu vhoṭhe. Hu tea uvha na kopi ya ili Bammbiri li tea u newa vhathu vhoṭhe vho dzhenelelaho. Luṅwalo lwa vhuṭanzi na Fomo ya thendelo I tea u iswa kha luambo lwa vhadzheneleli na fhethu hune vhathu avho vha dzula hone.

Thendelo

Tshitatamennde tsha thendelano ya vha dzhenelela kha iyi ṭhoḍisiso

- Ndi khou khwaṭhisedzelwa uri ndo vhudzwa nga musedzulusi (MALULEKE TINYIKO MILLICENT), nga ha vhuvha, kufarelwe, zwiwanwa na khombo dza ngudo idzi - Research Ethics Clearance Number: FHSSE/24/CSEM/05/0107 _,
- Ndo newa, nda vhala na u pfesesa mafhungo o ṅwalwaho afho nṱha kha Fomo ya vhadzheneleli, zwi tshi kwama ngudo idzi.
- Ndi a divha uri mawanwa a ngudo idzi, zwi tshikatela zwidodombedzwa zwi kwamaho minwaha, ḍuvha la mabebo, dzina ḵanga na zwe nda amba a zwinga bviselwa nṅa,
- Ro sedza zwi no khou ṱoḍea kha ṱhoḍisiso idzi, ndi a tenda uri mawanwa o kuvhanganywaho kha idzi ngudo dzi nga shumiwa dza dzheniswa kha khomphyutha nga mulanguli wa ṱhoḍisiso.
- Ndi a ḍivha uri tshifhinga tshiṅwe na tshiṅwe tshine nda funa, hu sina u dzhia sia, ndi a tendelwa u humela murahu nda si tsha dzhenelela kha ngudo idzi
- Ndo newa tshikhala tshinzhi tsha u vhudzisa mbudziso dziṅwe na dziṅwe nga lutamo lwanga ndo tenda uri ndo ḍi imisela u dzhenelela kha ngudo idzi
- Ndi a pfesesa uri mawanwa oṱhe maswa ane a do wanala kha ṱhoḍisiso idzi zwi tshi kwamana na u dzhenelela hanga zwi do itwa uri ndi kone u zwi wana.

Madzina nga vhubalo a mudzheneleli

Duvha

Tshifhinga

Signature

Nne, ...

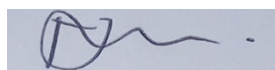
(MALULEKE TINYIKO MILLICENT) ndi a khwaṭhisedza uri mudzheneleli are afho nṭha o vhubzwa nga vhubalo nga ha vhubhi, kufarelwe na khombo dzi re kha ngudo idzi

Madzina nga vhubalo a muṭodisisi

MALULEKE TINYIKO MILLICENT

Date: 2024/07/03

Signature:



Madzina nga vhubalo a ṭhanzi (If applicable)

BALOYI DUMISANI JUSTICE

Date: 2024/07/03

Signature.....

Madzina ngavhubalo a muundi (If applicable)

.....

Date.....

Signature.....

APPENDIX F: Assent form

LETTER OF INFORMATION

Title of the Research Study : The Impact of Computer Simulations on Grade 11 Learners' Conceptual Understanding of Photosynthesis

Principal Investigator/s/ researcher : Maluleke Tinyiko Millicent, Bachelor of Science Honours in Life Sciences Education

Co-Investigator/s/supervisor/s : Dr Kaheru S.J.M, PhD
Dr Muthambi S.K PhD

Brief Introduction and Purpose of the Study:

Outline of the Procedures : This study is going to use a quantitative research design and the type of quantitative research design is quasi-experimental. There will be experimental and comparison groups which will be tested on the use of simulations as compared to the traditional teaching methods. Data will be collected using the pre-post tests and questionnaires. Purposive sampling is going to be used in this study and the four schools from the two circuits will form the population of the study and this is where the sample will be drawn from.

The research methodology to be used is quantitative. Two schools are going to be used as experimental and the other two schools as the control. All the four groups will be given a pre-test. Thereafter two schools are going to be exposed to Computer Simulations and the other two schools will be taught using traditional methods. After that, all four schools will be given a post-test. All the results will be recorded and analysed using quantitative data analysis. All learners will be given a questionnaire before and after the treatment to reflect on their feelings about the two types of teaching methods used. All ethical considerations will be observed and participants will be fully informed about their rights, their information will only be used for this study and they will remain anonymous to protect their identity.

Risks or Discomforts to the Participant: No foreseeable risks

Benefits : This study will be conducted in rural areas because of the challenges learners face in Life Sciences. Some of the challenges are limited access to quality education, resources and technology which can prevent them from producing good learning outcomes. The implementation of CS in rural areas can help address these challenges and provide quality education to learners. By conducting CS in rural areas, this study aims to gain an understanding of different challenges and opportunities that exist in these contexts, developing tailored interventions to improve educational outcomes. The findings of this study will help the Department of Education to come up with strategies on how to integrate technology into education to help learners from rural schools

Reason/s why the Participant May Be Withdrawn from the Study: participants will be allowed to withdraw from the study anytime should they wish not to participate for any reason. There will be no consequences for the participant should they choose to withdraw.

Remuneration : No remuneration will be received by participants

Costs of the Study : None

Confidentiality : To maintain confidentiality, all the data provided cannot be linked to any participant by name. The signed assent and consent from parents will be kept in a safe and locked place.

Research-related Injury : The research has no risks at all, there will not be compensation if anyone gets injured.

Persons to Contact in the Event of Any Problems or Queries:

(Dr Kaheru S.J.M,) Please contact the researcher (0720634892.), my supervisor (0727092626). University Research Ethics Committee Secretariat on 015 962 9058 / Vanecia.Khoza@univen.ac.za

Complaints can be reported to the University Research Ethics Committee Secretariat on 015 962 9058 / Vanecia.Khoza@univen.ac.za or Whistleblowing Ethics Hotline Tollfree Telephone number: 0800212755 Email.univenhotline@tipoffs.com

ASSENT FORM FOR PARTICIPANT

General:

Potential participants must be assured that participation is voluntary and the approximate number of participants to be included should be disclosed. A copy of the information letter should be issued to participants. The information letter and consent form must be translated and provided in the primary spoken language of the research population

ASSENT

Statement of Agreement to Participate in the Research Study:

- I hereby confirm that I have been informed by the researcher, (**MALULEKE TINYIKO MILLICENT**), about the nature, conduct, benefits and risks of this study - Research Ethics Clearance Number: FHSSE/24/CSEM/05/0107 __,
- I have also received, read and understood the above written information (Participant Letter of Information) regarding the study.
- I am aware that the results of the study, including personal details regarding my sex, age, date of birth, initials and diagnosis will be anonymously processed into a study report.
- In view of the requirements of research, I agree that the data collected during this study can be processed in a computerized system by the researcher.
- I may, at any stage, without prejudice, withdraw my consent and participation in the study.
- I have had sufficient opportunity to ask questions and (of my own free will) declare myself prepared to participate in the study.
- I understand that significant new findings developed during the course of this research which may relate to my participation will be made available to me.

Full Name of Participant Date Time Signature

I, ...

(**MALULEKE TINYIKO MILLICENT**) Herewith confirm that the above participant has been fully

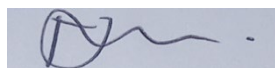
Informed about the nature, conduct and risks of the above study.

Full Name of Researcher

MALULEKE TINYIKO MILLICENT

Date: **2024/07/03**

Signature:



Full Name of Witness (If applicable)

BALOYI DUMISANI JUSTICE

Date: 2024/07/03

Signature.....

Full Name of Legal Guardian (If applicable)

.....

Date.....

Signature.....

APPENDIX G: University of Venda Ethical clearance certificate

ETHICS APPROVAL FORM (R&I)

RESEARCH AND INNOVATION
OFFICE OF THE DIRECTOR

NAME OF RESEARCHER/INVESTIGATOR:

Ms TM Maluleke

STUDENT NO:

11617587

PROJECT TITLE: Using simulations to improve conceptual understanding of grade 11 learners in Photosynthesis.

ETHICAL CLEARANCE NO: FHSSE/24/CSEM/05/0107

SUPERVISORS/ CO-RESEARCHERS/ CO-INVESTIGATORS

NAME	INSTITUTION & DEPARTMENT	ROLE
Dr SJM Kaheru	UNIVEN, Professional and curriculum studies	Supervisor
Dr SK Mufhambi	UNIVEN, Professional and curriculum studies	Co-Supervisors
Ms TM Maluleke	UNIVEN, Professional and curriculum studies	Investigator – Student

Type: Masters Research

Risk: *Straightforward research without ethical problems (Category 1)*

Approval Period: July 2024 – July 2025

The Research Ethics Social Sciences Committee (RESSC) hereby approves your project as indicated above.

General Conditions

While this ethics approval is subject to all declarations, undertakings and agreements incorporated and signed in the application form, please note the following:

- The project leader (principal investigator) must report in the prescribed form at to the REC:
 - Annually (or as otherwise requested), on the progress of the project, and upon completion of the project.
 - Within 48hrs in case of any adverse event (or any sudden final interrupts count ethical principles) during the course of the project.
 - Annually a number of projects may be randomly selected for an external audit.
- The approval expires annually in the protocol as stipulated in the application form. Would any changes to the protocol be deemed necessary during the course of the project, the project leader must apply for approval of these changes at the REC. Would there be deviation from the project protocol without the necessary approval of such changes, the ethics approval is immediately and automatically declared.
- The date of approval indicates the first date that the project may be started. Would the project have to continue after the expiry date; a new application must be made to the REC and new approval must be received before or on the expiry date.
- In the interest of ethical responsibility, the REC retains the right to:
 - Request access to any information or data at any time during the course or after completion of the project;
 - To ask further questions; Seek additional information; Requires further modification or monitor the conduct of your research or the informed consent process;
 - Withdraw or postpone approval if:
 - Any unethical principles or practices of the project are revealed or suspected;
 - It becomes apparent that any relevant information was withheld from the REC or that information has been false or misrepresented;
 - The required annual report and reporting of adverse events was not done timely and accurately;
 - New institutional rules, national legislation or international conventions. If necessary

ISSUED BY:

UNIVERSITY OF VENDA, RESEARCH ETHICS COMMITTEE

Date Considered: June 2024

Name of the RESSC Chairperson of the Committee: Prof M. Mole Marone

Signature: 



UNIVERSITY OF VENDA
RESEARCH AND INNOVATION
RESEARCH ETHICS COMMITTEE
15-16-17-18-19-20-21-22-23-24-25-26-27-28-29-30-31-32-33-34-35-36-37-38-39-40-41-42-43-44-45-46-47-48-49-50-51-52-53-54-55-56-57-58-59-60-61-62-63-64-65-66-67-68-69-70-71-72-73-74-75-76-77-78-79-80-81-82-83-84-85-86-87-88-89-90-91-92-93-94-95-96-97-98-99-100-101-102-103-104-105-106-107-108-109-110-111-112-113-114-115-116-117-118-119-120-121-122-123-124-125-126-127-128-129-130-131-132-133-134-135-136-137-138-139-140-141-142-143-144-145-146-147-148-149-150-151-152-153-154-155-156-157-158-159-160-161-162-163-164-165-166-167-168-169-170-171-172-173-174-175-176-177-178-179-180-181-182-183-184-185-186-187-188-189-190-191-192-193-194-195-196-197-198-199-200-201-202-203-204-205-206-207-208-209-210-211-212-213-214-215-216-217-218-219-220-221-222-223-224-225-226-227-228-229-230-231-232-233-234-235-236-237-238-239-240-241-242-243-244-245-246-247-248-249-250-251-252-253-254-255-256-257-258-259-260-261-262-263-264-265-266-267-268-269-270-271-272-273-274-275-276-277-278-279-280-281-282-283-284-285-286-287-288-289-290-291-292-293-294-295-296-297-298-299-300-301-302-303-304-305-306-307-308-309-310-311-312-313-314-315-316-317-318-319-320-321-322-323-324-325-326-327-328-329-330-331-332-333-334-335-336-337-338-339-340-341-342-343-344-345-346-347-348-349-350-351-352-353-354-355-356-357-358-359-360-361-362-363-364-365-366-367-368-369-370-371-372-373-374-375-376-377-378-379-380-381-382-383-384-385-386-387-388-389-390-391-392-393-394-395-396-397-398-399-400-401-402-403-404-405-406-407-408-409-410-411-412-413-414-415-416-417-418-419-420-421-422-423-424-425-426-427-428-429-430-431-432-433-434-435-436-437-438-439-440-441-442-443-444-445-446-447-448-449-450-451-452-453-454-455-456-457-458-459-460-461-462-463-464-465-466-467-468-469-470-471-472-473-474-475-476-477-478-479-480-481-482-483-484-485-486-487-488-489-490-491-492-493-494-495-496-497-498-499-500-501-502-503-504-505-506-507-508-509-510-511-512-513-514-515-516-517-518-519-520-521-522-523-524-525-526-527-528-529-530-531-532-533-534-535-536-537-538-539-540-541-542-543-544-545-546-547-548-549-550-551-552-553-554-555-556-557-558-559-560-561-562-563-564-565-566-567-568-569-570-571-572-573-574-575-576-577-578-579-580-581-582-583-584-585-586-587-588-589-590-591-592-593-594-595-596-597-598-599-600-601-602-603-604-605-606-607-608-609-610-611-612-613-614-615-616-617-618-619-620-621-622-623-624-625-626-627-628-629-630-631-632-633-634-635-636-637-638-639-640-641-642-643-644-645-646-647-648-649-650-651-652-653-654-655-656-657-658-659-660-661-662-663-664-665-666-667-668-669-670-671-672-673-674-675-676-677-678-679-680-681-682-683-684-685-686-687-688-689-690-691-692-693-694-695-696-697-698-699-700-701-702-703-704-705-706-707-708-709-710-711-712-713-714-715-716-717-718-719-720-721-722-723-724-725-726-727-728-729-730-731-732-733-734-735-736-737-738-739-740-741-742-743-744-745-746-747-748-749-750-751-752-753-754-755-756-757-758-759-760-761-762-763-764-765-766-767-768-769-770-771-772-773-774-775-776-777-778-779-780-781-782-783-784-785-786-787-788-789-790-791-792-793-794-795-796-797-798-799-800-801-802-803-804-805-806-807-808-809-810-811-812-813-814-815-816-817-818-819-820-821-822-823-824-825-826-827-828-829-830-831-832-833-834-835-836-837-838-839-840-841-842-843-844-845-846-847-848-849-850-851-852-853-854-855-856-857-858-859-860-861-862-863-864-865-866-867-868-869-870-871-872-873-874-875-876-877-878-879-880-881-882-883-884-885-886-887-888-889-890-891-892-893-894-895-896-897-898-899-900-901-902-903-904-905-906-907-908-909-910-911-912-913-914-915-916-917-918-919-920-921-922-923-924-925-926-927-928-929-930-931-932-933-934-935-936-937-938-939-940-941-942-943-944-945-946-947-948-949-950-951-952-953-954-955-956-957-958-959-960-961-962-963-964-965-966-967-968-969-970-971-972-973-974-975-976-977-978-979-980-981-982-983-984-985-986-987-988-989-990-991-992-993-994-995-996-997-998-999-1000

APPENDIX H: Province ethical clearance

CONFIDENTIAL



OFFICE OF THE PREMIER

Office of the Premier

Research and Development Directorate

Private Bag X9483, Polokwane, 0700, South Africa

Tel: (015) 230 9910, Email: mokobij@premier.limpopo.gov.za

LIMPOPO PROVINCIAL RESEARCH ETHICS

COMMITTEE CLEARANCE CERTIFICATE

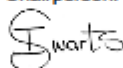
REVIEW DATE: 18 SEPTEMBER 2024

PROJECT NUMBER: LPREC/107/2024: PG

**SUBJECT: USING COMPUTER SIMULATIONS TO IMPROVE CONCEPTUAL
UNDERSTANDING OF GRADE 11 LEARNERS IN PHOTOSYNTHESIS.**

RESEARCHER: MALULEKE TM

Chairperson: Prof I Swarts



Chairperson: Limpopo Provincial Research Ethics Committee

The Limpopo Provincial Research Ethics Committee (LPREC) is registered with National Health Research Council (NHREC) Registration Number REC-111513-038.

Note:

- i. This study is categorized as a Low Risk Level in accordance with risk level descriptors as enshrined in LPREC Standard Operating Procedures (SOPs)
- ii. Should there be any amendment to the approved research proposal; the researcher(s) must re-submit the proposal to the ethics committee for review prior data collection.
- iii. The researcher(s) must provide annual reporting to the committee as well as the relevant department and also provide the department with the final report/thesis.
- iv. The researchers will be required to make presentations of the study findings and recommendations at the Provincial Research Conference/Departmental Research Day.
- v. The ethical clearance certificate is valid for 12 months. Should the need to extend the period for data collection arise then the researcher should renew the certificate through LPREC secretariat. PLEASE QUOTE THE PROJECT NUMBER IN ALL ENQUIRIES.



LIMPOPO
PROVINCIAL GOVERNMENT
REPUBLIC OF SOUTH AFRICA

OFFICE OF THE PREMIER

TO: MS MABOGO MG

FROM: PROF I SWARTS

CHAIRPERSON: LIMPOPO PROVINCIAL RESEARCH ETHICS COMMITTEE (LPREC)

REVIEW DATE: 18 SEPTEMBER 2024

**SUBJECT: USING COMPUTER SIMULATIONS TO IMPROVE CONCEPTUAL
UNDERSTANDING OF GRADE 11 LEARNERS IN PHOTOSYNTHESIS.**

RESEARCHER: MALULEKE TM

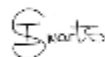
Dear Colleague

The above researcher's research proposal served at the Limpopo Provincial Research Ethics Committee (LPREC). The committee is satisfied with the methodological and ethical soundness of the proposed study.

Decision: The proposal is granted full approval

Regards

Chairperson: Prof I Swarts



Secretariat: Ms J Mokobi



Date: 13/11/2024



receipt_Maluleke-CO
MPUTER SIMULATION

APPENDIX I : Editor's certificate

Editing and Proofreading Report

February 2025

This letter serves to confirm that I, Trenance Khoza, have edited and proofread the Dissertation titled: **Using Computer Simulations to Improve Conceptual Understanding of Grade 11 Learners in Photosynthesis**, by **Maluleke Tinyiko Millicent**, Student Number: 11617587.

I carefully read through the proposal, focusing on proofreading and editorial issues. The recommended suggestions are clearly highlighted in red ink and can either be accepted or rejected using the Microsoft Word track changes system.

Yours sincerely



Trenance Khoza (PhD Eng)

+263 772389974 / 263 774779968

E-mail: ndlovutrenance2012@gmail.com or khozat@staff.msu.ac.zw



Maluleke-COMPUTER SI...



Match Overview



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