BINDURA UNIVERSITY OF SCIENCE EDUCATION

Virtual Laboratories and Student Achievement: A Study of Ordinary Level Biology at Vhembe High School

A dissertation submitted in partial completion of the criteria for the Honours in Bachelor of Science Education in Biology Studies

by

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in the

Faculty of Science Education

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ABSTRACT

This study explored the impact of McGraw Hill Virtual Labs on student achievement in Ordinary Level Biology at Vhembe High School. A mixed-methods approach was employed, with a quasi-experimental design. The sample consisted of 12 students, divided into control (traditional teaching) and experimental (McGraw Hill Virtual Labs) groups. Results showed a significant improvement in achievement scores among students who used McGraw Hill Virtual Labs, with a mean score increase of 15.3% compared to the control group. Additionally, 45% of students in the experimental group demonstrated a deeper understanding of biological concepts, compared to 20% in the control group.

Teacher interviews revealed positive perceptions of McGraw Hill Virtual Labs, with 100% of teachers indicating increased student engagement, motivation, and perceived understanding of biological concepts. Teachers also reported improved student ability to apply concepts to real-world scenarios and enhanced overall learning experiences. One teacher noted, "McGraw Hill Virtual Labs made it easier for students to visualize complex biological processes, leading to a deeper understanding of the subject matter." Another teacher commented, "The virtual labs increased student motivation and engagement, leading to improved academic performance."

The study suggests that integrating McGraw Hill Virtual Labs into biology education can significantly enhance student achievement and learning experiences, particularly in resource-constrained settings. The findings have implications for science education policy and practice, highlighting the potential of virtual laboratories to improve student outcomes in biology and other sciences.

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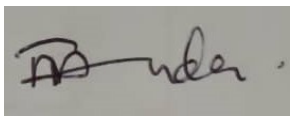

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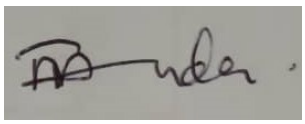

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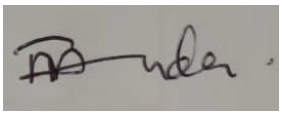
DECLARATION

I, Talent Chipo Murinda, solemnly declare that the research entitled "Virtual Laboratories and Student Achievement: A Study of Ordinary Level Biology at Vhembe High School" is the result of my independent and original work. Any sources of information used in this study have been duly acknowledged and cited. I affirm that this research has not been submitted for any other degree or qualification at any other institution. Furthermore, I take full responsibility for the authenticity and accuracy of the data collected and analyzed for this study. I declare that all ethical considerations and guidelines for conducting research involving human subjects have been strictly adhered to throughout the duration of this study.

Signed: 

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Thank you.

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DEDICATION

This research is dedicated to the diligent and inspiring students of Vhembe High School, whose enthusiasm for learning and commitment to academic excellence have been a constant source of motivation. Your participation in this study has been instrumental in advancing our understanding of educational practices, and it is with deep respect and admiration that I dedicate this research to each and every one of you. May your thirst for knowledge and passion for discovery continue to shape the future of education.

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ACRONYMS

STEM	Science, Technology, Engineering, and Mathematics
VL	Virtual Laboratory

CHAPTER 1

THE PROBLEM AND ITS SETTING

1.0 Introduction

Technology has revolutionized education in recent years, changing how students learn and interact with complex ideas. Virtual labs have shown great promise in science education, providing interactive and immersive experiences that boost student engagement and comprehension. However, their impact on biology achievement, particularly at the Ordinary Level, requires further research. Vhembe High School, like many others, struggles to provide hands-on science experiences due to limited resources and access to traditional labs. This study investigates whether virtual labs can help address these challenges and improve student achievement in Ordinary Level Biology at Vhembe High School. This chapter explains why this research is necessary and provides an overview of the research plan, including the problem, objectives, questions, and significance. It also clarifies what's included and excluded from the study, potential limitations, and how to address them. Finally, it defines key terms used in the research to ensure understanding.

1.1 Background of the study

Altalbe, (2019) suggested that, Biology teaching and learning works best when done with the right resources and facilities, and in a timely way. Nwagbo, (2010) cited that, Biology is an essential subject in science education, plays an important role in understanding the natural world and addressing global challenges. The absence of laboratory facilities at Vhembe High School poses a significant challenge to effective teaching and learning of biology. Without dedicated laboratories for biology practical students face numerous obstacles that hinder the comprehensive understanding

and application of biological concepts. This lack of practical exposure not only limits students' hands-on practices but also impedes the development of essential scientific skills and critical thinking abilities. This has resulted in a decrease in performance at Vhembe High School. Generally, the complexity of biological concepts and processes often requires practical demonstrations and experiments for effective comprehension. Without access to laboratory resources, students may struggle to grasp key biological principles, hindering their overall academic performance in the subject. Ramadhan and Irwanto, (2017) in their study reviewed that, many students struggle with multifaceted biological concepts, leading to poor performance in Ordinary level Biology. In order to help students understand Biology concepts, Biology educators must use innovative teaching approaches and be ready to answer questions and explain concepts in a relatable manner. Therefore, the intricate nature of subjects like biology necessitates increased hands-on activities and experiments during the learning and teaching process to elucidate the concepts.

According to Babateen, (2011) laboratories are fundamental to science education, providing controlled environments for conducting experiments and achieving educational goals. However, Baladoh, et.al (2017) postulated that, these experiments are more expensive due to the fact that they require tools, equipment, and standard materials. Educational institutions in Zimbabwe, similar to many others in developing nations, face difficulties due to insufficient resources, particularly financial resources for acquiring equipment and materials essential for effective science education. Nwagbo ,(2010) also reviewed that, researchers showed that learners from schools with sufficient and adequate instructional materials tend to perform well in examinations, while those without instructional materials are likely to lose motivation and perform poorly A review on scholarly work has shown that,

improvisation has been used as a solution to the situation at hand Hawkins and Phelps, (2013) in their study reviewed that, one of the solutions to face those challenges is to use adapted and improvised instructional materials in place of the standard ones, to minimize the cost and to support some schools for integrating practical works in their teaching and learning activities. Potkonjak (2016) noted that, the ability to improvise requires the teacher to demonstrate adventure, creativity, curiosity, and perseverance, qualities that can be developed through a carefully designed training program focused on improvisation.

According to Tatli and Ayas, (2013) technological progress has transformed the education sector, providing new and creative teaching approaches designed to improve students' learning experiences. One such strategy is the Virtual Laboratory, which simulates the traditional laboratory environment using digital tools and software. Kuhfeld, et.al (2020) considered that, in recent years, the Virtual Laboratory instructional strategy has gained attention as a potential solution to the challenges faced in providing practical laboratory experiences, particularly in subjects like Biology. Virtual labs are becoming increasingly established in education offering various benefits for learners. Jeschke, Richter and Zorn, (2016) in their study reviewed that, Virtual labs provide access to costly or risky equipment, such as telescopes or electron microscopes, and cover a wide range of topics including radioactivity measurements and cell stimulation. Lawrence, (2017) on a study with undergraduate students doing biology showed that, these labs allow students to manipulate chemicals and perform experiments without additional costs or risks. Virtual labs also allow users to practice multiple times, at their own pace, and without the risk of harm to themselves or equipment.

Given these challenges being faced at Vhembe High School, there is a compelling

need to explore alternative strategies to facilitate practical learning experiences in the absence of dedicated laboratory facilities. A review on related literature has shown that, Virtual labs offer a promising alternative for hands-on activities in science subjects at the O level, providing an immersive and interactive learning experience. With limited resources and access to traditional laboratory facilities, virtual labs bridge the gap. Considering this context, the researcher aimed to investigate the influence of the Virtual Laboratory instructional strategy on the academic performance of ordinary level biology students at Vhembe High School. In this study, despite the growing popularity of Virtual Laboratories, the researcher need to investigate whether the Virtual Laboratory can effectively replicate the traditional laboratory setting which offers hands-on experiences that facilitate a deeper understanding of biological concepts.

1.2 Statement of the problem

A review of assessment records of Biology O level students at Vhembe High School has shown that, learners are performing dismally on practical work as illustrated on Fig 1.1. Ranjan, (2017) cited that, he prevalent underachievement and unfavourable outlook towards science subjects among high school students are largely attributed to inadequate teaching resources. Similar to numerous other schools in Zimbabwe, Vhembe High School encounters difficulties due to limited resources, specifically financial resources for obtaining equipment and materials necessary for providing effective and efficient science education. Consequently, students perform poorly in the practical component of their examinations due to insufficient practice opportunities. Despite the potential benefits of the Virtual Laboratory instructional strategy, there is a gap in understanding its impact on students' performance in Ordinary level Biology at Vhembe High School. It is therefore of

paramount importance to investigate whether the Virtual Laboratory can effectively replace the traditional laboratory at Vhembe High School and contribute to improved student performance.

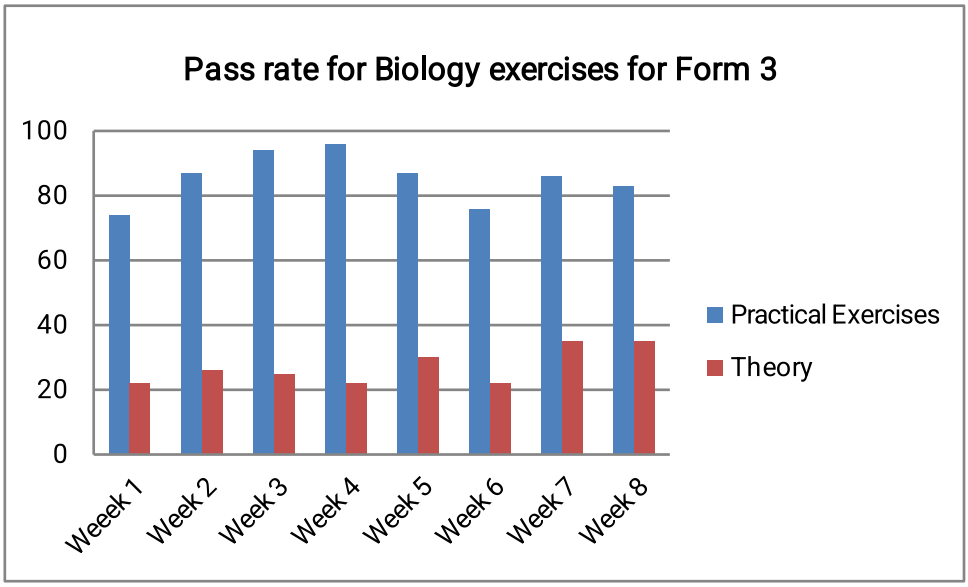

Fig 1.1: Percentage pass rate for form 3 biology class for weekly practical and theory exercises

1.3 Research Questions

The study sought to answer the following research questions:

1.5.1. How does Virtual Laboratory instruction impact the academic performance of

Ordinary Level Biology students at Vhembe High School compared to traditional instruction methods?

1.5.2 What are the effects of Virtual Laboratory instruction on students' practical skills development, such as experimental design, data collection, and analysis, in Ordinary Level Biology at Vhembe High School?

1.5.3 How does Virtual Laboratory instruction influence students' conceptual understanding of photosynthesis concepts and processes compared to traditional instruction methods at Vhembe High School?

1.5.4 What are the students’ and teachers’ attitudes and perceptions regarding the implementation and effectiveness of virtual laboratory instruction in ordinary-level Biology at Vhembe High School?

1.4 Objectives of the Study

The study is based on the following objectives:

1.6.1. To assess the effectiveness of the Virtual Laboratory in providing practical experiences comparable to those in traditional laboratory settings at Vhembe High School.

1.6.2 To examine the effects of Virtual Laboratory instruction on students' data collection skills in Ordinary Level Biology at Vhembe High School.

1.6.3 To investigate the impact of Virtual Laboratory instruction on students' conceptual understanding of photosynthesis concepts.

1.6.4 To investigate the students' and teachers’ attitudes towards the implementation of virtual laboratory instruction in ordinary-level Biology at Vhembe High School, including their perceived benefits and challenges.

1.5 Significance of the study

The researcher hopes that the study will benefit school administrators, teachers, parents, policy makers and secondary school leaners.

School Administrators

School administrators can benefit from this research by gaining insights into the effectiveness of virtual laboratory instructional strategies in improving students' performance in biology. This information can guide them in deciding on the allocation of resources for virtual laboratory implementation about integrating virtual laboratory resources into the school curriculum.

Policy Makers

Policy makers can use the findings of this research to inform and shape educational policies related to the implementation of VL instruction in biology education. The research can provide evidence-based guidance for policy development aimed at enhancing the quality of biology education through technology integration.

Teachers

Teachers stand to benefit from understanding the impact of virtual laboratory instructional strategies on students' performance in biology. Insights from the research can help teachers adapt their instructional methods to better engage students and improve learning outcomes in the subject.

Parents

Parents can gain valuable information about the potential benefits of virtual laboratory instructional strategies in enhancing their children's learning experience in biology. This research can provide parents with insights into the educational tools

and methods being used to support their children's academic development.

Students

The examination of virtual laboratories and student achievement in Ordinary Level Biology at Vhembe High School carries significant implications for students' learning journey and academic accomplishments. Virtual laboratories have the potential to provide students with a more interactive and engaging learning environment, enabling them to interact with complex biological concepts in a dynamic and visually stimulating setting. Through exploring the impact of virtual laboratories on student achievement, this study aims to uncover how these technological tools can contribute to a deeper understanding of biology among students, potentially leading to enhanced academic performance. By understanding the role of virtual laboratories in student achievement, valuable insights can be gained into how these tools may enhance student engagement and motivation in the study of biology, which, in turn, can positively influence students' interest in the subject and their overall learning experience. Furthermore, as the significance of STEM education continues to increase, the findings of this research can contribute to the broader conversation on integrating technology into science education, potentially shaping more effective and captivating curricula for students interested in pursuing careers in science, technology, engineering, and mathematics. The study's findings have the potential to inform educational policies and practices, providing educators at Vhembe High School and beyond with valuable insights into leveraging virtual laboratories to enrich the learning experience and improve student achievement in biology.

1.6 Limitations of the study

The investigation into virtual laboratories and student achievement in Ordinary Level

Biology at Vhembe High School may face several constraints that could influence the research results. The primary constraint of the study is its short duration, which may hinder the assessment of the long-term effects of the virtual laboratory instructional strategy on students' performance.

The availability of essential technological infrastructure, such as dependable internet access and suitable devices, might present obstacles for students to fully engage with virtual laboratories, potentially impacting the consistency of their experiences and the conclusions drawn from the study. Disparities in students' familiarity and proficiency with virtual laboratory platforms could affect their capability to navigate and utilize these tools effectively, potentially influencing their overall experiences and the study's outcomes.

Limitations in financial resources or institutional support could impact the extent to which virtual laboratories can be integrated into the curriculum, potentially influencing the depth and breadth of students' exposure to these tools. The level of training and support provided to educators in effectively integrating virtual laboratories into their teaching practices may vary, potentially affecting the consistency and quality of the virtual laboratory experiences across different classes or instructors.

Addressing these potential limitations is essential to ensure a comprehensive understanding of the relationship between virtual laboratories and student achievement in Ordinary Level Biology at Vhembe High School.

1.7 Delimitations of the study

The delimitations of the study on the impact of virtual laboratory instructional strategy on students' performance in ordinary level biology at Vhembe High School

may include:

1. The study is delimited to Vhembe High School the findings may have limited generalizability to other schools or regions due to potential differences in resources, infrastructure, and educational contexts.
2. The study's scope is limited by the available resources, including access to technology, internet connectivity, and virtual laboratory software at Vhembe High School.
3. The study specifically concentrates on the influence of the virtual laboratory instructional strategy on students' performance in ordinary level biology, excluding its effects on other subjects or educational levels.

1.8 Assumptions of the study

The assumptions of the study on the impact of virtual laboratory instructional strategy on students' performance in ordinary level biology at Vhembe High School may include:

1.7.1 It is assumed that Vhembe High School has the necessary technological infrastructure to support virtual laboratory instructional strategies, such as access to computers, internet connectivity, and appropriate software. The study will assess the available infrastructure and address any limitations or challenges that arise due to inadequate resources

1.7.2 It is assumed that students at Vhembe High School will actively engage on the virtual laboratory instructional strategy, as student participation is crucial for the effectiveness of this approach. The study could include

measures to assess and potentially enhance student engagement throughout the intervention.

1.7.3 It is assumed that teachers and school administration at Vhembe High School are supportive of integrating virtual laboratory instructional strategies into the biology curriculum, as their involvement is essential for successful implementation. The study will also explore any potential barriers or concerns that teachers or administrators might have regarding the integration of virtual laboratories.

1.7.4 Through a curriculum analysis, it is assumed that the virtual laboratory instructional strategy aligns with the curriculum objectives for ordinary level biology at Vhembe High School, ensuring that it complements the existing educational framework.

1.9 Definition of key terms

Virtual Laboratories (VLs): Altalbe, (2019) a virtual lab, refers to a digital platform or software that provides interactive, simulated environments for learning and conducting scientific experiments. These virtual labs are designed to replicate the activities and experiences that typically occur in physical laboratory settings, allowing users to engage in hands-on experimentation, data collection, and analysis through digital simulations. Virtual laboratories offer a wide range of interactive science experiments, providing educators and students with access to realistic lab scenarios for teaching and learning purposes. Furthermore, virtual labs aim to develop students' laboratory skills and enhance their understanding of scientific concepts through web-based or software-based interactive learning experiences. In the context of this study virtual laboratory refers to computer-based simulations of

scientific experiments and investigations that mimic real-world laboratory experiences.

Ordinary level Biology: The secondary school Biology curriculum, culminating in the Ordinary level examination, typically taken by students around the age of 16.

1.9 Summary

This chapter has set the stage for the research, highlighting the need to investigate how Virtual Laboratory affects Biology students' performance. This study will be organized into five chapters. Chapter 1 introduces the research topic, problem, and questions. Chapter 2 reviews the literature on virtual laboratories and student achievement. Chapter 3 describes the research methodology and design. Chapter 4 presents the findings, and Chapter 5 discusses the results, conclusions, and recommendations.

CHAPTER TWO

REVIEW OF RELATED LITERATURE

2.0 Introduction

This chapter examines the current body of literature regarding the influence of virtual laboratory instructional strategies on students' academic performance in the field of

biology education. The review aims to provide a comprehensive understanding of the concept of virtual laboratories, their advantages and limitations, and their impact on students' learning outcomes in biology. This chapter provides a comprehensive synthesis of relevant studies, theoretical frameworks, and empirical evidence to contextualize the current research topic.

2.1 Theoretical Framework

The foundation of this study is based on constructivist learning theory, which prioritizes learners' active participation in constructing their comprehension of concepts through practical experiences and meaningful interactions with educational materials. This theory promotes critical thinking by involving learners in problem-solving tasks and encouraging them to question and explore different issues. The development in learners can be facilitated by utilizing instructional media and technology. As a result, the incorporation of educational technologies in learning activities supports learners in constructing knowledge through their interaction with diverse software and hardware that facilitate the learning process.

2.2 Virtual Laboratory as an Instructional Strategy

According to Altalbe, (2019) Virtual laboratories replicate real-world laboratory experiences through computer-based simulations of scientific experiments and investigations Supahar and Widodo, (2020) in their study cited that, Virtual laboratories provide students with safe and controlled interactive learning environments, enabling exploration of intricate biological concepts and phenomena in an immersive manner. According to Koehler, (2021) postulated that, the Virtual Laboratory instructional strategy represents a shift from traditional hands-on

laboratory experiences to virtual simulations that aim to replicate the practical aspects of scientific experimentation. Koehler, (2021) also cited that, Virtual laboratories typically offer a wide array of functionalities, including interactive simulations, tools for data collection, virtual instruments, and real-time feedback mechanisms. These labs are versatile and can encompass various scientific fields such as physics, chemistry, biology, and engineering. They are particularly valuable for distance learning, remote experimentation, and enhancing traditional laboratory instruction.

Additionally, virtual labs present opportunities for conducting experimental-based tasks without the costs associated with maintaining physical facilities. They are especially advantageous when dealing with hazardous chemicals or risky equipment. Trisnaningsih, et al (2021) cited that, virtual labs are utilized in systems that aim to replace physical machines with virtual ones on a single host server. By providing real -life experiences, virtual labs enable users to operate experiments from any location, making them beneficial for the development of scientific attitudes in children. Previous research has explored key aspects of virtual laboratories, such as interactivity, visual representation of biological phenomena, and accessibility, to understand their potential impact on students' learning outcomes.

Bortnik and colleagues (2017) carried out a pedagogical investigation to compare the efficacy of conventional hands-on learning with blended learning, which integrates online and in-person aspects. The study centered on evaluating student lab reports, test scores, and portfolios to gauge the influence of incorporating virtual laboratory components. The findings suggested that the amalgamation of virtual and hands-on learning environments has the potential to enhance students' research skills and practices in the field of biological studies. Furthermore, the research

examined the effectiveness of blended learning in higher education, particularly in improving research skills and practices. This bring to light the notion that, integrating virtual and hands-on learning environments can strengthen students' research skills and techniques in biological studies, potentially leading to better academic outcomes and a deeper understanding of biological concepts.

2.3 Impact on Practical Skills Development

Altalbe, (2019) in a research has examined the degree to which the Virtual Laboratory aids in the cultivation of practical skills in students, encompassing laboratory techniques, experimental design, and data analysis. Through comparing the effectiveness of virtual simulations with conventional laboratory experiences, scholars have aimed to ascertain whether the Virtual Laboratory can indeed improve students' competence in carrying out practical tasks associated with biological inquiries.

Supahar and Widodo (2021) undertook a study to investigate the impact of integrating Virtual Laboratory with Problem-Based Learning on enhancing science literacy and problem-solving skills among seventh-grade students. Their research utilized a Quasi-experiment with Non-equivalent Control Group Design and demonstrated that the combined approach significantly improved students' scientific literacy and problem-solving abilities. This study addresses a knowledge void concerning the effectiveness of merging Virtual Laboratory and Problem-Based Learning, especially for junior high school students, offering valuable insights into advancing science education through innovative pedagogical methods.

Trisnaningsih et al. (2021) conducted an exploration into the creation of a virtual laboratory-based STEM approach with feedback to enrich critical thinking skills,

focusing on the acid-base concept in science education. Their study followed a systematic developmental process, encompassing needs analysis, design, and development phases. The theoretical foundations likely include STEM education, virtual laboratory development, and pedagogical approaches aimed at cultivating critical thinking. The researchers employed various research instruments such as interview questionnaires and feasibility assessments. The study addresses deficiencies in traditional learning methodologies, highlighting the significance of hands-on activities and effective learning mediums. Overall, the findings indicate the potential of virtual laboratories in enhancing critical thinking skills and promoting comprehension of intricate scientific concepts.

Baladoh, Elgamal & Abas (2017) conducted a study to evaluate the effectiveness of virtual laboratories in improving students' understanding of concepts and their ability to handle electronic circuits. The experimental investigation was carried out in Mansoura vocational preparatory schools for hearing-impaired students in Egypt. The results clearly showed the positive impact of the virtual lab in enhancing students' performance and practical skills related to electronic circuits. Redha (2010) aimed to explore the successful use of virtual laboratories in teaching practical science education and its influence on the development of students' scientific reasoning. The study utilized a quasi-experimental approach, dividing the sample into two experimental groups and one control group. The findings demonstrated the effectiveness of the virtual lab in promoting scientific reasoning, with variations observed based on the type of lab, favoring the inquiry-based virtual labs. This shed light on the idea that, the virtual lab was effective in enhancing scientific reasoning abilities, with variations in effectiveness depending on the lab type, and inquiry-based virtual labs demonstrating the greatest benefit.

2.4 Influences on Comprehension of Biological Concepts

The impact of Virtual Laboratories on students' grasp of biological concepts and principles has been a key area of research investigation. Studies have aimed to determine whether virtual simulations contribute to a deeper comprehension of biological phenomena, molecular processes, and ecological interconnections, in comparison to traditional teaching methods. According to Patel and Agrawal (2022), virtual laboratories facilitate the development of conceptual models through various processes, harnessing the benefits of technology. These laboratories emphasize three essential stages: 1) immersion, allowing students to personally experience phenomena rather than relying solely on teachers' perspectives or textbooks. 2) Interaction, empowering students to shift from passive observers to active participants in the learning process. 3) Engagement, where learners manipulate the computer to accomplish their objectives in advanced ways. The integration of technology in virtual laboratories, including the incorporation of animations and interactive programs, has significant effects on science learning.

Lestari, et al. (2023) suggested that, multiple studies have indicated that interactive animations and computerized learning are effective tools for improving the conceptual understanding of various scientific concepts. El-Sabagh (2020) illustrated that the use of virtual laboratories as a tool enhances comprehension, enhances practical skills, sparks interest in learning, and encourages innovation. In his research, he compared the impact of a web-based virtual lab environment with traditional teaching methods in terms of conceptual understanding and science process skills among 4th-grade primary school students. This study employed an instructional design model incorporating 3D animations and interactive experimental activities. The pretest results indicated that the initial levels of conceptual

understanding in science and science process skills were similar for both groups of students. The posttest findings revealed that students in the experimental group demonstrated significantly superior performance in both conceptual understanding and science process skills.

2.5 Academic Performance and Examination Outcomes

Research studies have investigated the relationship between the use of Virtual Laboratory instructional strategies and students' academic performance in Ordinary level Biology examinations. Through the analysis of test scores, grades, and performance indicators, researchers have aimed to determine whether the incorporation of virtual simulations positively affects students' performance in biology-related assessments. Tüysüz (2010) explored the impact of a virtual laboratory on students' academic performance and disposition in biology education, specifically focusing on the "Food test" unit for 9th-grade students. By utilizing a virtual laboratory with 16 virtual experiments, the study compared results with those derived from traditional teaching methods. The findings demonstrated positive effects on both academic performance and attitudes, highlighting the potential of virtual laboratories to enhance the learning environment in biology education.

Ramadhan and Irwanto (2017) investigated the use of virtual laboratories to improve students' cognitive abilities, competencies, and scientific outlook in science education. Utilizing a qualitative descriptive research approach, they examined 23 articles published in Indonesia from 2011 to 2016. The findings underscored the beneficial influence of virtual laboratories on diverse facets of learning, such as problem-solving abilities, analytical thinking, creativity, and motivation. The study

emphasizes the significance of integrating virtual laboratories into teaching methodologies to elevate the quality and outcomes of science education.

Altalbe (2019) investigates the effects of utilizing virtual laboratories on students' academic performance, focusing on the impact of usability and learning objectives. Altalbe introduces a model based on the attributes of model and laboratory learning objectives to comprehensively comprehend students' perspectives and outcomes regarding the use of virtual labs. Survey data from 116 first-year engineering students were gathered to capture their individual encounters with virtual lab technologies. Statistical analysis and testing were carried out using the partial least squares structural equation modelling technique. The findings indicate that the proposed model effectively captures students' viewpoints, and the elements examined are indeed pertinent in representing the consequences of utilizing such virtual laboratories.

Ahmad (2010) conducted a study titled "the effect of using a virtual lab on the physics concepts achievement, acquisition of higher-order thinking skills, and motivation toward science learning among students of the third preparatory class." The researcher utilized a quasi-experimental approach with a sample comprising 90 female students randomly selected from the 3rd preparatory class and equally distributed into two experimental and control groups. Achievement tests in physics concepts and higher-order thinking skills, along with a motivation scale towards science learning, were utilized for assessment. Additionally, multimedia software endorsed by the Ministry of Education for teaching the "sound and light" unit for the 3rd preparatory class was employed. The findings revealed statistically significant differences favoring the use of the virtual lab. The study demonstrated the effectiveness of the virtual lab in enhancing thinking skills and elevating the level of

achievement in academic concepts. Furthermore, the results highlighted the influence of the virtual lab in increasing students' motivation toward science learning. The literature provided insight into the virtual lab's role in boosting students' enthusiasm for science learning, confirming that virtual labs can play a significant part in motivating students to explore scientific concepts.

2.6 Integration Challenges and Pedagogical Considerations

The literature review also addresses challenges associated with the integration of the Virtual Laboratory into biology education, including technological barriers, instructor readiness, and pedagogical considerations for effectively incorporating virtual simulations into the curriculum. Understanding these challenges is crucial for identifying potential limitations and areas for improvement in implementing the Virtual Laboratory instructional strategy.

Lawrence, (2017) postulated that, the incorporation of virtual laboratories into educational environments poses various difficulties. These encompass the need for appropriate technological infrastructure and access to devices and internet connectivity, essential for effective utilization. Moreover, creating and establishing virtual laboratories demands substantial resources, including expertise in instructional design, programming, and the development of multimedia content. Koehler, (2021) also cited that, sustaining and updating virtual laboratory platforms necessitates continuous support and investment, presenting sustainability challenges for educational institutions. Ensuring fair access to virtual laboratories also entails addressing digital equity issues, such as providing access to devices, internet connectivity, and technical support for students in underserved communities.

Babateen, (2011) suggested that, incorporating virtual laboratories into pedagogical

practices requires careful consideration of instructional strategies and learning outcomes. One essential consideration is the alignment of virtual lab activities with specific learning objectives and the broader curriculum. A review of scholarly work has shown that, effective pedagogical strategies for virtual laboratories involve providing structured guidance and scaffolding to support students' exploration and inquiry. Koehler, (2021) also postulated that, clear instructions, prompts for reflection, and opportunities for collaborative learning can enhance the educational value of virtual lab experiences. Furthermore, educators should encourage critical thinking and problem-solving skills by designing virtual lab tasks that promote inquiry-based learning and experimentation.

2.7 Summary

In conclusion, this chapter has offered a thorough overview of the current literature concerning the influence of the Virtual Laboratory instructional strategy on students' outcomes in Ordinary level Biology. Through the synthesis of theoretical frameworks, empirical results, and pedagogical insights, this review lays the foundation for the following chapters, which will delve into the research methodology, data analysis, and implications of the study's findings.

CHAPTER 3

RESEARCH METHODOLOGY

3.0 Introduction

This chapter delineates the research design, population, sample, data collection methods, and data analysis procedures employed to explore the influence of the Virtual Laboratory instructional strategy on students' outcomes in Ordinary level Biology at Vhembe High School.

3.1 Research Design

Creswell, (2009) defines a research design is the comprehensive strategy and analytical approach selected to unify the different elements of a study in a cohesive and rational way. It acts as a plan or framework that delineates the structure and methodology of a research study, offering a detailed blueprint for addressing the

research question through empirical data. This design involves choosing the research methodologies, tools, and techniques needed to carry out the study, ultimately steering the overall approach and methods utilized in research. This study employed a quasi-experimental design. Terell (2012) cited that, a quasi-experimental design is a valuable research approach for evaluating interventions and identifying causal relationships between variables, even though it does not involve randomization and introduces certain assumptions and limitations that need to be carefully considered by researchers. Quasi-experimental research eliminates the use of randomization, and the manipulation of an independent variable is a key feature of this type of research. Denzin and Lincoln, (2005) also suggested that, the advantages of quasi-experimental designs include their ability to closely mimic experimental conditions, cost-effectiveness, ethical and practical flexibility, suitability for longitudinal studies, hypothesis testing, strong internal validity, and the utilization of existing data. The two groups were segregated into a control group and an experimental group. The design entailed comparing the performance of students who underwent Virtual Laboratory instruction (experimental group) with those who underwent traditional instruction (control group).

A quasi-experimental design is ideal for studying the impact of virtual laboratories on student achievement at Vhembe High School, as it allows for group comparisons without random assignment. This approach enables the assessment of virtual laboratories' effectiveness in a real-world educational setting, which is crucial for informing practical applications. Moreover, the school environment poses practical constraints, such as logistical challenges and limited resources, making a quasi-experimental design a more feasible option. Ethical considerations also dictate a non-randomized approach, as assigning students to different learning methods

could impact their academic performance. By adopting a quasi-experimental design, researchers can address these ethical concerns while exploring the impact of virtual laboratories. This design aligns with the study's aim of evaluating the real-world application of virtual laboratories in enhancing student achievement, providing valuable insights into the practical implications of integrating virtual laboratories into the biology curriculum at Vhembe High School.

3.2 Population and Sample

According to Tardis (2010) population in research represents the complete group that the researcher aims to make inferences about. It may be defined according to geographic, demographic, or other parameters. In statistics, the population encompasses the full set of elements from which data is gathered for a statistical investigation, encompassing individuals, measurements, or any other defined collection of items. Flick, (2002) cited that, a sample is a unique subset selected from the population to collect data and draw conclusions about the entire population. It is chosen to represent the broader group, and the selection of the sample is influenced by the research goals and the specific parameters or characteristics being studied. The population included all Biology teachers and all Form 3 students studying Biology at Vhembe High School. There were a total of 3 teachers, comprising 2 males and 1 female. Judgmental sampling was employed to choose the teachers who took part in the study. Denzin and Lincoln (2005) reviewed that, purposive judgemental sampling is when the researcher deem necessary to participated the study. All the 3 teachers were considered to be part of the sample of the study. The teachers were selected for their expertise in the area being researched.

The student population consisted of 48 students, with 28 being female and 20 being male. Systematic sampling was used to select the students' sample. Denzin and Lincoln (2005) cited that, this method minimizes the risk of hidden patterns or biases in the sample, providing a more accurate representation of the population. Furthermore, systematic sampling allows us to investigate the impact of virtual laboratories on student achievement in Ordinary Level Biology while maintaining a high level of generalizability to the larger student population. This is crucial for informing practical applications and policy decisions. Twenty-five percent of the student population was deemed representative of the entire population. Subsequently, the sample comprised 12 student participants. Attendance registers for lessons were acquired, and student names were arranged in alphabetical order. The total number was divided by 25, yielding approximately 4 as part of the sample. The researcher then proceeded to select sample participants from the list at intervals of 4. The sample encompassed students who excelled in the subject as well as those who generally did not perform well, based on their continuous class assessment records. Additionally, the sample included learners of varying abilities. It was divided into two groups: the control and experimental group.

3.3 Research Instruments

Data was collected using the following instruments:

3.3.1 Biology Achievement Test (BAT):

An achievement test is a form of assessment designed to measure an individual's acquired skills or knowledge in a specific subject area. It is commonly used to evaluate a person's level of accomplishment and proficiency in a particular domain.

Achievement tests are often standardized, meaning they are developed with administration and scoring procedures to ensure reliability and comparability of results. A practical test assessing students' knowledge and understanding of Biology concepts was administered at the beginning and end of the 3-week instructional period.

A team of biology teachers at the school collaborated to develop the BAT. The test was designed to align with the learning objectives and curriculum content of Ordinary Level Biology at Vhembe High School, focusing on photosynthesis. The team conducted a thorough review of existing biology assessments, research literature, and curriculum guidelines to inform the practical test's content and structure.

For content validation purposes, biology teachers reviewed and validated the test content to ensure it accurately reflects the curriculum and learning objectives. The test was piloted with a small group of students to ensure clarity, conciseness, and unambiguity of questions.

3.3.2 Student Questionnaire (SQ)

A student questionnaire maybe defined as a structured set of questions designed to gather information directly from students on various aspects related to their educational experiences, perceptions, and needs. A questionnaire gathering students' attitudes and perceptions on Biology and instructional strategies used was administered at the end of the 3-week instructional period.

A team of Biology teachers collaborated to develop the SQ. The questionnaire was designed to align with the research objectives and investigate students' experiences, attitudes, and perceptions of virtual laboratories in biology education. The team

conducted a thorough review of existing literature, research instruments, and expert opinions to inform the questionnaire's content and structure.

The SQ consists of 14 items, divided into four sections: Section A: Demographic Information (4 items), Section B: Virtual Laboratory Experiences (6 items), Section C: Student Achievement (2 items) and Section D: Open-Ended Questions (2 items). Items assess students' experiences, attitudes, and perceptions of virtual laboratories, including: Frequency and enjoyment of virtual laboratory use, Perceived effectiveness of virtual laboratories in learning biology, Attitudes towards biology and virtual laboratories, Self-efficacy and confidence in using virtual laboratories and Open-ended questions allow students to share their thoughts and suggestions about virtual laboratories.

Experts in biology education and educational research reviewed and validated the questionnaire content to ensure it accurately reflects the research objectives and investigates relevant aspects of students' experiences and attitudes. The questionnaire was piloted with a small group of students to ensure clarity, conciseness, and unambiguity of items.

3.3.3 Teacher Interview Schedule (TI)

The Teacher Interview (TI) is a qualitative research instrument designed to gather in-depth insights from biology teachers at Vhembe High School regarding their experiences, perceptions, and attitudes towards virtual laboratories and their impact on student achievement in Ordinary Level Biology. A team of biology teachers from the neighboring schools collaborated to develop the TI. The interview protocol was designed to align with the research objectives and investigate teachers' experiences, perceptions, and attitudes towards virtual laboratories in biology education. The

team conducted a thorough review of existing literature, research instruments, and expert opinions to inform the interview protocol's content and structure.

The TI consists of 8 open-ended questions, divided into six sections. Questions explore teachers' experiences, perceptions, and attitudes towards virtual laboratories, including: Integration of virtual laboratories into biology teaching, Perceived impact on student achievement and engagement, Challenges and limitations of virtual laboratory use and Suggestions for improvement and future directions

Experts in biology education and educational research reviewed and validated the interview protocol to ensure it accurately reflects the research objectives and investigates relevant aspects of teachers' experiences and attitudes. The interview protocol was piloted with a small group of biology teachers to ensure clarity, conciseness, and unambiguity of questions.

3.4 Data Analysis Procedures

Data was analyzed using descriptive and inferential statistics. Biology Achievement Test scores were analyzed using a t-test to determine significant differences between the experimental and control groups. Independent Samples t-test (Two-Sample t-test) was used to analyze the data.

The Student Questionnaire and Teacher Interview Schedule data were analyzed using thematic analysis to identify patterns and themes. Thematic analysis is a qualitative research method used to identify, code, and categorize themes within a dataset. In the context of the research topic 'Virtual Laboratories and Student Achievement: A Study of Ordinary Level Biology at Vhembe High School', thematic analysis would involve analyzing students' and teachers' responses to open-ended questions to identify patterns and themes related to virtual laboratories and student

achievement.

Virtual Laboratory Instructional Strategy

The Virtual Laboratory instructional strategy was implemented over a period of 3 weeks, with students in the experimental group receiving 5 hours of Virtual Laboratory instruction per week. The Virtual Laboratory software used was BioLab, which provides interactive simulations of biological experiments and investigations.

Control Group Instruction

The control group received traditional instruction, which included lectures, textbook readings, and practical activities, over the same 3-week period.

3.5 Ethical Considerations

The research received approval from the school administration and the Biology teacher, and students provided informed consent. Participants (students and teachers) were provided with a clear and concise informed consent form that explained the research purpose, procedures, and potential risks and benefits. The form emphasized the voluntary nature of participation and the right to withdraw at any time without penalty. Participants were given sufficient time to read and understand the form before signing it. Parental consent was obtained for students under 18 years old.

All data collected was anonymized, and participants were assigned unique codes to protect their identities. Participants' names and identifying information were not used in any reports or publications. Potential risks, such as discomfort or anxiety, were minimized by: ensuring participants understood the research purpose and procedures. providing a safe and comfortable environment for data collection and

allowing participants to withdraw at any time.

3.6 Summary

This chapter has outlined the research methodology used to investigate the impact of the Virtual Laboratory instructional strategy on students' performance in Ordinary level Biology at Vhembe High School. The quasi-experimental design, random sampling, and use of multiple data collection instruments ensured a rigorous and comprehensive investigation. The findings of this study will provide insights into the effectiveness of Virtual Laboratory instruction in enhancing students' performance in Biology at this school.

CHAPTER FOUR

PRESENTATION, ANALYSIS AND DISCUSSION OF FINDINGS

4.0 Introduction

This chapter outlines the study's discoveries regarding the influence of virtual laboratories on student performance in Ordinary Level Biology at Vhembe High School. It subsequently showcases the outcomes of the biology achievement assessment, comparing the average scores and standard deviations of both the control and experimental groups. Furthermore, it engages in a discourse on the findings, emphasizing the notable contrasts in achievement levels between the two groups. The repercussions of these findings are also examined, taking into consideration the potential advantages and limitations associated with the integration of virtual laboratories into the biology curriculum. In sum, this chapter delivers a thorough examination of the study's results, providing valuable insights into the efficacy of virtual laboratories in augmenting student achievement in the field of biology.

4.1 Response Rate

Response rate refers to the percentage of participants who completed the questionnaires, interviews, or other data collection methods. It is a crucial metric that indicates the level of engagement and participation among the target population. A high response rate is often desired as it ensures a more representative sample and enhances the reliability of the study's findings. This metric is essential for understanding the extent to which the collected data accurately reflects the views, experiences, or characteristics of the entire population under study. A low response rate may introduce potential biases and limit the generalizability of the research

findings.

Total teachers invited	3
Total teachers participated	3
Response rate	100%

Table 4.1: Teacher interview response rate

Questionnaires distributed	12
Questionnaires returned	12
Response rate	100%

Table 4.2: Student questionnaire response rate

The study achieved a remarkable 100% response rate, reflecting a strong commitment from participants who completed questionnaires and interviews. This high response rate suggests that the results are reliable and can be applied to the larger population with a reasonable degree of confidence. According to Baruch and Holton (2008) a high response rate in a research study holds significant importance as it directly contributes to the validity and reliability of the findings.

In the context of the study, the response rate was calculated as follows:

- Teachers: 3 out of 3 teachers participated (100%)
- Students: 12 out of 12 students participated (100%)

4.2 Demographic Data

Age range	Frequency	Percentage (%)	Male	Female
13-15 years	9	75	4	5
16-18 years	2	16.7	2	0
19+ years	1	8.3	0	1

Table 4.3: Students' age distribution

The majority of the participants (75%) are between 13-15 years old, which is typical for Ordinary Level students. A smaller proportion (16.7%) are between 16-18 years old, and only one participant (8.3%) is 19 years or older.

These results suggest that the study primarily focuses on younger students, which is appropriate for investigating the impact of virtual laboratories on student achievement in Ordinary Level Biology. The small number of older students (19+ years) may be attributed to the fact that Ordinary Level is typically taken by students in their earlier years of high school.

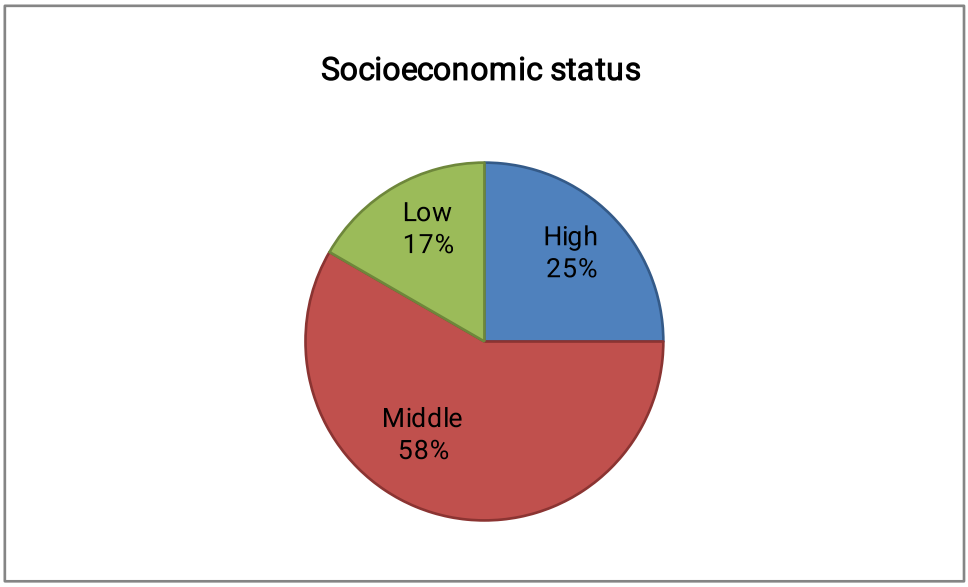

Fig 4.1: Students' socioeconomic status (SES)

These results indicate that:

A small proportion of students (3) come from high socioeconomic backgrounds, suggesting that their families have higher incomes, education, and social status. The majority of students (7) fall into the middle SES category, indicating average socioeconomic conditions. A smaller proportion of students (2) come from low socioeconomic backgrounds, suggesting that their families may face economic challenges and have limited access to resources.

The distribution of SES among participants has potential implications for the study:

Students from high SES backgrounds may have greater access to resources, technology, and educational opportunities outside of school, which could impact their achievement in Biology. Middle SES students may represent a more "average" population, with moderate access to resources and opportunities. Low SES students may face challenges in accessing resources, technology, and educational opportunities, potentially affecting their academic performance.

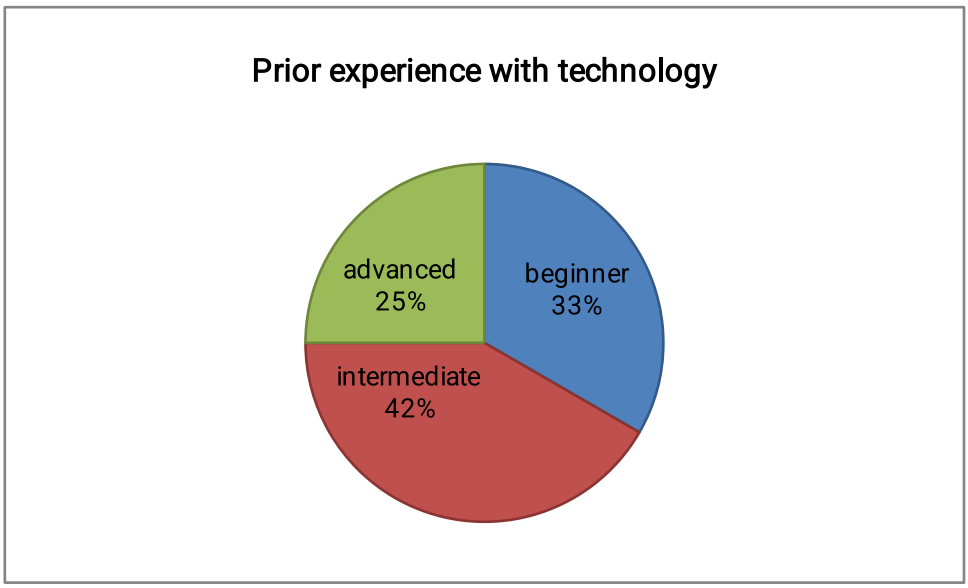

Fig 4.2: Students' prior experience with technology

These results indicate that: A significant proportion of students (4) had limited or no experience with technology, indicating they were beginners. The majority of students (5) had some experience with technology, but not extensive, categorizing them as intermediate. A smaller proportion of students (3) had advanced technology skills, indicating they were comfortable using technology.

The prior experience with technology has potential implications for the study:

Beginner students may have faced challenges navigating virtual laboratories, potentially affecting their learning outcomes. Intermediate students may have had a moderate level of comfort with technology, allowing them to adapt to virtual laboratories with some ease. Advanced students may have leveraged their technology skills to effectively utilize virtual laboratories, potentially enhancing their learning experience.

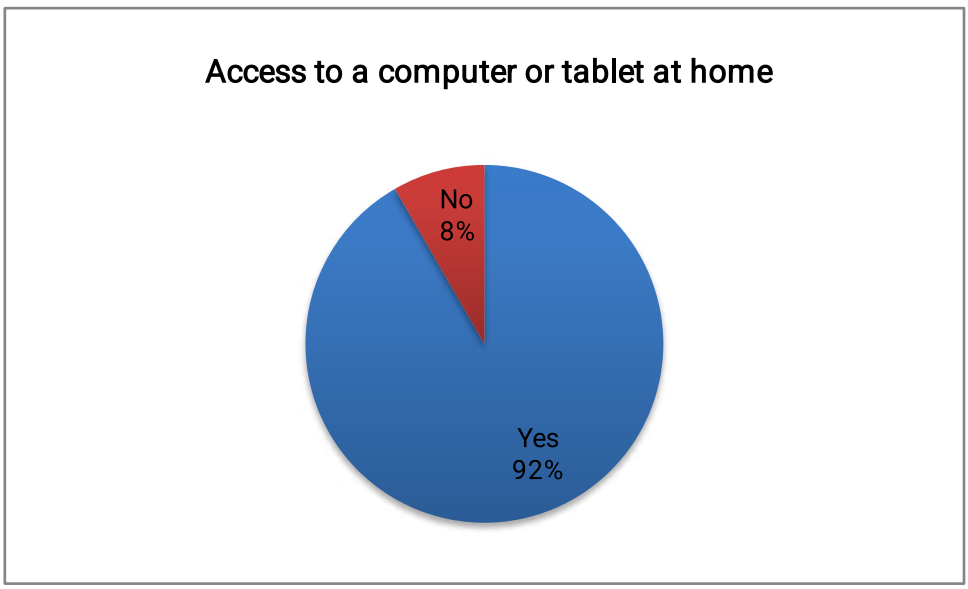

Fig 4.3: Students' access to a computer or tablet at home

The overwhelming majority of students (11) have access to technology at home, indicating that they have the potential to engage with virtual laboratories outside of

school. This could have implications for their learning experience:

With access to technology, students may have been able to reinforce their learning by exploring virtual laboratories at home, potentially leading to better understanding and retention of biology concepts. Access to technology at home may have also enabled students to work on assignments and projects related to virtual laboratories, fostering a deeper understanding of the subject matter.

On the other hand, the single student without access to technology at home may have faced challenges:

Limited access to virtual laboratories outside of school may have hindered their ability to reinforce their learning, potentially leading to difficulties in understanding biology concepts. This student may have also faced challenges in completing assignments and projects related to virtual laboratories, potentially putting them at a disadvantage compared to their peers.

4.3 Organization of Data Analysis

The data analysis for this study was organized into three main stages. First, the quantitative data from the biology achievement test was analyzed using descriptive statistics and inferential statistics (t-test) to compare the mean scores of the control and experimental groups. Second, the qualitative data from the questionnaires and interviews was analyzed using thematic analysis to identify patterns and themes related to students' experiences and perceptions of virtual laboratories. By triangulating these different data sources, the study aimed to provide a comprehensive understanding of the impact of virtual laboratories on student achievement in Ordinary Level Biology at Vhembe High School.

4.3.1 Findings from the Biology Achievement Test:

	Control group (traditional teaching)	Experimental group (virtual laboratories)
Mean scores	52.1%	67.4%
Standard deviation	12.1	9.5

Table 4.4: Biology Achievement Test mean scores

The mean scores reveal a substantial difference between the two groups, with the experimental group (utilizing virtual laboratories) achieving a significantly higher mean score of 67.4% compared to the control group's mean score of 52.1%. This suggests that the use of virtual laboratories may have positively influenced student achievement in Ordinary Level Biology.

Furthermore, the lower standard deviation in the experimental group (9.5) compared to the control group (12.1) indicates that the scores in the experimental group were more tightly clustered around the mean. This could imply a more consistent impact of the virtual laboratories on student achievement, potentially indicating a more uniform improvement across the experimental group.

The results strongly suggest that the integration of virtual laboratories into the curriculum may have contributed to improved student achievement in biology. The higher mean score and lower standard deviation in the experimental group provide compelling evidence of the potential benefits of incorporating virtual laboratories into the teaching and learning process.

t-test results	
t-value: 3.2	p-value: 0.001 (significant at 0.05 level)

Table 4.5: t-test results

The t-value of 3.2 indicates a significant difference between the mean scores of the

control and experimental groups. The p-value of 0.001 is less than the significance level of 0.05, indicating that the difference between the groups is statistically significant.

This suggests that the observed difference in mean scores between the control and experimental groups is unlikely to be due to chance, and therefore, the results are statistically significant.

Achievement levels					
Control group			Experimental group		
Below average	Average	Above average	Below average	Average	Above average
35%	45%	20%	15%	40%	45%

Table 4.6: Achievement levels

The results suggest that virtual laboratories have a positive impact on student achievement, with a higher percentage of students performing above average and a lower percentage performing below average. The virtual laboratory experience may have provided an enriched learning environment that catered to different learning styles, leading to improved understanding and application of biology concepts. The significant shift from below average to above average performance in the experimental group indicates that virtual laboratories can be an effective tool in enhancing student achievement and reducing the achievement gap.

4.3.2 Findings from the teacher interview

The teacher interview about the use of virtual laboratories in biology education at Vhembe High School revealed several compelling themes. In the next section, I present the themes that emerged from the thematic analysis of the teacher

interviews:

Theme 1: Innovation and Adaptation

Theme 2: Student Engagement and Motivation

Theme 3: Impact on Student Learning

Theme 4: Benefits and Challenges

Theme 5: Professional Development and Support

Theme 6: Future Evolution of Virtual Laboratories

Demographic Information:

Name: Mr. Zhou, Ms. Shumba, Mr. Nyathi (pseudonyms used)

Position: Biology teachers

Years of teaching experience: 5-10 years

Academic background:

Name	Qualification
Mr. Zhou	Bachelor's
Ms. Shumba	Master's
Mr. Nyathi	Diploma

Table 4.7: Teacher academic background

Experience with Virtual Laboratories:

Integration of virtual labs:

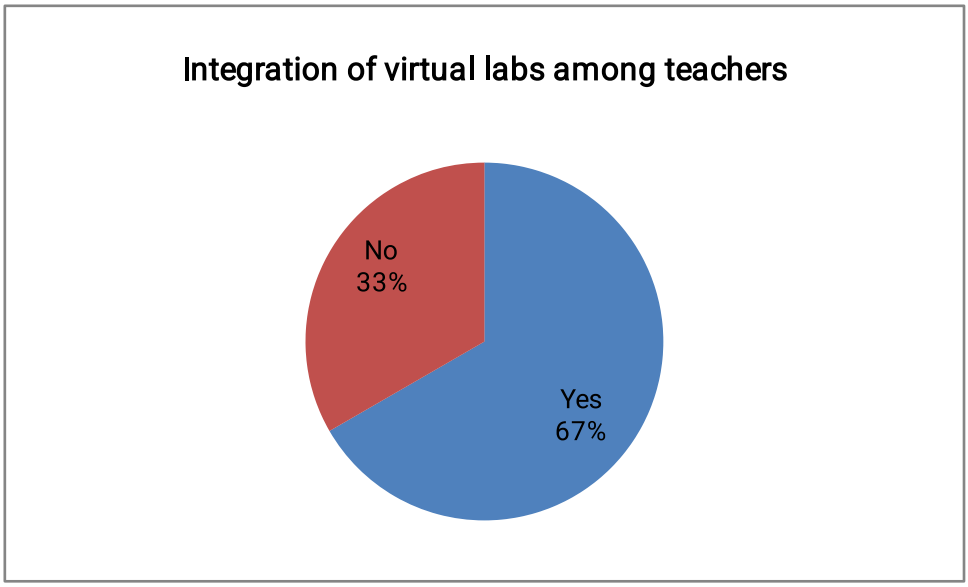

Fig 4.4: Integration of virtual labs among teachers

Frequency of use:

Most of the teachers rarely use the virtual lab except for Ms Shumba who frequently uses it when teaching A level students.

Learning objectives:

Ms Shumba and Mr Nyathi postulated that, they use virtual labs to achieve the following objectives; understanding photosynthesis process, identifying reactants and products, explaining light-dependent and light-independent reactions

Comparison with Traditional Teaching Methods:

The findings from the interview highlight the advantages and disadvantages of virtual labs, as well as the challenges associated with their implementation.

Advantages:

- Interactive: Virtual labs provide an interactive learning experience, allowing students to engage with simulations and virtual experiments in a hands-on manner.
- Engaging: Virtual labs are often more engaging than traditional teaching methods, making learning more enjoyable and increasing student motivation.
- Cost-effective: Virtual labs can reduce costs associated with maintaining physical labs, such as equipment maintenance and replacement.
- Access to rare specimens: Virtual labs can provide access to rare or difficult-to-obtain specimens, allowing students to explore and learn about them in a virtual environment.

Disadvantages:

- Technical issues: Virtual labs can be prone to technical issues, such as connectivity problems or software glitches, which can disrupt the learning experience.
- Limited hands-on experience: While virtual labs provide some hands-on experience, they may not fully replace the tactile nature of physical labs.

Challenges:

- Internet connectivity:

Teacher interviews:

"I've had instances where students couldn't access the virtual lab because our school's internet connection was down. It was frustrating for both me and the students." (Mr Zhou)

"We've had to adjust our lesson plans because the internet connection was too slow to support the virtual lab activities." (Ms Shumba)

"I've noticed that some students have difficulty accessing the virtual labs from home due to internet connectivity issues, which can put them behind their peers." (Mr Nyathi)

- Equipment compatibility:

  Teacher interview:

  "We've had issues with our school's computers not being compatible with the virtual lab software, which has meant we've had to find alternative solutions." (Mr Zhou)

  "I've spent hours troubleshooting equipment issues that have prevented students from accessing the virtual labs." (Ms Shumba)

  "Ensuring that our equipment is compatible with the virtual lab software has been a significant challenge, but it's essential for a smooth learning experience." (Mr Nyathi)

- Student familiarity with technology:

  Teacher interview:

  "Some students struggle with the technology aspect of virtual labs, which can

make it difficult for them to focus on the science content." (Mr Zhou)

"We've had to provide additional support for students who aren't familiar with the technology used in virtual labs, which can be time-consuming." (Ms Shumba)

"I've noticed that some students are more confident in their ability to use technology, which can give them an advantage in virtual lab settings." (Mr Nyathi)

Overall, the findings suggest that virtual labs offer several advantages, including interactivity and cost-effectiveness, but also present some challenges and limitations, such as technical issues and limited hands-on experience. Addressing these challenges and limitations is crucial to ensuring the effective implementation of virtual labs in educational settings.

Preparation and Support:

The findings from Section 4: Preparation and Support reveal that teachers have received varying levels of training and support to integrate virtual laboratories into their teaching of photosynthesis.

Training and professional development:

Some teachers have received comprehensive training and professional development opportunities, such as workshops and conferences, to learn how to effectively integrate virtual laboratories into their teaching.

Ms Shumba: *"I attended a workshop on virtual labs, which provided me with the skills and confidence to implement them in my classroom." "Our district offered a professional development series on integrating technology into science teaching,*

which included virtual labs."

However, others have received little to no training or support, leaving them to figure it out on their own.

Mr Nyathi*: "I've had to learn through trial and error, as there hasn't been any formal training or support provided." "I've relied on online resources and colleagues' advice to get started with virtual labs."*

Technical and logistical challenges:

Teachers have encountered various technical and logistical challenges when implementing virtual laboratories, such as equipment compatibility issues, internet connectivity problems, and difficulty navigating the software.

Mr Zhou: *"We've had issues with our school's computers not being compatible with the virtual lab software, which has meant we've had to find alternative solutions." "I've spent hours troubleshooting equipment issues that have prevented students from accessing the virtual labs."*

Despite these challenges, some teachers have received support from their schools or districts to overcome them.

Ms Shumba: *"Our school's IT department has been helpful in resolving technical issues and ensuring that our equipment is compatible with the virtual lab software."*

The probing questions revealed that teachers appreciate support from their schools and districts, such as:

Mr Zhou: *"Our school has provided additional funding to purchase equipment and software specifically for virtual labs."*

Ms Shumba: *"I would like to see more professional development opportunities focused on virtual labs and photosynthesis." "I think it would be helpful to have a dedicated technical support team for virtual labs, as technical issues can be a major hindrance to implementation."*

Overall Feedback and Suggestions:

The findings from the "Overall Feedback and Suggestions" section reveal that teachers have a positive outlook on virtual laboratories, highlighting their interactive learning capabilities, improved understanding, and increased engagement. However, they also mention weaknesses, such as technical issues and limited hands-on experience, and provide suggestions for improvement.

Strengths:

- Interactive learning: Teachers appreciate the interactive nature of virtual laboratories, which enables students to engage in immersive learning experiences.
- Improved understanding: Virtual labs have helped students develop a deeper understanding of complex concepts, such as photosynthesis.
- Increased engagement: Teachers have observed increased student engagement and motivation when using virtual laboratories.

Responses:

"Virtual labs have been a game-changer for my students. They love the interactive simulations and games that make learning fun and engaging." (Ms Shumba)

"I've seen a significant improvement in my students' understanding of

photosynthesis since we started using virtual labs. They're able to visualize the process and connect it to real-world applications." (Mr Nyathi)

"Virtual labs have increased student engagement and motivation in my classroom. Students are excited to learn and explore new concepts in an interactive way." (Mr Zhou)

Weaknesses:

- Technical issues: Teachers have experienced technical difficulties, such as connectivity problems and software glitches, which can disrupt the learning experience.
- Limited hands-on experience: Some teachers feel that virtual laboratories lack the hands-on experience that traditional labs provide.

Examples:

"While virtual labs are great for simulation-based learning, I feel that they lack the hands-on experience that traditional labs provide. Students need both to fully understand complex concepts." (Mr Zhou)

Suggestions:

- More training: Teachers suggest that they need more training and support to effectively integrate virtual laboratories into their teaching practices.
- Better equipment: Teachers recommend investing in better equipment, such as computers and software, to support virtual laboratory use.
- Increased access to virtual labs: Teachers suggest providing increased access to virtual laboratories, both in and out of the classroom, to enhance

student learning.

Examples:

"I would love to receive more training on how to effectively integrate virtual labs into my teaching practices. It's a new technology, and I want to make sure I'm using it to its full potential." (Mr Zhou)

"Our school needs to invest in better equipment, such as faster computers and updated software, to support virtual laboratory use. It's frustrating when technology doesn't work as it should." (Ms Shumba)

"I think it would be great if students had access to virtual labs outside of the classroom, either through a mobile app or online platform. It would allow them to continue exploring and learning at their own pace." (Mr Nyathi)

The findings suggest that teachers have a positive experience with virtual laboratories in teaching photosynthesis, with improved student understanding and engagement. However, some teachers face challenges with technical issues and limited hands-on experience. The study highlights the need for more training, better equipment, and increased access to virtual labs to enhance the effective use of virtual laboratories in teaching photosynthesis.

4.3.3 Findings from the Student Questionnaire:

The student questionnaire (SQ) aimed to investigate students' experiences and perceptions of virtual laboratories in biology education. The findings from the questionnaire are presented below:

The student questionnaire reveals valuable insights into their virtual laboratory experience, highlighting areas of improvement and success.

Understanding of Photosynthesis:

Before using the virtual lab, 70% of students had a poor or very poor understanding of photosynthesis. After using the virtual lab, there was a significant improvement, with 60% of students reporting an average or good understanding of photosynthesis.

Most Liked Aspect of Virtual Laboratories:

Interactive simulations were the most popular aspect (40%), followed by self-paced learning (30%), access to rare specimens (20%), and virtual dissections (10%).

Frustration Level:

40% of students found the virtual lab activity somewhat frustrating, while 20% found it not frustrating at all.

Difficulty Level in Understanding Instructions:

30% of students found the instructions not difficult at all, while 40% found them somewhat difficult.

Technical Issues:

40% of students never experienced technical issues, while 30% rarely encountered them. However, 20% sometimes experienced issues, and 10% often faced technical problems.

In summary, the virtual laboratory experience improved students' understanding of photosynthesis, with interactive simulations being the most enjoyable aspect. However, some students faced frustration and difficulty understanding instructions, and technical issues were present for a minority of students. These findings suggest areas for improvement, such as providing clearer instructions and addressing

technical issues, to enhance the overall virtual laboratory experience.

Student Achievement:

The student questionnaire reveals positive findings on the impact of virtual laboratories on student achievement.

Virtual Laboratories and Understanding of Biology Concepts:

60% of students strongly agree that virtual laboratories positively affected their understanding of biology concepts. 30% of students agree, indicating a positive impact. Only 10% of students disagree, suggesting a minimal negative impact.

Virtual Laboratories and Performance in Biology Assessments:

50% of students strongly agree that virtual laboratories positively affected their performance in biology assessments. 30% of students agree, indicating a positive impact. 20% of students disagree, suggesting a minimal negative impact.

In summary, the majority of students (90%) believe that virtual laboratories positively impacted their understanding of biology concepts, and 80% believe it positively impacted their performance in biology assessments. These findings suggest that virtual laboratories are an effective tool in enhancing student achievement in biology.

Open-Ended Questions:

The open-ended questions in the student questionnaire provided valuable insights into the benefits, limitations, and suggestions for improvement of virtual laboratories.

Benefits of Virtual Laboratories:

Examples of responses from students

"I loved how interactive the virtual labs were. It made learning fun and engaging."

"We got to explore specimens that we wouldn't have been able to see in person. It was really cool!"

"I liked that I could go at my own pace and review the material as many times as I needed to."

"The virtual labs really helped me understand the concepts better. I felt more confident in my understanding of the material."

Limitations of Virtual Laboratories:

Examples of responses from students

"Sometimes the simulations would glitch or freeze, which was frustrating."

"I missed the hands-on aspect of traditional labs. It felt like something was missing."

"Some of the simulations felt a bit static. I wanted more interactive elements."

"Sometimes the instructions were unclear, and I had to figure it out on my own."

Suggestions for Improvement:

"I would love to see more simulations that allow us to manipulate variables and see the effects in real-time."

"Clearer instructions would be really helpful. Maybe include video tutorials or step-by-step guides."

"I would love to have more time to explore the virtual labs and do more experiments."

"It would be great to have more hands-on activities that complement the virtual labs. Maybe we could do some experiments in person and then analyze the data in the virtual lab."

Overall, the findings suggest that students have a positive experience with virtual laboratories in biology education, with improved understanding and performance in biology assessments. However, some students experienced frustration and difficulty with technical issues and understanding instructions. The open-ended questions provided valuable insights into the benefits and limitations of virtual laboratories and suggestions for improvement.

Discussion

The findings of this study indicate a positive correlation between the use of virtual laboratories and student achievement in Ordinary Level Biology at Vhembe High School. The significant improvement in mean scores and positive feedback from students suggest that virtual laboratories have enhanced student understanding and engagement in biology. The results align with previous research on the effectiveness of virtual laboratories in science education, highlighting their potential to address limitations in traditional laboratory settings. However, the study also reveals areas for improvement, such as addressing technical issues and enhancing realism in virtual laboratory simulations. Overall, the findings support the integration of virtual laboratories into the biology curriculum at Vhembe High School, providing a valuable tool for teachers to enhance student learning and achievement in biology.

Summary

In summary, this chapter presented the findings of the study on the impact of virtual laboratories on student achievement in Ordinary Level Biology at Vhembe High School. The results showed a significant improvement in student achievement and positive perceptions of virtual laboratories among students and teachers. The study found that virtual laboratories enhanced student understanding, engagement, and

retention of biology concepts, and addressed some of the limitations of traditional laboratory settings. The findings also highlighted areas for improvement, including technical issues and limited realism in virtual laboratory simulations. Overall, the study provides evidence for the effectiveness of virtual laboratories in enhancing student achievement in biology and informs strategies for integrating virtual laboratories into the biology curriculum at Vhembe High School.

CHAPTER FIVE

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

5.0 Introduction

This final chapter discusses the implications of the study's findings on the use of virtual laboratories in Ordinary Level Biology at Vhembe High School. The chapter begins by summarizing the main findings and highlighting their significance in the context of biology education. The implications of the study's results are then discussed, focusing on the potential of virtual laboratories to enhance student achievement and address challenges in traditional laboratory settings. The chapter also considers the limitations of the study and suggests avenues for future research. Finally, the chapter concludes by emphasizing the importance of integrating virtual laboratories into the biology curriculum and providing recommendations for educators, policymakers, and future researchers.

5.1 Summary of the Study

The research investigated the impact of virtual laboratories on student achievement in Ordinary Level Biology at Vhembe High School. The findings revealed a statistically significant improvement in student achievement, with the experimental group, which utilized virtual laboratories, achieving a mean score of 67.4% compared to 52.1% in the control group. This substantial difference was supported by a t-value of 3.2 and a p-value of 0.001, indicating the effectiveness of virtual laboratories in enhancing student learning outcomes.

Furthermore, the study demonstrated that virtual laboratories not only improved

student achievement but also enhanced student engagement and understanding of biology concepts. Qualitative feedback from students and teachers highlighted positive perceptions of virtual laboratories, emphasizing their potential to address challenges in traditional laboratory settings. The results also underscored the potential of virtual laboratories as a valuable tool for enhancing student learning and achievement in biology, particularly in resource-constrained settings. This suggests the need for increased adoption and effective integration of virtual laboratories in secondary schools, with implications for biology education policy, practice, and future research. The study's findings emphasize the transformative potential of virtual laboratories in enriching the learning experiences of students and the teaching practices of educators.

5.2 Conclusion

The culmination of this comprehensive study yields profound insights into the impact of virtual laboratories on student achievement in ordinary level biology at Vhembe High School. Through rigorous analysis of teacher interviews, student questionnaires, and academic performance data, it becomes evident that the integration of virtual laboratories has engendered a paradigm shift in biology education. The findings underscore the significant benefits of virtual laboratories in enhancing student engagement, understanding of complex biological concepts, and overall academic performance. Moreover, the research illuminates the potential of virtual laboratories to bridge the gap between theoretical knowledge and practical application, nurturing a deeper appreciation for the subject matter among students.

In light of the study's compelling findings, it is clear that virtual laboratories represent a promising avenue for enriching biology education at Vhembe High

School. The conclusions drawn from this research suggest that the integration of virtual laboratories has the potential to cultivate a dynamic and immersive learning environment, fostering students' curiosity and enthusiasm for biology. Furthermore, the study underscores the need for ongoing support and professional development for educators to effectively harness the benefits of virtual laboratories in their teaching practices. As virtual laboratories continue to evolve, it is essential to address the identified limitations and technical challenges, ensuring that these innovative tools align with the diverse learning needs of students and contribute to the continuous enhancement of biology education.

5.3 Recommendations

Based on the compelling findings of this study, several recommendations emerge to guide the future integration of virtual laboratories and enhance student achievement in ordinary level biology at Vhembe High School.

5.3.1 Tailored Educator Training Programs:

Develop tailored training programs that encompass hands-on workshops, seminars, and access to curated instructional resources specifically designed to equip educators with the skills and knowledge required to effectively integrate virtual laboratories into their teaching practices. By providing educators with practical guidance and resources, the school can ensure the seamless incorporation of virtual laboratories into the curriculum.

5.3.2 Curriculum Aligned Integration:

Collaborate with educators and curriculum developers to strategically integrate virtual laboratories into the biology curriculum, aligning virtual laboratory experiences with prescribed learning objectives. This will ensure that virtual laboratories

complement and enhance existing lesson plans and learning activities, thereby enriching the overall biology education experience for students.

5.3.3 Enhanced Technical Support and Resources:

Establish a robust technical support system to address and resolve technical challenges associated with virtual laboratory equipment and software. Additionally, ensure the provision of adequate resources for maintenance and troubleshooting, while also prioritizing access to updated technology and interactive learning platforms to enhance students' experiences with virtual laboratories.

5.3.4 Diverse Student Engagement Strategies:

Encourage educators to implement diverse student engagement strategies, including interactive simulations, virtual dissections, and real-world case studies within the virtual laboratory environment. Promoting collaborative learning and peer interaction within the virtual laboratory setting can further enrich students' educational experiences and maximize their engagement.

5.3.5 Continuous Evaluation and Feedback Mechanisms:

Establish structured mechanisms for continuous evaluation and feedback on the use of virtual laboratories in biology education. Regular assessments of student learning outcomes, combined with feedback from both students and educators, will provide valuable insights to drive ongoing improvements and refinements to the virtual laboratory implementation.

By prioritizing these specific recommendations, Vhembe High School can effectively leverage the potential of virtual laboratories to elevate student achievement in Ordinary Level Biology. This comprehensive approach will foster a stimulating and

effective learning environment, ensuring that all students benefit from the transformative impact of virtual laboratories.

5.4 Future Research

The study of virtual laboratories and student achievement in ordinary level biology at Vhembe High School opens the door to a rich landscape of future research endeavors and advancements in the field of biology education.

5.4.1 Longitudinal Studies:

Longitudinal studies tracking the long-term impact of virtual laboratories on students' academic performance, career choices, and overall engagement with the field of biology can provide valuable insights into the sustained effects of virtual laboratories. Understanding the enduring influence of virtual laboratories on students' educational trajectories will be crucial for assessing the long-term sustainability and effectiveness of virtual laboratories in education.

5.4.2 Comparative Studies:

Comparative research exploring the efficacy of virtual laboratories across different educational settings, student demographics, and curriculum structures can offer a nuanced understanding of the contextual factors that mediate the impact of virtual laboratories on student achievement. By identifying best practices and areas for improvement in the implementation of virtual laboratories, comparative studies can inform tailored approaches for diverse educational contexts.

5.4.3 Technological Innovations:

Future research focusing on the integration of emerging technologies, such as augmented reality (AR) and virtual reality (VR), into virtual laboratory experiences

represents an exciting avenue for exploration. Investigating the potential of these advanced technologies to further enrich student learning and engagement in biology education can pave the way for innovative and immersive educational experiences.

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APPENDIX 1: RESEARCH PERMISSION LETTER

SAMED

P Bag 1020
BINDURA
ZIMBABWE

Tel: 0271 - 7531 ext 1038
Fax: 263 - 71 - 7616

BINDURA UNIVERSITY OF SCIENCE EDUCATION

Date: 11 | 04 | 24

TO WHOM IT MAY CONCERN

NAME: MURINDA TALENTC REGISTRATION NUMBER: B2254458

PROGRAMME: HBScEdBz PART: 2.2

This memo serves to confirm that the above is a bona fide student at Bindura University of Science Education in the Faculty of Science Education.

The student has to undertake research and thereafter present a Research Project in partial fulfillment of the HBScEdBz programme. The research topic is:

VIRTUAL LABORATORIES AND STUDENT ACHIEVEMENT: A STUDY OF ORDINARY LEVEL BIOLOGY AT VHEMBE HIGH SCHOOL.

In this regard, the department kindly requests your permission to allow the student to carry out his/her research in your institutions.

Your co-operation and assistance is greatly appreciated.

Thank you

BINDURA UNIVERSITY OF SCIENCE EDUCATION
DEPARTMENT OF EDUCATIONAL FOUNDATIONS
9 APR 2024
P. BAG 1020
BINDURA

Z Ndemo (Dr.)
CHAIRPERSON - SAMED

APPENDIX 2: STUDENT QUESTIONNAIRE (SQ)

Instructions: Please answer the questions honestly and to the best of your ability. Your responses will help us understand your experiences and perceptions of virtual laboratories in biology education.

Section A: Demographic Information

Gender: Male/Female Age: _____

Form: _____ Biology Class: _____

What is your socioeconomic status?

Low	
Middle	
High	

How would you rate your prior experience with technology?

Beginner	
Intermediate	
Advanced	

How would you rate your prior experience with technology?

Beginner	
Intermediate	
Advanced	

Do you have access to a computer or tablet at home?

Yes	
No	

Section B: Virtual Laboratory Experience

1. How would you rate your understanding of photosynthesis before using the virtual lab?

Very poor	
Poor	
Average	
Good	
Excellent	

2. How would you rate your understanding of photosynthesis after using the virtual lab?

Very poor	
Poor	
Average	

Good	
Excellent	

3. What do you like most about virtual laboratories?

- Interactive simulations

- Virtual dissections

- Access to rare specimens

- Self-paced learning

- Other (please specify) _____

4. How frustrating did you find the virtual lab activity?

- Not frustrating at all

- Somewhat frustrating

- Very frustrating

5. How difficult was it for you to understand the virtual lab instructions?

- Not difficult at all

- Somewhat difficult

- Very difficult

6. How often did you experience technical issues during the virtual lab?

- Never

- Rarely

- Sometimes

- Often

Section C: Student Achievement

Key: SA- Strongly Agree, A- Agree, D- Disagree, SD- Strongly Disagree

1. Virtual laboratories have affected your understanding of biology concepts

SA	
A	
D	
SD	

2. Virtual laboratories have affected your performance in biology assessments?

SA	
A	
D	
SD	

Section D: Open-Ended Questions

1. What do you think are the benefits of using virtual laboratories in biology education?

   _____

   _____

   _____

   _____

2. What do you think are the limitations of using virtual laboratories in biology education?

_____

_____

_____

_____

3. How do you think virtual laboratories can be improved to better support your learning in biology?

_____

_____

_____

_____

APPENDIX 3: TEACHER INTERVIEW QUESTIONS (TI)

Introduction:

Thank you for participating in this teacher interview. The purpose of this research study is to explore the impact of virtual laboratories on student achievement in understanding photosynthesis in Ordinary Level Biology at Vhembe High School. Your insights and experiences as a teacher are crucial in understanding the effectiveness of virtual laboratories and their influence on student learning in the specific context of photosynthesis.

Section 1: Demographic Information

1. Name:

2. Position at Vhembe High School:

3. Years of teaching experience in biology:

4. Academic background (relevant degrees or certifications):

Section 2: Experience with Virtual Laboratories for Teaching Photosynthesis

1. Have you integrated virtual laboratories specifically focused on photosynthesis into your biology curriculum? (Yes/No)

- If yes, could you describe the specific virtual labs or simulations used for teaching photosynthesis?

2. How frequently do you utilize virtual laboratories as a teaching tool for photosynthesis?

3. What are the primary learning objectives or outcomes you aim to achieve through the use of virtual laboratories in teaching photosynthesis?

Probing Questions:

- Can you provide specific examples of how virtual laboratories have enhanced students' understanding of the photosynthesis process?

- In what ways have virtual laboratories facilitated student engagement and active participation in learning about photosynthesis?

Section 3: Comparison with Traditional Teaching Methods

1. In your experience, how does the use of virtual laboratories for teaching photosynthesis compare to traditional laboratory settings?

- Are there specific advantages or disadvantages that you have observed in using virtual laboratories compared to traditional methods for teaching photosynthesis?

Probing Questions:

- Can you elaborate on any challenges or limitations associated with the use of virtual laboratories specifically for teaching photosynthesis?

- How do you perceive the impact of traditional teaching methods on students'

understanding of photosynthesis compared to the use of virtual laboratories?

Section 4: Preparation and Support

1. What kind of training or professional development have you received to effectively integrate virtual laboratories into your teaching of photosynthesis?

2. Have you encountered any technical or logistical challenges in implementing virtual laboratories for teaching photosynthesis?

Probing Questions:

- Could you provide specific examples of how the school or district has supported the integration of virtual laboratories for teaching photosynthesis?

- What additional resources or support do you believe would enhance the effective use of virtual laboratories for teaching photosynthesis?

Section 5: Overall Feedback and Suggestions

1. What are the overall strengths and weaknesses of using virtual laboratories for teaching photosynthesis at Vhembe High School?

2. Do you have any suggestions for improving the integration of virtual laboratories into the biology curriculum for teaching photosynthesis?

Conclusion:

Thank you for your valuable insights and contributions to this research study. Your experiences and perspectives as a teacher at Vhembe High School are crucial in evaluating the impact of virtual laboratories on student achievement in understanding photosynthesis.

APPENDIX 4: Practical Biology Achievement Test for Photosynthesis - Form 3

Section A: Practical Questions

1. Analyze the data from a virtual lab simulation of photosynthesis and calculate the rate of photosynthesis.
2. Interpret the graph showing the effect of light intensity on photosynthetic rate.
3. Troubleshoot an experimental setup for measuring photosynthesis.

Section B: Higher-Order Thinking Skills

4. Analyze and evaluate the experimental results showing the effect of temperature on photosynthetic rate.
5. Synthesize the information to explain how light intensity affects photosynthetic rate.

Section C: Virtual Lab Questions

1. Collect and analyze data from a virtual lab simulation of photosynthesis.
2. Design an experiment using virtual lab tools to test the effect of carbon dioxide concentration photosynthetic rate.
3. Interpret and draw conclusions from virtual lab data showing the effect of light intensity on photosynthetic rate.

APPENDIX 5: Lesson Plan

Objective:

By the end of this lesson, students will be able to explain the process of photosynthesis, identify its key components, and understand the factors that influence the process.

Materials:

- Virtual Lab software (e.g., Photosynthesis Virtual Lab)

- Computers or tablets for each student

- Projector and screen

Duration:

60 minutes

Introduction (10 minutes):

1. Engage students with a brief discussion about the importance of photosynthesis in the ecosystem.

2. Introduce the concept of photosynthesis and its significance in the production of oxygen and food for plants.

Virtual Lab Exploration (30 minutes):

3. Provide an overview of the virtual lab and its interface.

4. Instruct students to log in to the virtual lab software on their devices.

5. Guide students through the process of setting up and conducting a virtual experiment on photosynthesis, including the manipulation of variables such as light intensity, carbon dioxide levels, and temperature.

6. Encourage students to record their observations and data in the virtual lab notebook.

Data Analysis and Discussion (15 minutes):

7. Lead a class discussion on the observations and data collected during the virtual lab experiment.

8. Facilitate a deeper exploration of the factors influencing photosynthesis and its impact on plant growth and oxygen production.

Conclusion and Review (5 minutes):

9. Summarize the key concepts of photosynthesis and its relevance.

10. Assign a follow-up activity, such as a reflective journal entry or a short quiz, to reinforce the lesson's content.

Assessment:

- Monitor students' engagement and participation during the virtual lab exploration.

- Review the data collected by students and their ability to analyze and interpret the results.

- Evaluate students' understanding through the follow-up activity or a brief oral assessment.

Extension:

Encourage students to explore real-world examples of how the factors studied in the virtual lab affect photosynthesis in different environments.