Addressing Rural Grade 10 Physical Sciences Learners' Alternative Conceptions about Waves and Sound through Information and Communications Technology (ICT) Simulations

By

Nokubonga Mzolo

206516153

A dissertation submitted in fulfilment of the academic requirements for the degree of Master of Education (Science Education) in the School of Education, College of Humanities, University of KwaZulu-Natal

Supervisor: Professor Nadaraj Govender

Co-supervisor: Doctor Bongani Prince Ndlovu

December 2023

Abstract

Physical Sciences continues to be one of the underperformed subjects, and the underperformance tends to be more noticeable in the provinces with rural schools. Among the contributing factors, the poor performance in Physical Sciences can partly be attributed to alternative conceptions associated with various content knowledge. Waves and sound topics are some of the topics that confuse learners. Therefore, the Department of Basic Education has recommended the integration of ICT simulations in teaching and learning. As a result, the purpose of this study was to identify rural grade 10 Physical Sciences learners' alternative conceptions about waves and sound and address those through Information Communication Technology (ICT) simulations. The study followed the conceptual change theory, which was supported by the social constructivism framework. The study was located within the interpretative paradigm and a qualitative action research design was adopted. The study employed two action research cycles, and purposively selected grade 10 Physical Sciences learners from the rural school in Zululand district, in KwaZulu-Natal province. The study answered the following question: What are the impacts of ICT simulations on the learners' performance? What are the learners' views on the use of ICT simulations in teaching and learning? Data were generated through pre/post-tests, interviews, and lesson observations. First, the conceptual test was administered to all participants to determine the alternative conceptions they had on the topic of waves. The findings from the pre-test revealed that learners had waves and sound alternative conceptions that impeded their understanding of Physical Sciences. Moreover, the analysis after the ICT simulation-based intervention revealed significant differences between the pre-test and post-test results. The findings from the post-test showed that the ICT simulations helped to resolve some of the rural grade 10 learners' waves and sound alternative conceptions. Furthermore, elicited responses indicated that learners perceived the use of ICT simulations to develop a better conceptual understanding of the waves and sound concepts. Thus, the study concludes by recommending the use of ICT simulations in day-to-day classroom practice and further research on other topics.

Keywords: Rural education, Physical Sciences learners, Alternative conceptions, Waves, Sound, ICT simulations, Conceptual understanding

Declaration

I, **Nokubonga Fortunate Mzolo** declare that

1. The research reported in this thesis, except where otherwise indicated, is my original research.

2. This thesis has not been submitted for any degree or examination at any other university.

3. This thesis does not contain other persons' data, pictures, graphs, or other information unless specifically acknowledged as being sourced from other persons.

4. This thesis does not contain other persons' writing unless specifically acknowledged as being sourced from other researchers. Where other written sources have been quoted, then:

a. Their words have been re-written but the general information attributed to them has been referenced

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5. This thesis does not contain text, graphics, or tables copied and pasted from the Internet, unless specifically acknowledged, and the source is detailed in the thesis and the References sections.

Student: Nokubonga Fortunate Mzolo

Signature: [redacted] Date: 6 December 2023

Supervisor: Professor Nadaraj Govender

Signature: [redacted] Date: 6 December 2023

Co-supervisor: Dr Bongani Prince Ndlovu

Signature: [redacted] Date: 7 December 2023

Dedication

First of all, I would like to dedicate my research study to God, the Almighty, for providing me with strength throughout the entire journey and for completing this project successfully. I also dedicate my study to my family (especially my mother) and friends, who have always been supportive of my academic endeavours. My children are also a source of strength for me. I dedicate this research to my kids, Lusizo and Sizonotha for their tolerance in allowing me to take time away from them to complete this project. Thank you very much, and may God abundantly bless you.

Acknowledgments

First and foremost, I would like to express my gratitude to God, the Almighty, for providing me with the opportunity and strength to accomplish this study endeavour. I am eternally grateful for His love and grace.

I would like to extend my deepest appreciation to my supervisors, Professor Nadaraj Govender and Doctor Bongani Prince Ndlovu, for their expert advice and guidance. Thank you for not giving up on me. I could not have finished my thesis without your support. You were truly God sent. May God richly bless you.

I wish to thank the KwaZulu-Natal Department of Education for allowing me to work in one of their Zululand district schools.

I would like to thank my colleagues for their contribution to this project, and for making this study possible through piloting activities.

Finally, I would like to thank my grade 10 learners for being the most enthusiastic participants, ready to engage and generate data.

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CHAPTER 1

BACKGROUND OF THE STUDY

1.1. Introduction

Physical Sciences is a subject within the scientific disciplines that are taught to learners in South African secondary schools during the Further Education and Training (FET) phase, spanning from grade 10 to grade 12. It is regarded as one of the gateway subjects geared towards national economic growth (Krakehl et al., 2020). International literature has reported that this is one of the underperformed subjects in the schooling years (Ullah et al., 2020). Furthermore, local research has shown that rural learners are still underperforming in science despite the changes made in education policies (Mohale et al., 2021; Mupira & Ramnarain, 2018) .Amongst the contributing factors, Mete (2020) argued that poor performance in Physical Sciences can partly be attributed to alternative conceptions associated with various content knowledge. The traditional teaching method in a science class is ineffective for scientific conceptual understanding. The lack of understanding and motivation forces learners to revert to their preconceptions even if they often conflict with science concepts being taught in the classroom as argued by Mirana (2016).

Rural learners of all ages and levels struggle to understand scientific concepts since they have no other resources than the textbook and the teacher. The literature have revealed that the quality of science teaching and learning may be affected by many factors including content knowledge and pedagogical skills of the teacher due to poor teacher preparation, lack of motivation for teachers (Quansah et al., 2019; Zinger et al., 2020). Furthermore, the learners are required to read textbooks while teachers elucidate the concepts to them, rather than engaging in activities as recommended by the integrated science curriculum (Azure, 2015). This implies that a well-designed curriculum is not the only approach that is necessary for learners to understand the subject. The Department of Basic Education (DBE) emphasized that teachers must consistently find intervention strategies and implement them to ensure that science learners understand complex topics (DBE, 2022a). As a result, in the White Paper on e- Education and Learning, the government encourages the use of information and communication technology (ICT) in secondary school teaching and learning (DBE, 2004)

ICT is the interaction, generation, and management of information using computers, network equipment, and software (Das, 2019). The use of ICT in education has become extremely important worldwide. The use of ICT in teaching and learning has been praised for getting learners' attention and interest, making lessons enjoyable, and most importantly improving learner performance (Bester & Brand, 2013). The ICT simulations can help engage learners in science class. Widiyatmoko (2018) argued that ICT simulations develop learners' conceptual understanding and improve learners' academic performance. ICT simulations provide dynamic, real-world, and relevant learning experiences since the simulations allow learners to make observations and receive immediate reactions (Smetana & Bell, 2012). In South Africa, the incorporation of Information and Communication Technology (ICT) in rural schools is frequently impeded by insufficient infrastructure and resources (Qhibi, 2008). To mitigate these obstacles, it is recommended that a laptop and a projector be provided for all learners to observe the ICT simulations on a screen. As a consequence, ICT simulations such as PhET, Physics Classroom, Java Lab, and oPhysics may be effectively used to address alternative conceptions related to Physical Sciences topic knowledge areas.

The Physical Sciences diagnostic report from (DBE, 2022a) revealed that the sound, waves, and light knowledge area has achieved 55%, which is less than the percentage of mechanics. It is against this background that seeks to find effective teaching and learning strategies. The learner- centred teaching approach has proven several times to be more effective than the teacher- centred approach. As a result, the study seeks to identify rural grade 10 Physical Sciences learners' alternative conceptions about waves and sound and address them through ICT simulations. The wave concept is one of the foundational concepts of science since it covers a variety of physics areas such as optics, quantum mechanics, and electromagnetic waves (Çalış & Ergül, 2022). Furthermore, this wave concept within physics contributes to a better understanding of physics (Aykutlu et al., 2021). Waves and sound are important in daily life processes. Without waves and sound, people couldn't communicate. Communication technologies also use these concepts to transmit sound. The study attempts to find teaching strategies that will address the challenges faced in Physical Sciences to improve learner performance in the subject. As a result, learners should be capable of identifying and resolving problems in both, science class and in real life. Moreover, their rural communities develop, as the waves and sound can help them understand how electricity is generated from water waves and how to purify water. The waves and sound can also assist in understanding the communication through use of technology.

1.2. Problem Statements

According to (DBE, 2020), learners in grade 12 underperformed badly in Physical Sciences. "The decline in performance is noticeably sharper in provinces with a significant rural constituency and is less pronounced in provinces with more urban settings" (DBE, 2020, p. 5). In the argument of (Mhamed et al., 2021), the majority of rural learners come from low-income homes with parents (or other relatives) that lack education and are unable to help their children.

As a result, learners' alternative conceptions are not addressed. According to the National Senior Certificate (NSC) examination diagnostic report, poor outcomes result from the learner's alternative conceptions (DBE, 2020). In the year 2022, KwaZulu-Natal (KZN) matric results showed a 6.2% improvement from 76.80% in 2021 to 83% in 2022 (DBE, 2022a). However, the NSC Exams has reported that the province is among the three provinces that have schools that performed below 40% over five years (2018–2022). The province is still working hard to improve the majority of schools' performance. In addition, the Zululand district has schools that performed below 40% over five years (DBE, 2022b). Zululand is one of the districts with many rural schools. Some of the reasons for the poor performance in most of the rural schools were faced with multi-grade teaching and physical resources, such as labs and equipment, were scarce. The results from DBE (2022) indicated that the majority of learners achieved level three (40- 49%) and level four (50-59%). The results further showed a decline in the number of learners who achieved level seven (80-100%). As a result, few learners select science careers at tertiary institutions. Moreover, this could result in South Africa having no future scientists because Physical Sciences not only prepare learners for future study but also play an important part in the development of the nation's economy and the communal well-being of its residents (DoE, 2004).

If no competing ideas impede the growth of scientific conceptual knowledge, learners will be able to produce excellent outcomes. Rural learners have different views of physics; especially concerning themes involving waves and sound (Fish et al., 2017; Que, 2021). Some learners live far away from the sea and have no experience with sea waves. The lack of well-equipped science laboratories, illiterate rural communities, inadequate teacher training, and other issues specific to rural high schools affect learners' conceptual understanding and academic performance in the Physical Sciences (Masinire, 2015; Nkambule, 2017). Learners find it easier to study science once alternative beliefs are disproved (Yang et al., 2014). Even when it comes to career decisions, learners are impacted by this issue. Because of their subpar performance in Physical Sciences classes, they deviate from pursuing STEM occupations (Grimes et al., 2019; Rafanan & De Guzman, 2020).

Just like urban schools, rural schools require and deserve excellent teachers who will recognise learners' obstacles and work to overcome them to boost their academic achievement. Resources for rural learners, such as science labs, libraries, and trained teachers, still need to be included. As a result, because simulations are free and widely available, it is desirable to employ them as teaching tools. In this project, the researcher wanted to figure out alternative conceptions and use ICT simulations to confront these conceptions in teaching science in a rural setting.

1.3. Purpose Statements

The overall research aim was to expose alternative science conceptions held by rural learners in waves and sound and address these alternative conceptions using ICT simulations. This is hypothesised to transform rural learners' alternative perceptions into accurate scientific conceptions in waves and sound, given their reputable affordances reported in the literature. To carry out this research work, the main purpose was broken down into three operationalizable objects listed below:

1.4. Research Objectives

1. To identify rural grade 10 Physical Sciences learners' alternative conceptions about waves and sound.

2. To explore using ICT simulations to address rural grade 10 Physical Sciences learners' alternative conceptions.

3. To explore rural grade 10 Physical Sciences learners' perceptions of learning through ICT simulations.

1.5. Research Questions

For the study to address the revealed problem above, the questions were formulated. In line with the objectives above, the following are the research questions.

RQ1. What are the rural grade 10 Physical Sciences learners' alternative conceptions about waves and sound?

RQ2. How can ICT simulations address rural grade 10 Physical Sciences learners' alternative conceptions about waves and sound?

RQ3. How do rural grade 10 Physical Sciences learners' perceptions of learning through ICT simulations relate to their performances?

1.6. Rationale of the study

From my 12 years of teaching experience, I have seen that learners struggle with understanding waves, sound, and light. As a result, the learners have a high failure rate in the subject. The many interpretations of waves and sound have led to the subject's failure; consequently, most learners no longer show interest in it. Assuming this is the case, the problem of alternative conceptions may be addressed in the classroom. To ensure that learners perform to their full potential, teachers must use various instructional strategies. The use of ICT simulations is the teaching strategy that the researcher intends to employ to address the alternative conceptions that rural grade 10 learners in Physical Sciences have. One of the competencies in studying science is conceptual understanding. According to Widiyatmoko (2018), ICT simulations help learners better enhance their conceptual knowledge. ICT simulations assist learners in grasping complex scientific ideas (Sarabando et al., 2014).

The government regularly updates the national curriculum to strengthen the nation's educational system. Moreover, among the enhancements is the use of ICT in classroom instruction (DoE, 2004). Based on the literature review, ICT simulations are useful in scientific teaching and learning (Lavonen, 2008; Mhamed et al., 2022). Meaningful learning has been achieved as a consequence of ICT usage. The results showed that learners enjoyed classes that included simulations and had improved conceptual knowledge (Çelik, 2022). The requirement to comprehend complicated scientific phenomena is addressed through ICT simulation. Using simulations, learners may examine and engage with models of many phenomena and processes. The necessity to apply newly learned scientific principles to real-world settings is what simulation is all about. Simulations may be used to teach learners scientific phenomena that are difficult to witness in real-time, such as slow motion. Simulations can also emphasize the breadth and depth of a student's scientific understanding. Simulations boost learners' interest in studying science. The researcher hypothesises that ICT simulations might address the rural grade 10 learners' alternative conceptions of the issues of waves and sound. This explains the primary motivation for the present research study's conduct.

The researcher plans to adopt the action research technique since it enables concurrent participation and study. Therefore, by using ICT to teach Physical Sciences in grade 10, the study will help the researcher become a better teacher. Due to learners' increased interest in watching and learning about waves and sound via simulations, it will also help teachers better manage the classroom. Additionally, the researcher used ICT simulations to improve the academic performance of rural learners in physics.

According to Sleeter (2014), educational research may be important for policy and practice. In keeping with Tseng (2012) and Whitty (2006), research impacts choices about policies and practices. The study will be useful in recognising current issues and figuring out how to address them in various educational strategies. Policy changes might result from the research (Sleeter, 2014). Research is done to produce successful policies by correcting flaws in existing ones. As claimed by Lingard (2013), research helps in professional practice. At the project's conclusion, the researcher hoped to have grown personally and professionally. (Borg, 2015) declared that research aims to understand what occurs in the classroom. New teaching strategies, including online pedagogy, will be developed with the help of this study. In addition, the study will help learners become better problem solvers.

1.7. Significance of the Study

The teaching and learning of Physical Sciences will be improved by using ICT simulations. It will improve student success by assisting learners in developing conceptual comprehension. It will expose learners to ICT tools narrowing the ICT gap between rural and urban learners. This research is important for rural school management since so many rural schools need more resources and do not succeed in enhancing their instructional methods. The study's findings will add to the information curriculum writers need to create ICT-based lessons for rural learners. The results may help administrators and policymakers devise professional development initiatives for teachers to educate them on utilising technology in rural classrooms.

This study aims to contribute to the existing body of literature concerning the rural schooling context, by providing a new approach to improve the performance of rural learners. Furthermore, the findings of this study will provide insight into how ICT simulations can be integrated with lesson plans. Also included is the contribution of rural learners' perspectives on the usage of ICT simulations for promoting teaching and learning to the existing literature. As a result, provide the necessary information on the daily preparations. In addition, the results of the study will provide insights that can inform policies and practices for improving rural learners' academic success.

1.8. Researcher and Positionality

This section allows for introspective reflection on a researcher's location, experience, gender, and positionality (Holmes, 2020). In addition, positionality is the practice of a researcher describing his or her viewpoint on the study, with the implication that this perspective may impact elements of the study (Creswell & Creswell, 2017). The researcher teaches Physical Sciences and Natural Sciences at a school in the KwaZulu-Natal (KZN) province, Zululand district. My teaching career began in a well-resourced boarding high school with appropriate facilities. The majority of learners studied Physical Sciences. The investigations/experiments were carried out in a Physical Sciences laboratory. My career as a science teacher was continuously evolving. Teachers were constantly exposed to teacher development programmes. To mention a few, the researcher participated in several programmes, including Valued Citizens and the Dinaledi initiative, as well as Fundisa for Change, a collaboration with Rhodes University. The programmes were designed to assist and educate teachers to incorporate environmental and sustainability knowledge and skills into the scientific curriculum. As a result, teachers advanced professionally.

After five years, I was transferred to a low-quintile high school in a rural neighbourhood. The school is a no-fee school; it does not collect school fees because it is located in an area with a low socioeconomic status. People from this area have less access to educational, financial, health and social resources. Meals are supplied for learners. The school provides three curriculum streams: sciences, commerce, and humanities. Unlike in the previous school, most learners choose the humanities stream because they have a negative stereotype Bruun et al. (2018) regarding the Physical Sciences subject. Learners see Physical Sciences as a tough topic (Ramdas & Yashoda, 2020). This is because the same learners are unmotivated (Mirana, 2016). As a result, enrolment in Physical Sciences has decreased (Wang et al., 2017). Furthermore, the number of learners who wrote Physical Sciences in the previous year, 2022 has decreased in KZN province (DBE, 2022a). At the present school, Physical Sciences is studied by a few learners who want to pursue a science profession. However, the learners continue to underperform the topic. As a result, the learners pursue higher education institutions and jobs that are not science-related.

In addition to teaching at the school, the researcher helps community learners who are studying science. These learners come from various schools. I noticed the issue while teaching these learners and those from my school. I've seen that learners who come from grade nine struggle with some physics topics, such as waves and sound. These waves and sound issues triggered my interest since the concepts apply to everyday living. Sound, for example, is vital in our perception of our surroundings. Furthermore, sound waves are used in communication technology such as phones, radios, and ultrasound devices in the medical field, as mentioned earlier. Waves and sound topics enable us to understand how sound behaves in different media.

Experiencing different cultures and educational systems at these schools has given me insight into how to implement a science curriculum in my classroom. As a senior Physical Sciences teacher at my school, I felt motivated and responsible to develop new teaching strategies involving ICT integration, as technology continues to dominate our century. I also lack expertise in using ICT in a science lesson as a teacher. I would like to learn more about the use of ICT in the classroom and how it affects student performance. Teachers must be continually developed; unfortunately, there are no efforts or programmes in place to help rural science teachers develop. I wish to improve both my professional development and the intellectual comprehension of my learners. My goal after recognising the problem was to do action research and relate my teaching to the lives of my learners. I applied to the University of KwaZulu-Natal for a master’s degree. I chose this university since I received my Bachelor of Science degree there and believed it would be a perfect fit for me as I would get supportive feedback that would assist my development as a writer and researcher. Having experience in assisting children with schoolwork as well as socialising in the community on weekends helped me to utilize social constructivism theory, as learners discuss to find solutions during teaching and learning. As a teacher-researcher, I aspire to increase learners' academic achievement while also growing professionally.

1.9. Outline of the Thesis

This thesis consists of six chapters. A summary of each chapter is presented in the following sections.

Chapter one

The goal of this chapter was to provide the study's pertinent background. It also described the study's problem statement and rationale for carrying it out. The study's purpose was stressed in this chapter, along with how it will affect various groups of people and industries. It also described the study's goals and objectives. The research questions, which acted as a roadmap for the study, were presented in this chapter. The researcher presented the positionality of the researcher, and lastly, the thesis outline was discussed in this section.

Chapter two

The researcher conducted a literature review on alternative conceptions in science education, examining the topics of waves, sound, and light, as well as the difficulties in teaching and learning physics. The role of ICT simulations in science education, teaching through ICT simulations, learners' perceptions towards ICT in teaching, and learners' performance in ICT-based science teaching were also explored. The chapter concluded with a discussion of the conceptual change and social constructivism theories that served as the study's guiding frameworks.

Chapter three

The methodology and research design used to conduct this study are presented in this chapter. The researcher explained why the qualitative action research methodology used in this study was adopted. The study used the interpretivism research paradigm as its foundation. The chapter covered the purposive sampling technique used to choose the rural grade 10 Physical Sciences learners as the study's sample. The researcher also described the methods used for gathering and analysing data. In this study, the trustworthiness of the qualitative data was explored. This researcher presented the ethical clearance acquired from the Research Ethics Committee at the University of KwaZulu-Natal. The researcher also included the permits obtained from the school principal and the Department of Education. Finally, the limitations of the study were highlighted.

Chapter four

The focus of this chapter was to report on the alternative conceptions held by rural grade 10 learners about waves and sound. In this chapter, the researcher presented the qualitative analysis and findings from the pre-test written by rural learners to answer the first researcher question. Furthermore, the qualitative data obtained from the interviews before the ICT simulation-based intervention were presented. Finally, the qualitative results obtained from the pre-test and interviews were discussed.

Chapter five

The main focus of this chapter was to provide an overview of the use of ICT simulations to address the alternative conceptions of waves and sound held by rural grade 10 students. The researcher also presented the learners' perceptions of learning through ICT simulations. The researcher then analysed the qualitative data from the lesson observation, post-test, and interviews to answer the second and third research questions. The chapter concluded with a discussion of the findings from these instruments.

Chapter six

This chapter aim to provide conclusions and recommendations based on the findings of this study. The researcher provided the conclusions in response to the research question of the study. Moreover, the contributions of the study's knowledge to the existing literature were discussed. The researcher also acknowledged the limitations of this study. Finally, the recommendations and suggestions for future research were offered.

1.10. Chapter summary

In this chapter, the contextual background, problem statement, and rationale of the study were discussed. Furthermore, the significance of the study and the purpose of the study were highlighted. The research questions that guided this study were discussed in this chapter. Moreover, the chapter gave a detailed description of the researcher and positionality. Finally, the chapter concluded by outlining the chapters of the thesis. The next chapter reviews the literature concerning the alternative conceptions of waves and sound and ICT simulations in teaching and learning.

CHAPTER 2

LITERATURE REVIEW

2.1. Introduction

The research focuses on addressing the rural grade 10 Physical Sciences learners' alternative conceptions about waves and sound using ICT simulations as an intervention teaching strategy. So, the literature review is structured to cover the relevant bodies of knowledge to provide the study's rationale. The chapter consists of four sections. Firstly, the study focuses on alternative conceptions in science education. The second section reviews the literature on waves and sound under the knowledge area of waves, sound, and light and its alternative conceptions. Furthermore, the challenges in teaching and learning of science are discussed. In addition, the chapter reviews the literature on teaching in urban and rural schools. The next section discusses the role of ICT in teaching. Moreover, teaching through ICT simulations, learners' perceptions towards ICT in teaching, and learners' performance in ICT-based science teaching are argued. Lastly, the literature examines the theoretical frameworks that guided the study.

2.2. Alternative conceptions in science education

Understanding how conceptual change happens, is ultimately one of the essential aims of a learning process that requires studying learners' abstract worlds (Arboleda-Hernandez et al., 2022). Research on alternative conceptions is critical for intervening and refining strategies for education. As a consequence, the literature review started by looking at the findings and observations of the studies conducted in the 1970s and 1980s. The literature showed that the researchers noticed that children had their conceptions in the 1970s. And their ideas were referred to as misconceptions(Doran, 1972; McClelland, 1985), children science (Osborne & Freyberg, 1985) and alternative conceptions (Arrhenius et al., 2020; Driver & Easley, 1978). The terms misconception and alternative conception were mostly used. However, Natividad (2022) argued that some teachers preferred to use the term alternative conception over misconception because the term misconception indicates that learners have done something whereas they have an incomplete understanding. Furthermore, Natividad (2022, p. 22) added that "'Mis' in misconception gave an impression of error or incorrectness when the learner only gives his/her interpretation or understanding". A study conducted by Maskiewicz and Lineback (2013) with the title, 'Misconceptions are so yesterday', argued that the term 'misconception' is no longer relevant in science education research because the term is not in line with constructivist theory.

Contrary to this, Crowther and Price (2014) disagreed with the argument that the misconceptions are so yesterday. The authors argued that the use of the term depends on the type of audience. Moreover, the term misconception is avoided because the learners could perceive it pejoratively (Crowther & Price, 2014). According to Malones (2022) alternative conceptions are also called misconceptions. But again, considering that the misconception stresses that the learner's knowledge is inaccurate concerning scientifically accepted ideas, science teachers have begun to use the phrase alternative conception rather than misconception and other defensibly acceptable terminology (Malones, 2022). The study of Leonard et al. (2014) is in agreement with the previous argument when the authors argued that misconception and alternative conception have the same meaning, which refers to scientifically incorrect ideas. Furthermore, the authors suggested that the term must be defined in a study to get a sense of the term related to the study's phenomenon. In addition, misconceptions can also be defined as errors, since misconceptions systematically produce errors (Mishra, 2020). Moreover, Neidorf et al. (2020) argued that errors come from being careless, reckless, and alternative conceptions, which indicates poor understanding. Considering that the alternative conception is more educationally fitting with learners and respects their conceptual frameworks, it was adopted in this study (Adu-Gyamfi & Ampiah, 2019). Additionally, the term alternative conception has no negative connotations like misconception (Stojanovska et al., 2015). Hence, the researcher adopted the term alternative conception to refer to the rural grade 10 Physical Sciences learner's existing or prior knowledge about waves and sound. These alternative conceptions are the basis for building their next knowledge (Redhana et al., 2017).

According to Mayangsari et al. (2017), alternative conceptions are learners' conceptions of scientific concepts that are inconsistent with the conceptions of scientists. The alternative conceptions are also, known as naive ideas, the ideas that learners hold (Hanson, 2020). These initial concepts are important in understanding an object being studied (Henry, 2019; Jauhariyah et al., 2018). Furthermore, Samsudin et al. (2021), Nurjani et al. (2020) , and Iqbal (2021)argued that alternative conceptions are caused by observing natural objects, being exposed to social media; the language used daily, and teachers' explanations and instruction. In accordance with Behera (2019), alternative conceptions come from the knowledge learners acquire from the community. Learners' alternative conceptions differ from scientific concepts and usually contradict science, so there's a need to confront and address these conceptions (Hasanah & Wasis, 2021). Hence, the study sought to identify and address the rural learners' alternative conceptions.

Dawson et al. (2010) state that alternative conceptions are essential in teaching science. This means that the alternative conceptions enhance understanding of science concepts and their applications (Ferreira et al., 2019). This is in agreement with Putra and Hamidah (2020) and when the researchers argued that learners understand science concepts when they have alternative concepts. Learners build scientifically accepted concepts based on alternative conceptions. Moreover, Asghar et al. (2019) argued that the incorrect ideas by learners influence the way science is taught and the ability of science teachers to help learners develop a conceptual understanding. Research shows that learners hold alternative conceptions even after the teachers' explanations and instructions (Yang et al., 2014). The teacher-centred learning approach in a science classroom is mostly unsuccessful in developing a conceptual understanding because the learners' alternative conceptions persist even after teaching (Asghar et al., 2019). Therefore, designed practical activities that challenge learners' prior conceptions are required (Behera, 2019). Such new strategies will enable learners to understand complex and abstract scientific concepts. Hanson (2020) suggested that teachers must create favourable classroom conditions to facilitate the proper study of scientific concepts required at the secondary school level. This can cause learners to gain interest in science.

Learning effectiveness is determined by learners' comprehensive understanding of science concepts. A study conducted by Unver and Ozkarabacak (2018) found that teacher candidates had partial understanding or knowledge; they had many alternative conceptions. Currently, alternative conceptions contribute to the challenges in education. The challenges include, these learners' ideas being entrenched into their thinking and very resistant to instruction as learning requires the replacement or drastic rearrangement of learners' knowledge (Lucariello & Naff, 2013). Furthermore, this places teachers in a position to change the way they think to bring about a significant conceptual change in their knowledge (Behera, 2019).

Alternative conceptions in Physical Sciences subject are still a problem that affects the quality of learners' academic performance (Irawati & Sofianto, 2019). This finding complies with Saparini et al. (2021) results, which prove that a poor understanding of physics leads to failing the subject. Teachers must use learners' alternative conceptions for learning (Sadler & Sonnert, 2016). In addition, learners' alternative conceptions could be a resource for discussing ideas during teaching and learning (Ramnarain & Moosa, 2017). Moreover, during classroom discussions, learners can try to justify their decisions while working through problems (Sabin, 2021).

2.3. Alternative Conceptions about waves and sound

Physical Sciences is a science that focuses on the process of acquiring information through creation, presentation, and the application of systematic and specific principles. Physics is predicated on the idea that to employ facts, ideas, principles, laws, and processes in their daily lives, learners must first comprehend those (Suryani et al., 2021) . According to the South African Curriculum and Assessment Policy Statement, (CAPS), matter and materials, chemical systems, chemical change, mechanics, waves, sound, and light, and electricity and magnetism are the six core knowledge areas that underpin the topics of Physical Sciences (CAPS, 2020). In Grade 10, the following topics are studied: Transverse pulses on a string or spring (amplitude, superposition). The wavelength, frequency, amplitude, period, and speed of a transverse wave. Longitudinal waves including wavelength, frequency, amplitude, period, wave speed, and sound waves on a spring are also studied. And, electromagnetic radiation (EM radiation's dual (particle/wave) nature, EM spectrum, EM as particle - the energy of a photon related to frequency and wavelength).

The CAPS document states that the highlighted topics above must be taught in grade 10, however studies by Caleon and Subramaniam (2010) and Reyes and Rakkapao (2018) revealed that learners are facing challenges to the Wave and Sound, and this may be linked to their poor performance. The literature showed several methods to teach waves and sound that were investigated and implemented. These include; student worksheets based on a multi-representation approach (Doyan et al., 2021), cognitive conflict and scientific approach (Krisdiana et al., 2018), inquiry-based learning, worksheets based on comics (Khaira et al., 2020) and simulations (Banda & Nzabahimana, 2021). All of the methods mentioned above have been reported to be successful by the relevant authors. As a result, the study focused on identifying the alternative conceptions of waves and sound and addressing those through ICT simulations, however, the study was conducted in a rural setting.

For the past many years, several studies conducted by Linder (1992) and Wittmann et al. (2003) show that the waves and sound are problematic. It is concerning that in the current study conducted by Tumanggor et al. (2020), waves and sound are still challenging for learners. The research on the learners' understanding of concepts is interesting since physics is deeply linked to day-to-day life. Hence the researchers have conducted studies on waves and sound and found several alternative conceptions related to pulses, transverse waves, longitudinal waves, and sound. The sound concept has been revealed as the most common concept with the alternative conceptions. In a study by Eshach et al. (2018) the learners' materialistic thinking of sound was examined. Furthermore, the finding showed that the learners' reason for sound propagating through solid matter was that "a solid object has holes in it and sound passes through the holes, or that sound can pass through a solid object if it is harder or stronger than the object" (Eshach et al., 2018, p. 665). The author also revealed that learners were asked “why intensity decreases as we go far from a playing band”; their answer was, "Sound is heavy and goes down before it gets to our ears" (Eshach et al., 2018, p. 667). Moreover, the literature showed that even university students hold alternative conceptions about waves and sound. A study by Küçüközer (2009) investigated whether student teachers comprehend the concept of sound. The author used three unanswered questions regarding sound generation, propagation, and nature, and found that the prospective science teachers had difficulties in understanding the topic. This is in line with the study by Saparini et al. (2021) when the scholars investigated the prospective physics teachers' understanding of the characteristics of sound. The authors utilized a diagnostic test instrument to determine alternative conceptions about wavelength, frequency, amplitude, and velocity of wave propagation, which also apply to sound waves. The results of their study revealed that the prospective physics teachers had alternative conceptions, including the idea that a sound's amplitude and frequency affect the speed at which sound waves propagate and that the loudness of the motion of a dust particle in front of the source will be affected by sound. Additionally, learners also believed that the pitch of the sound influenced the speed of the sound waves, although the speed of sound waves in the air remains constant (Wittmann et al., 2003).

The research further showed the following alternative conceptions about waves. Some of the wave’s concepts revealed from the literature concern the properties of the medium. In the study of Olaniyan (2022), learners had the alternative conception that moving the string faster with a higher frequency or larger amplitude would produce a faster pulse. Furthermore, when Bolat and Kocacan (2018) explored the effect of adopting diverse ways of teaching sound themes in a secondary school curriculum on student accomplishment, the authors mentioned that learners associated flicking the string faster and the height of the flick with the pulse produced. In the study of Barniol and Zavala (2016), other learners’ conception was that, for a pulse to take a shorter, a girl should not change the string characteristics because the speed of a string's pulse depends on frequency and wavelength according to $v=f. \lambda$.

This paragraph further discusses alternative conceptions regarding transverse waves, longitudinal waves, and pulses. The most common alternative conception was that learners perceived sound waves as a transverse waves that require a medium to propagate. Moreover, alternative conception was reported in the investigation by Caleon and Subramaniam (2010); (Kryjevskaia et al., 2011) which investigated students' difficulties with the sequence of two or more pulses. These findings from the reviewed literature show that learners often have alternative conceptions of Physical Sciences.

Consequently, Wilhelm et al. (2019) and Wittmann et al. (2003) have suggested that teachers must work hard to ensure learners understand the concepts of waves and sound. These alternative conceptions must be addressed to develop conceptual understanding. In addition, the researchers also saw a gap in developing the teaching methods to identify and clear learners' conceptualisation. These teaching strategies were tutorials (McDermott, 1984; McDermott & Redish, 1999), conceptual change text (Okur & Artun, 2016), and PowerPoint presentations (Pavlos et al., 2020). Hence the study employed ICT simulations to address the waves and sound alternative conceptions and develop a conceptual understanding.

2.4. Challenges in teaching and learning science

Teaching science has its challenges which contribute to learner underperformance. Studies have discovered and reported the challenges in teaching Physics. Dusabimana and Leon (2022) reported the insufficiency of teaching and learning materials, and infrastructure as challenges that the teachers faced when implementing curriculum in their physics teaching. Similarly, a study conducted by Nsengimana (2020) regarding opportunities and challenges of competence-based curriculum implementation in Rwanda reported that teachers' key concerns are a shortage of laboratory apparatus and teaching and learning resources.

It is not only the teachers who face challenges. However, the literature also showed that learners have difficulties developing a conceptual understanding of waves and sound (Muliyati et al., 2019). This is because the concepts learned in Physics are abstract and invisible. In a study conducted by Negoro and Karina (2019), an investigation to develop a diagnostic test to uncover difficulties in vibration and waves was conducted. The authors revealed that learners' conceptions are an indication of difficulties that learners encounter in learning Physics. Another contributing factor to conceptual difficulties in teaching Physics is the English language as the language of instruction to learners with a different home language. Poor English language on the side of learners is a challenge during teaching and learning (Semeon & Mutekwe, 2021). This is because the learners fail to understand the subject as a result of the English language as a barrier. The learners are second-language users. This is in harmony with what was reported by Kagwesage (2012) in a study conducted to investigate the reflections of learners on the use of English as a medium of instruction. The author revealed that students including master's and doctorate students had a problem understanding courses taught in the English language. Similarly, a study conducted by Lo and Macaro (2012) in secondary schools revealed that poor English did not allow learners to share ideas during the teaching and learning process which caused the lessons to be teacher-centred rather than student-centred. Moreover, this makes developing conceptual understanding difficult as learners are expected to express themselves in English, even during the writing of tests or examinations.

Poor conceptual understanding may also occur due to the textbooks used during teaching and learning. A textbook is found to be one of the sources of alternative conceptions (Eshach et al., 2018; Iqbal, 2021). Guisasola et al. (2013) focused on learners' confusion resulting from textbook design. The researchers analysed 19 textbooks, of which were published in the USA, and evaluated them in terms of topic coverage and connectivity, concept explanations linking to the learners' prior knowledge, examples and questions, etc. (Heeks, 2017). The authors found that even if the physics meaning behind related mathematical operations was discussed correctly, the way the textbooks presented concepts was not always helpful. Another challenge is that the teacher is a source of alternative conceptions. The author further asserted that teachers sometimes serve as the primary providers of alternative conceptions among their learners, particularly when they lack the qualification, competence, or experience to deal with such ideas. In addition, a teacher's classroom instruction has developed alternative conceptions (Iqbal, 2021).

As the teacher instruction was discussed above, this implies that the traditional teaching method that is teacher-centred is also a challenge to learners. Consequently, the traditional teaching method will not produce a scientific conception in learners' minds, instead, it leads to an alternative conception (Darman et al., 2019). The report by Saparini et al. (2021) showed that there is a need for learning innovations to improve conceptual understanding and reduce alternative conceptions of waves that occurred during the learning process. Once again, the ICT simulations are an effective strategy for developing conceptual understanding (Chumba et al., 2020). This study used ICT simulations to address rural learners' alternative conceptions about waves and sound, hence the next section discusses the teaching of science in urban versus in rural schools.

2.4.1 Teaching science in urban schools

Physical Sciences is one of the subjects that learners perceive as difficult and abstract (Guido, 2018). In addition, Physics is a very complicated subject that reduces learners' motivation for learning the subject (Dusabimana & Leon, 2022). This observation is found to be more common in rural schools than in urban schools. Urban learners are generally highly motivated and have better knowledge than rural learners (Saleh, 2014). The reason for better attitude and performance in physics in urban schools is that urban schools have more favourable conditions, such as functioning laboratories, libraries, and exposure to technology (Ibrahim et al., 2019).

In addition, Kusairi et al. (2020) reported that the results of the Mann U Whitney test showed that there are significant differences in learners' conceptual understanding between urban and rural areas. The authors added that the mean rank indicated that learners in urban areas have better conceptual understandings. Furthermore, urban learners could give correct explanations and descriptions related to waves and sound (Que, 2021).

2.4.2 Teaching science in rural schools

Rural learners have a higher failure rate in Physical Sciences (Tsoka, 2020). The National Senior Certificate (NSC) examination diagnostic report in 2020 highlighted that "the decrease in performance is notably sharper in provinces that have a significant rural constituency and is less pronounced in provinces with more urban settings" (DBE, 2020, p. 5). As a result, rural learners do not choose STEM careers when they reach tertiary level (Wood & Kaszubowski, 2008). The higher failure rate in Physical Sciences may result from the lack of teaching and learning materials, and qualified teachers (Waller & Maxwell, 2016). Moreover, rural schools lack libraries, electricity, enough classrooms, and even water (Du Plessis & Mestry, 2019).

Some rural schools have computer laboratories, however, they lack an internet connection. The ineffective laboratories may result from rural teachers that are not developed to utilise ICT tools, they lack the skills to use technology in the classrooms. This is because of limited or no professional development opportunities from the government. Similarly, the government policy document highlighted that due to school distances from town, insufficient facilities, and restricted service delivery, it is challenging to recruit and educate qualified educators in a rural environment . Nevertheless, the majority of the teachers are interested and willing to integrate ICT into teaching and learning, and they are ready to use ICT despite the existing financial, technical, and digital skills challenges at their schools (Mwapwele et al., 2019) . The lack of teachers' skills results in rural learners being disadvantaged as they don't receive meaningful learning. Jonassen and Strobel (2006) argued that meaningful learning takes place when learners are present in class by being active, constructive, intentional, cooperative, and working on given tasks.

During teaching and learning, rural learners have been found to hold more alternative conceptions than urban learners (Abdul & Akhilesh, 2008). In addition, rural learners use their life experiences to explain the waves and sound concepts (Fish, 2016). To assist this and other problems such as absenteeism and learners' dropping out of school, the policy recommended an increased diffusion of ICTs to rural schools (Education, 2017). However, the use of ICT in rural areas is faced with various socio-economic, geographical, political, and cultural issues (Que, 2021). As mentioned above, some rural areas have no electricity to utilise technological tools. This implies that South Africa is not close to ending 'the digital divide because some rural schools still cannot integrate ICT with education to enhance teaching and learning (Ramnarain, 2020). Urban learners are now exposed to the benefits of ICT but on the rural side, they still lag behind this (Rahaman & Akter, 2017). Hence, this study focused on using ICT simulations to address the rural learners' alternative conceptions of waves and sound. According to (Trikoilis, 2021) (2021, p. 30), "Rural learners' academic performance can be affected positively by the PhET interactive simulations". This is in agreement with the study by Mphafudi (2020) as the findings revealed positive and, the pre-test and post-test results were marked differently when simulations were used as an intervention. Furthermore, the author recommended that the schools must develop and implement ICT policy to enhance teaching and learning and fulfill the needs and demands of 21st-century education (Rahim et al., 2020).

2.5. ICT in teaching

Information and communications technology (ICT) has been defined differently by the authors. According to Das (2019), ICTs are a diverse range of products, services, and applications that are used to create, store, process, disseminate, and exchange information. In essence, they are information-handling technologies. Data projectors, computing devices, and tablets are a few examples of ICT in classrooms (Saal et al., 2019). With the aid of these tools, teachers may interact with learners more effectively and in a way that makes learning easier. In addition, electronic tools or gadgets used to assist teachers in meeting goals and objectives for teaching and learning in the smallest amount of time are considered information and communication technologies (Ojo & Adu, 2018).

The Department of Education (DoE, 2004) claimed that ICT might be characterized as convergent in the Information Draft White Paper on E-Education. They went on to say that ICT is the hardware, software, and network combinations that allow for the processing, management, and sharing of data, information, and knowledge. Moreover, the Draft White Paper on E-education stated that ICT tools are also tools for engagement, cooperation, and communication. During the previous several decades, ICT has supplied a huge variety of communication possibilities, transforming society into a global village. The ICT also brought a massive change in the field of education (Amutha, 2020).

ICT has played a catalyst role in promoting education (Zafar, 2019). Das (2019) argued that ICT has the potential to improve the education system of the nation. According to Zafar (2019), the integration of information and communication technologies (ICTs) has facilitated and elevated educational experiences across various levels, settings, and demographic groups, thereby making learning more accessible and inclusive for individuals from diverse backgrounds. For teachers, the newly dominated technology has been found to develop and promote teachers' methods of instruction (Medh, 2020). It has made teachers more creative and collaborative problem solvers and adoptive and socially aware experts by fluently using innovative technology.

Furthermore, ICT has been found to enhance student performance and achievement (Mirzabek et al., 2022). The literature showed integration of ICT in teaching and learning is an effective strategy. Bentaleb et al. (2022) investigated the effectiveness of the integration of ICTs in teaching and learning quantum physics concepts and found that ICT makes learners active, and motivates learners to engage in learning effectively. These ICTs include visualization, tools, programming, games, virtual experimentation, and E-learning. Furthermore, the authors found computer simulation visualization to be beneficial in learning quantum physics concepts that are always too abstract and counterintuitive. Similarly, the observation from the research of Mirzabek et al. (2022) showed that ICT engages learners and keeps them interested in class; it encourages student engagement throughout the learning process; increases the effectiveness of teaching, and improves learners' learning; the use of ICT helps students to learn them with ease and retain them in their memory for a very long period. Consequently, the study focused on using ICT tools to address the identified alternative conceptions of waves and sound. The ICT tools in the classrooms promote quality education. The studies by Amutha (2020), Zafar (2019), and Das (2019) found that teachers, policymakers, and administrators use ICT tools and resources and collaborate with other educational participants researchers, families, cultural and professional institutions, and other stakeholders and eliminating inefficiencies, digital divide, inequality and stretching beyond the walls of traditional classrooms and promoting everywhere and all time learning and making effective assessments by analysing individual abilities, needs, overall strengths and weaknesses of learners.

2.5.1 Teaching through ICT Simulations

ICT simulation is one of the ICT tools used as a pedagogical tool in teaching and learning (Almasri, 2022). The author further described the ICT simulations as programs that allow learners to carefully investigate hypothetical environments, participate in them, and study the changes that occur as a result of their participation. According to Wilson (2016), ICT simulation is a computer program that tries to imitate abstract concepts and phenomena. Moreover, the author argued that computer simulations make understanding new concepts easier than the normal teaching method. This is because simulations are scientifically accurate, highly illustrative, and dynamic representations of principles of physics (Abou Faour & Ayoubi, 2017). These ICT simulations can be sourced from different websites downloaded, and used at any time to understand physics concepts. Physics Education Technology (PhET) simulation is one of the simulations commonly used to explain and describe complex concepts. Waves and sound are some topics explained using PhET, oPhysics, JavaLab and Physics Classroom simulations. These simulations are animated, user-friendly, and highly interactive, and learners can change the variables to observe the outcomes (Podolefsky et al., 2010; Tsoka, 2020)

The literature also revealed other ICT-based strategies in teaching science, such as PowerPoint presentations, computer simulations, and YouTube videos (du Plessis, 2016), However, ICT simulations have proven to make abstract science concepts visible and easy. In addition, simulations are clearer than other teaching resources, such as textbooks, live demonstrations, and even real equipment (Abou Faour & Ayoubi, 2017). According to Ramnarain and Moosa (2017, p. 2), "simulations effectively eliminate alternative conceptions and thereby support conceptual understanding in science". As a result, the study aimed to use ICT simulations in classroom lessons on waves and sound to improve cognitive learning and allow learners to work independently, allowing them to repeat a learning experience while seeking to grasp the concepts. In the study of Abou Faour and Ayoubi (2017), the findings revealed that learners who learned through computer simulations performed better than learners who were taught through traditional methods. The traditional teaching method was ineffective. Hence, teachers need appropriate support to employ simulations to help learners comprehend abstract concepts and improve learners thinking skills. Although challenges such as teacher development, lack of ICT support, and time should be overcome for effective teaching and learning (Anderman et al., 2012).

2.5.2 Learners’ perceptions towards ICT in teaching

Learners' views impact teachers' pedagogical decisions and behaviours, and their attitudes about ICT determine whether or not ICT is used in their classes (Taimalu & Luik, 2019). Teachers focus on learners learning from them while rarely considering what they learn from learners. Studies investigated the learners’ views to determine the quality and success of the simulation-based lessons conducted. The study of Hartley and Treagust (2006) reported that the majority of students (87,5%) indicated that they were extremely excited about the prospect of using computers for the first time when they started at the beginning of the year. This is an indication that learners were engaged in an ICT-based classroom. The term "learners' engagement" refers to the extent of cognitive and sensory investment that learners exhibit when interacting with simulation-based educational resources (Almasri, 2022). In the study by Lisene and Jita (2018), the participants pointed out that they expected their achievements in Physical Sciences to increase with the aid of computer-assisted learning. Moreover, in the same study, the majority of learners (75%) also expressed that they were happy with the way they were being involved in the computer-assisted classes and that they participated readily in discussions with both the teacher and their fellow students. Learners perceived their learning in Physical Sciences to have improved because they managed to answer the questions on the computers after the lessons. This is because learners believed that the use of ICT-based learning involves a relatively low workload and cognitive effort, which indicates that the ICT-based learning tools used makes learning simple Banda and Nzabahimana (2023). On the other hand, in the study of Santhi et al. (2019) the participants believed that the use of ICT improved their English language skills. Furthermore, learners revealed that after doing the project, their English was better, and their creativity increased.

2.5.3 ICT simulation-based Learning on the Learners' Performance

When ICT is fully integrated into Physics class; it can improve students' academic achievement in Physics (Aina, 2013). This observation is indicated by the research studies (Díaz & Cano, 2019; Ugwuanyi & Okeke, 2020). The study of Ben Youssef et al. (2022) examined whether improvements in student performance are the result of ICT. The authors reported that university investment in ICT has a positive impact on student performance. This was because students were able to utilize the ICT tools, hence ICTs allowed students to perfect their learning in the forms of teamwork, as a result, the students performed well. This is in line with the study of Gómez-Fernández and Mediavilla (2021) who reported that their results showed that higher availability of ICT tools per student in the schools was associated with higher levels of academic performance. Teachers play a crucial role in learners' performance. According to Suleman et al. (2017), computer-assisted instruction techniques should be used by science teachers to stimulate and boost students' academic achievement in Physical Sciences at the secondary level. Hence, the study utilised ICT tools to address rural learners' conceptions.

The South African context revealed pre-and post-tests as the most used instruments to measure learners' performance. In South Africa, Mphafudi and Ramaila (2020) utilized tests, interviews and lesson observations to address misconceptions of grade 11 Physical Sciences learners using computer simulations, and the results indicated favourable and substantial discrepancies between the pre-test and post-test scores upon implementing simulations as an intervention. In Northern Cape Province, Philip (2021) conducted a study to determine the effect of computer simulation on Grade 11 learners' conceptualisation of stoichiometric chemistry. The author used the pre- and post- tests to generate data and found significant and positive results. Learners perform better when computer simulations are used to help with their learning (Dunn & Ramnarain, 2020). Learners enhance their performance as a result of their understanding of various concepts following lessons (Philip et al., 2023). The findings of Chumba et al. (2020) study demonstrated that computer simulations improve a positive attitude. The more positive one's attitude, the greater one's achievement in school. Philip et al. (2023) suggested that employing computer simulations for the teaching and learning of Physical Sciences is an effective way to promote conceptualisation in South African schools throughout the FET phase. The findings of these studies may have implications for South African science classrooms, particularly in rural schools. As a result, this study employed the ICT simulations as an alternative to traditional teaching to address rural grade 10 learners' alternative conceptions about waves and sound.

2.6. Theoretical frameworks

The main purpose of this study was to identify rural grade 10 Physical Sciences learners' alternative conceptions in waves and sound topics and address their conceptions through ICT simulations. Hence, the study was guided by two theoretical frameworks to carry out this inquiry. These were conceptual change and social constructivism theories. Conceptual change is the learning theory that describes the nature of changes in the existing learner conception into a scientifically accepted conception (Chi et al., 1994). On the other hand, constructivism is the learning theory that describes the process of actively constructing new knowledge by the learner (Bada & Olusegun, 2015). The study used ICT simulations as the conceptual change theory tool to change the learners' alternative conceptions. Hence, the social constructivism theory supported the conceptual change theory since learning occurred in a social setting, where there was a collaboration between learners and the teacher. In this chapter, the two theoretical frameworks will be explained. This will be followed by an account of how each theory underpinned the current study. The first section discusses conceptual change theory.

2.6.1 Conceptual change

The conceptual change theory was originally proposed by the psychologist Jean Piaget (Carey, 1999). The author further asserted that, Piaget's work in developmental psychology laid the foundation for understanding how individuals construct knowledge and how their understanding of the world evolves over time. However, in the context of science education, the term "conceptual change" gained prominence in the 1970s and 1980s. The purpose of conceptual change theory was to provide a framework for understanding how individuals learn and develop new understandings, particularly in fields such as science education (DiSessa, 2014). Conceptual change theory recognizes that learning is not simply about acquiring new information but often involves reorganizing or restructuring one's existing mental representations of concepts (Finn, 1992). While Piaget laid the groundwork for conceptual change theory, it has been further developed and expanded upon by various researchers in fields such as education, cognitive psychology, and science education (DiSessa, 2014).

Conceptual change is the learning theory that describes how knowledge is created based on prior information and experiences of the learners (Posner et al., 1982), unlike conceptual development, which refers to creating the meaning and understanding of new knowledge. Taber (2019) defined the theory as the learning that transforms the existing way of thinking. This is inconsistent with the explanation (Nadelson et al., 2018). The author described the theory as follows, "Conceptual change is building on an existing conception to form a new explanation while retaining an explanation of the original extant conception" (Nadelson et al., 2018, p. 154). Duit and Treagust (2003) on the other hand, argued that conceptual change had been interpreted as an exchange of pre-instructional conceptions for science, whereas the term refers to the learners' prior conceptions that must be restructured to understand the new scientific concepts.

The following researchers have described the conceptual change theory using the following perspectives.Vosniadou and Brewer (1992) described the theory from the perspective of mental models. Furthermore, the authors described mental models as “constraints that emerge out of the structure of previously acquired knowledge, and in turn exert their influence on the acquisition of new knowledge" (Vosniadou & Brewer, 1994, p. 124) . Conceptual change is the theory that lifts mental models during the learning process. From a motivation perspective, (Pintrich et al., 1993) viewed motivation and interest as important cognitive strategies that could affect conceptual change, and they are needed for learning. The perspective of Piaget (1970) viewed conceptual change through epistemology, a belief about knowledge and knowing. Furthermore, Piaget asserted that conceptual change involves assimilation, a process of learning the new concept through the existing knowledge, and accommodation, which is a process of understanding and fitting the new concept in mind.

The conceptual change model focuses on three main components (Sinatra, 2005). Firstly, cognitive factors influence conceptual change. These are motivation, interest, and learning environment, which affect the construction of new knowledge. The second component is developmental changes in learners' knowledge representation. This pertains to the ability of learners to create a correct meaning from new knowledge. The third component refers to social and contextual factors that must be considered during teaching and learning.

Since this study is about learner alternative conceptions, what is of interest in this work are cognitive factors. In this component, conceptual change has four cognitive conditions that must be met for successful learning. Figure 2.1 shows the step-by-step process of achieving the conceptual understanding. The cognitive conditions include dissatisfaction, intelligibility, plausibility, and fruitful (Posner et al., 1982).

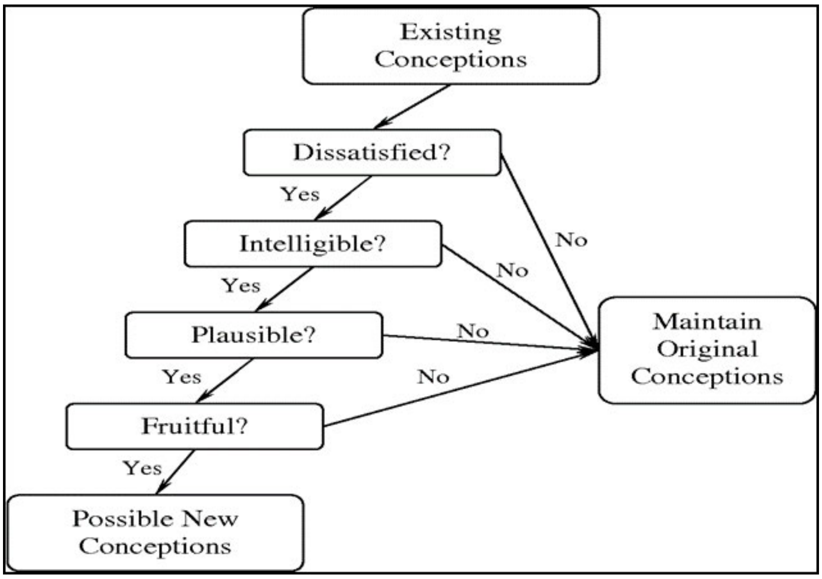


Figure 2.1: A conceptual change model.

The dissatisfaction condition describes how learners change their alternative conceptions (Iqbal, 2021). Learners must be aware of their wrong and incomplete ideas. Learners must realise that their ways of thinking do not solve problems. As a result, they must become dissatisfied. The dissatisfaction leads to an intelligible. Posner et al. (1982) argued that for learners to accommodate a new concept, they must find it intelligible. This means learners should be able to create new scientific knowledge in their minds. In this study, ICT simulations were implemented for learners who had difficulty distinguishing between new and old ideas, so that learners would believe in new concepts and change old conceptions that were no longer applicable, and learners would be able to apply new concepts appropriately in everyday life. The new concept should be clear enough to make sense and be able to explain that concept to other classmates. The new concept must be plausible to be accommodated. In this study, the ICT simulations such as PhET and oPhysics assisted in developing learners' conceptual understanding. Learners' new scientific concepts should make sense and be believable (Samsudin et al., 2021). A new concept should be applied to solve problems. For the concept to be fruitful, learners should be able to apply the new knowledge in their daily lives. The new concept should solve the problems at hand and open new areas of inquiry (Posner et al., 1982).

The conceptual change theory was adopted because it is more specific to transforming the learners' conceptions to scientifically accepted conceptions and is still adopted in recent research studies (Asgari et al., 2018; Chhabra & Baveja, 2012; Mabalane, 2019; Natividad, 2022). The studies mentioned above have revealed that learners come to the classroom with alternative conceptions. Hence the alternative conceptions will be a foundation for the conceptual change theory to develop conceptual understanding. The conceptual change theory aligns with the constructivist learning theory, which is about constructing new knowledge based on existing knowledge (Özmen, 2007). As mentioned earlier, the dissatisfaction phase requires a learner's prior knowledge (constructivism) to develop a conceptual understanding (conceptual change). Hence, the constructivism theory guided this study. The participants worked in groups to address alternative conceptions through ICT simulations. Hence the next section describes the constructivism theory, the learning theory that supports the conceptual change approach.

2.6.2 Constructivism

Constructivism, as a theory of learning, has evolved over time and has been developed by several influential scholars. However, Jean Piaget is widely recognized as one of the key figures in the development of constructivism (Fosnot & Perry, 1996). His work in developmental psychology, particularly his theory of cognitive development, emphasized the active role of learners in constructing their understanding of the world through interactions with their environment (Piaget & Cook, 1952). Piaget's ideas have had a profound impact on educational theory and practice, contributing to the development of constructivist approaches to teaching and learning. The theorist, Vygotsky's followed after the work of Piaget. Hence, the constructivism was developed based on two theories; Piaget's cognitive development and Vygotsky's structural theories (Igwe et al., 2020) between 1920s and 1930s. Piaget and Cook (1952) believed that children are active learners because they continually learn as they interact with the world. Furthermore, learners build upon the existing knowledge and adapt the prior knowledge to accommodate the new knowledge. Vygotsky et al. (1978) believed that learning is more effective in social and cultural settings than solely within the individual. Piaget and Vygotsky's theories are supported by the cognitive theory of Bruner (1966) which reveals that learners construct their knowledge by organising or categorising the information in their minds.

Constructivism is the learning theory defined in numerous ways by different researchers. Ausubel et al. (1968) defined constructivism as the learning theory where learners create new information from the existing knowledge. In the study of Pavlik and Haddock (2022), the theory of constructivism is defined as an approach to learning that causes people to construct knowledge from their experiences actively. (Kanselaar, 2002) described constructivism theory as epistemological beliefs, psychological beliefs, and educational beliefs. The beliefs are explained as follows. From an epistemological perspective, the learners' knowledge is determined by society and culture. Psychological beliefs refer to being able to create and understand knowledge. A set of educational beliefs about pedagogy refers to learners being allowed to define their learning objective and that knowledge comes from constructive interactions between the teacher and learners (Kanselaar, 2002).

There are three major types of constructivism in the classroom; these are cognitive constructivism, radical constructivism, and social constructivism. Cognitive constructivism explains that learners actively create knowledge from their existing knowledge. Radical constructivism is an approach to the problem of knowledge that starts from the assumption that knowledge is constructed based on experience and that knowledge is actively constructed by cognising the idea rather than passively receiving it (Von Glasersfeld, 2013). On the other hand, social constructivism is the social learning theory adopted in this study. The description of this kind of constructivism is therefore explained below.

2.6.2.1 Social constructivism

Social constructivism considers learners' knowledge and meanings (about their world) constructed in their minds (Ausubel et al., 1968). It allows the building of concepts through interactions between learners and their teachers (Kalina & Powell, 2009). Social constructivism is a social theory that emphasizes the significance of context and cultural factors in understanding what occurs in society and generating knowledge based on that understanding (Kim, 2001), as displayed in Figure 2.2. The social constructivism theory considers the roles of all members (teachers, learners, family members) in the community in teaching the learners (Moll & Diaz, 1987. The learners from the learning community influenced by constructivism successfully mediate knowledge within the social context {Hirtle, 1996 #2756).

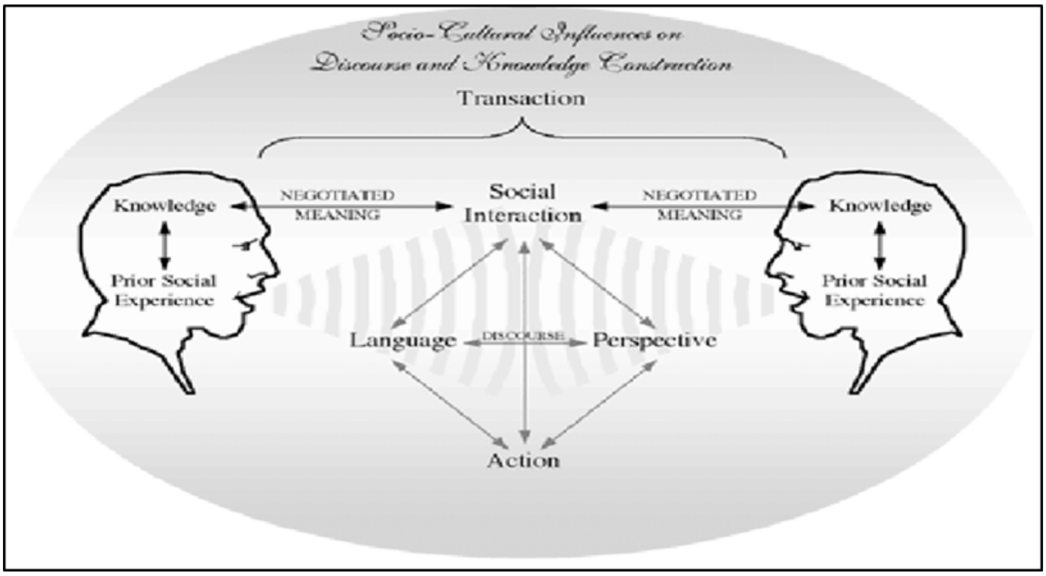


Figure 2.2: A diagrammatic representation of social constructivism.

The fundamental aspects of Vygotsky's social constructivism that the study adopts are a zone of proximal development (ZPD), scaffolding, and more knowledgeable others (MKO). Vygotsky's zone of proximal development was created with child development in mind (Fani & Ghaemi, 2011). This theory describes how a learner/child is assisted during teaching and learning (L. S. Vygotsky, 1962). The zone proximal development describes the movement as a result of social interaction (Wertsch, 1984). Vygotsky and Cole (1978) believed that learning is a continual movement from the level where learners can construct knowledge without assistance to where their teachers can assist them (see Figure 2.3). The ZPD has three stages that learners may fall in according to the skills they possess (Lake, 2012). As a teacher, knowing the learner's stage is important to facilitate learning. In the first stage, learners can work independently; they do not need help. The next ZPD stage shows that learners can do work with a teacher's or other learners' assistance. This phase is regarded as their zone of proximal development. In the last stage, learners need help to do the work. The level of difficulty increases in the last phase. The second aspect, scaffolding, is elaborated as follows.

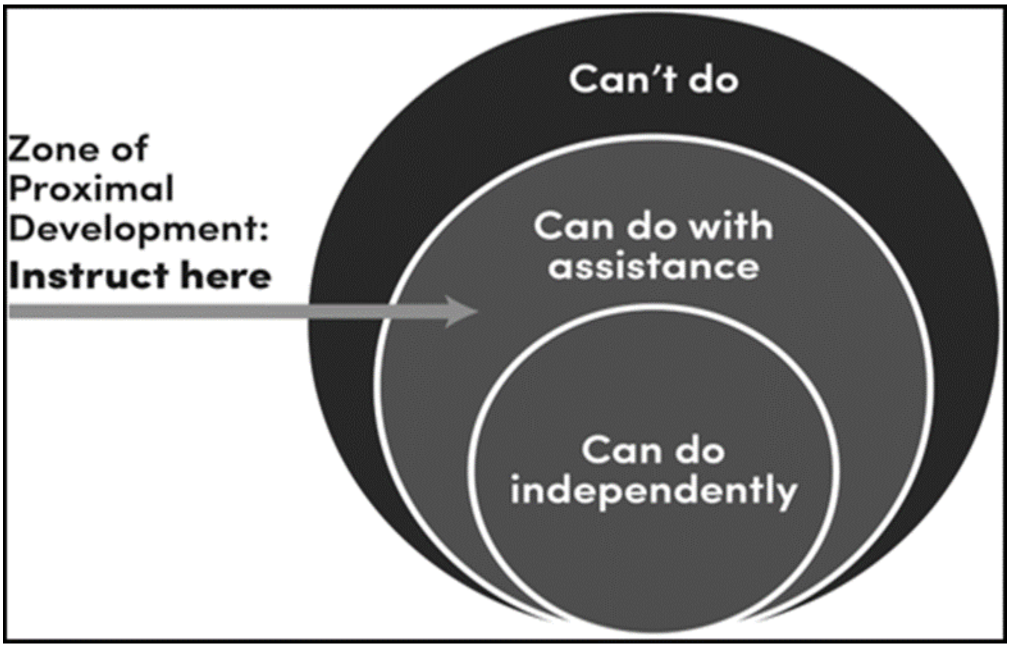


Figure 2.3: The Vygotsky's zone of proximal development theory.

Scaffolding is the theory that focuses on the ability of a learner to receive information (Kalina & Powell, 2009). The scaffolding theory is used to understand that children learn more effectively when they receive assistance from others (Vygotsky, 1962). When scaffolding is applied effectively, it can help learners learn new concepts that they would not have learned on their own. The role of a teacher and others in supporting learners is important in ensuring effective learning (Raymond, 2000). Learners will continue to receive help until they have enough skills to work and understand independently. In this study, learners will be given pre-tests, class activities, and post-tests as scaffolding. Scaffolding is the theory that gradually builds knowledge because learners are offered assistance. Scaffolding is the assistance learners receive as they are led through the ZPD. The scaffolding is for the learners to develop independence and problem–solving skills (Hartman, 2002). Scaffolding emphasizes classrooms that use social constructivist strategies to build and understand knowledge (Agius, 2013). The last aspect of social constructivism is more knowledge of others (MKO). The MKO is the teacher as he or she is the more knowledgeable in class (Mariage, 2000).

Social constructivism also emphasizes the importance of the learners' social interaction with experienced and knowledgeable people from society (Wertsch, 1997). In a constructivist class, teachers should be able to guide learners in transforming their alternative conceptions into new and correct scientific concepts (Mvududu & Thiel-Burgess, 2012). Constructivism is not passive; learners are active because they can negotiate their ideas in the new learning situation. Learners will also be engaged in discussions and other activities. The classmates can also be more knowledgeable and assist the other children. Thus, the learning becomes more meaningful (Amineh & Asl, 2015).

Social constructivism was employed in this study to help learners gain knowledge about scientific concepts by creating knowledge based on the foundation of personal experience. Social constructivism is a highly effective theory when teaching since learners understand when there is collaboration. Through classroom discussions, learners can create the meanings of the concepts (Risse, 2007). Discussions make learners pose related questions accordingly. Learners would only construct and understand ideas by interacting with the environment directly around the learning process (Thomas, 2014). Social constructivism has been successful since learners can construct and think positively (Irvin, 2008). Meaningful learning occurs when learners interact and work together. Classroom language usage is the most important process in a social constructivist setting (Kalina & Powell, 2009). Through the daily interactions between people in the communities, concepts become constructed. Therefore, social interaction of all kinds, especially language, is of greater interest to social constructivists (Burr, 2015). Social constructivists asserted that when learners study concepts, they use language and social artifacts (Schwandt, 1994). Vygotsky mentioned that language improves the quality of teaching and learning science education and precedes knowledge or thinking. Everyday learning, collaboration in a social setting, and the ability to solve problems are through speech (Halliday, 1975). The words, both spoken and written in a social setting, are used to construct concepts or knowledge (Vygotsky, 1962). Corporative learning is integral to creating a deeper conceptual understanding through small group discussions (Doolittle, 1995). It is part of creating a social constructivist classroom (Kalina & Powell, 2009).

Based on the discussions of the two theoretical frameworks, it can be said that conceptual change and social constructivism theories guided the study. The purpose of this study was to identify rural grade 10 Physical Sciences learners' alternative conceptions about waves and sound and address those using ICT simulations. The literature has demonstrated that technology such as simulations can be effective for cognitive dissonance and conceptual shift (Bell et al., 2007; Trundle & Bell, 2010). These simulations are intended to clarify and understand abstract concepts (De Jong & Van Joolingen, 1998). The ICT simulations assisted conceptual change theory to transform learners' alternative conceptions in waves and sound, resulting in meaningful science learning (Smith et al., 1993). An effective classroom is one in which the teacher can teach constructively because the teacher employs constructivist strategies (Kalina & Powell, 2009). The authors went on to say that for teachers to have effective classes, they should know where their learners are in terms of subject knowledge so that they can help them develop new knowledge. As a result, in this study, a pre-test about waves and sound was administered to rural learners to identify their alternative conceptions. These conceptions served as the foundation for conceptual change. The ICT simulations will be integrated into waves and sound lessons as a conceptual change approach from the second phase, intelligibility (Natividad, 2022). Learning took place in a social setting (groups of six learners) to allow learners to interact. The more knowledgeable others, such as the teacher and fellow learners, scaffold others through ZPD during group discussions. After the ICT-based intervention, the post-test was administered to rural grade 10 learners to determine whether learners developed conceptual understanding through conceptual change and social interaction. The data analysis will be carried out following the conceptual change theory.

2.7. Chapter summary

This chapter discussed the relevant literature on alternative conceptions in science education. Furthermore, the chapter looked at the alternative conceptions, particularly in waves and sound topics. This was linked to how ICT simulations have been used to address the alternative conceptions of waves and sound. The chapter also discussed the rural learners' perceptions and performance as far as ICT simulation-based intervention is concerned. The last part of the chapter highlighted the theoretical frameworks that underpinned this study. These included conceptual change theory and social constructivism theory. The next chapter describes in detail the methodology and research design employed to generate data.

CHAPTER 3

RESEARCH DESIGN AND METHODOLOGY

3.1. Introduction

The main purpose of this study was to identify alternative conceptions of waves and sound from rural grade 10 learners and utilize ICT simulations to address them. As a result, this chapter describes the research design and methodology employed to achieve the main goal. It begins by examining the research paradigm under which this study was developed. It thereafter includes a detailed discussion of the methodology, which relates to the nature of the research study. Furthermore, the chapter describes in full the methods and procedures utilized to generate and analyse data during the study. This features a description of the instruments that were utilized, such as a conceptual test, interviews, and lesson observations. Finally, the chapter concluded by examining ethical issues and how they are addressed to provide accurate and trustworthy data.

3.2. Research paradigm

This research study is based on human behaviour, where participants will interact and work with everyone involved. This type of research study requires the application of a research paradigm to improve the credibility and generalizability of the study (Kankam, 2019). A research paradigm is considered a group of beliefs and values shared by society members about the problem and how it can be resolved (Kuhn, 1970). There are different types of research paradigms, which are different collections of beliefs used to address research problems. These types include positivism, interpretivism, pragmatism, post-positivism and critical theory, and these entire paradigm represent different ontological, epistemological and methodological orientations toward research (Hua, 2015). According to Morgan (2014) paradigms are thus social worlds where researchers adopt beliefs and their actions are accepted. Easterby-Smith and Thorpe (2002) stated that choosing the research paradigm is crucial because the paradigm determines research designs and methodologies suitable for the research study.

This study is conceptualized under the interpretive paradigm, as stated in chapter 1. Other researchers regard this paradigm as constructivist in its approach (Wahyuni, 2012). According to the interpretivism paradigm, the goal of social study (and consequently education research) is to comprehend the meaning that informs human action in a given environment (Bertram &

Christiansen, 2014). As such, Cohen et al. (2017) on the other hand, claim that the interpretative research technique aims to comprehend the world of human interaction and that reality is socially produced. An interpretive researcher focuses on the participants' beliefs, experiences, perceptions, ideas, and thinking (Wahyuni, 2012).

An interpretive researcher deeply comprehends the socio-cultural contexts as the participants share the same experiences. The interpretivism paradigm allows the researcher to act as a participant and researcher. As a result, the researcher was part of identifying rural grade 10 Physical Sciences learners' alternative conceptions of waves and sound topics. Through the interpretivism paradigm, the problem was addressed using ICT simulations, as the paradigm stresses the importance of the active role of the researcher in creating data and theories (Goldkuhl, 2012). The interpretive researcher, according to Creswell and Creswell (2017) is more likely to depend on qualitative data generation and analysis approaches. The interpretive method of data generation for the researcher is based on natural approaches to data generation Examples include interviews, observations, document reviews, and visual data analysis (Mackenzie & Knipe, 2006). As a result, the next section summarizes the qualitative methodology used in this study following the requirements of an interpretivism paradigm.

3.3. Research Methodology

As highlighted in chapter 1, the study aimed to identify rural grade 10 Physical Sciences learners' alternative conceptions about waves and sound and use ICT simulations to address those. Consequently, this study followed the qualitative research approach. According to Creswell and Creswell (2017), qualitative research is a set of procedures for gathering and analysing data to get a deeper understanding of a topic or situation using non-numerical data. In line with the latter assertion, Cohen et al. (2017) pointed out that qualitative research data generation strategies that are frequently used include one-on-one interviews, focus group interviews, structured or unstructured questionnaires, observations, etc. Some of these data generation strategies were employed in this research study as well. Predominantly, the qualitative research method does not rely on a single data source (Cohen et al., 2017). As a result of the above, in this study, pre-test/post-test, interviews, and observations were used to explore how the ICT simulations could be integrated to clear learners' alternative conceptions of waves and sound and hence develop their conceptual understanding.

Several approaches are linked to qualitative research. Action research is one of the designs linked to qualitative research. Given the main purpose of this study and the need to respond to the immediate problem linked to rural grade 10 learners' alternative conceptions of waves and sound, the most suitable research method adopted for developing learners' understanding of waves and sound using ICT simulations was action research. Hence, the next section outlines the research design that was followed.

3.4. Participants and Research Site

Research site refers to the specific location, either physical or virtual, where researchers conduct empirical investigations, gather data, or engage with participants to explore research questions or hypotheses within a particular field of study (Creswell & Creswell, 2017). The chosen research site was a school located in a rural community. The school was a high school that offers grade 10 Physical Sciences subject. The school was convenient, accessible and suitable for addressing research questions.

Sampling is the critical process in the methodology of the research study. Alvi (2016) defined sampling as the process through which a certain group of individuals is selected from a population. Parida et al. (2016) stated that the inference and results of the study become accurate and generalizable when a sample represents the population. The researcher adopted purposive sampling in this study. "Purposive sampling is a sampling that relies on the judgment of the researcher when it comes to units (people, cases, and events.) to be studied" (Sharma, 2017, p. 751). Alvi (2016) described purpose sampling as a sampling where the participants are approached having a prior purpose.

As mentioned earlier, the researcher's purpose is to explore rural grade 10 Physical Sciences learners' alternate conceptions about waves and sound and address those using ICT simulations. Purposive sampling allows the researcher to choose the whole population with similar experiences, backgrounds, knowledge, and beliefs (Rai & Thapa, 2015). Therefore, all learners in grade 10 Physical Sciences classes from the chosen school were taken as a sample. Grade 10A had 47 learners, with 25 girls and 22 boys. The learners are generally from a rural school in Zululand district in the Province of KwaZulu-Natal. All these participating learners are Second Language Speakers of English who are predominantly Zulu speakers. The learners were chosen purposively because they reside in rural communities and share the same experiences. The school is also located in a rural area. Purposive sampling is selected to meet the specific needs (Cohen et al., 2017). The researcher also believed the sample would effectively answer the research questions (Farrugia, 2019). The presentation about the research was conducted at the selected school. The sampling is summarised in the table below.

Table 3.1: Selection of the participants.

Activity	**Sample Size**	**Selection Technique**	**Criteria**
Pre and post-tests	47 learners	Purposive	All rural grade 10 Physical Sciences learners
Classroom intervention	47 learners	Purposive	All rural grade 10 Physical Sciences learners
Interviews	6 learners	Random selection	6 learners from the class

3.5. Research design

In this study, the researcher employed an action research design. Clark et al. (2020) described action research as a methodology approach to educational research commonly used in education by teachers and other professions to identify and immediately resolve problems, hence improving their pedagogy and practice. The researcher chose this methodology because it works best on problems immediately identified by the teacher (Cohen et al., 2017). Through an action research-based classroom project, the researcher hoped to identify and rectify waves and sound alternative conceptions using ICT simulations. In action research design, the researcher is both a participant and a researcher (Checkland & Holwell, 2007). The reasons for choosing this methodology are based on the fact that the problem is in class. So the action research design will improve learners' performance and teachers' methodology. Niemi (2019) argued that action research in classrooms is teacher research that combines theory, practice, and improvement of practice in classrooms. Furthermore, Megowan-Romanowicz (2010, p. 993) also reported that "teachers' action research experiences changed them in fundamental ways, challenging their folk wisdom about teaching and learning, building confidence in their abilities, and renewing their commitment to teaching as a vocation".

In this study, the researcher adopted the two action research (AR) cyclical processes by Zuber-Skerritt (2003) and Clark et al. (2020) (see Figure 3.1). For approximately four months, two AR cycles were utilized to conduct the study. Each AR cycle includes four processes or stages, which are; 1) planning, 2) action, 3) observation, and 4) reflection (Kemmis et al., 2014) (see Figure 3.1)

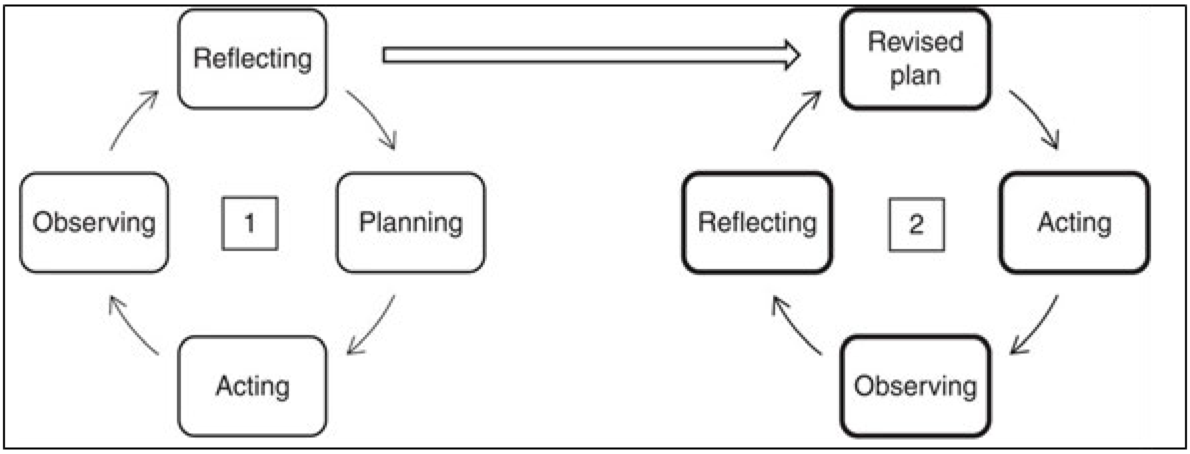


Figure 0.1: The two action research cycles.

These cycles can be repeated whenever it is necessary. The reflection of each cycle informs how the next cycle ensues. In this next section, each of these phases of the action research is explained in line with how the study was conducted. In this study, two action research cycles were completed. The first cycle is discussed in the next

3.5.1 Action Research Cycle 1

(i) Planning

The first phase of the cycle was planning, which involved identifying the learners' alternative conceptions. The concept test (pre-test) instrument was prepared. This test (see Appendix H) was administered to grade 10 learners. The concept test aimed to reveal the alternative conceptions about waves and sound topics that rural grade 10 learners bring as prior knowledge to the science classroom. The second part of this phase included designing and preparing an intervention that was geared to use ICT simulation. The learners' alternative conceptions were then used to prepare for the intervention phase. The ICT simulations were sourced from websites, such as PhET, oPhysics, Java Lab, and Classroom Physics. This intervention was located in the day-to-day teaching of grade 10 in line with the annual teaching plan (ATP). Six lessons were conducted. The lessons covered transverse pulses, transverse waves, longitudinal waves, and sound topics.

(ii) Acting

The second phase of the cycle was acting on the alternative conceptions held by grade 10 learners. This phase generally includes questioning and, or generating data related to the problem. For this study, the ICT simulations were utilized as a means to address prior knowledge about the waves and sound. Six lessons were conducted to address rural grade 10 learners' alternative conceptions. The researcher employed the conceptual change theory to conduct these lessons. This theory included four phases; dissatisfaction, intelligibility, plausibility, and fruitfulness (Posner et al., 1982) which were adopted during social constructivism theory. The social constructivism theory allowed the participants to work in groups to develop conceptual understanding (Rannikmäe et al., 2020). Table 3.1 shows the structure of the ICT simulation-based intervention.

Table 3.2: The ICT simulation-based intervention.

Lesson	Content	Duration	Simulation used
1	Transverse Pulses	1 hour	PhET
2	Superposition of pulses	1 hour	OPhysics
3	Transverse waves	1 hour	Classroom Physics
4	Longitudinal waves	1 hour	oPhysics, Classroom Physics
5	Sound quality	1 hour	PhET, Java Lab
6	Ultrasound	1 hour	Java Lab

(iii)Observing

After the implementation of the ICT simulations-based intervention, another set of data was generated in the form of group activities. In addition to this, the data set generated in the observation phase, and lesson observations taken as video records of the lesson were taken. This data set was important to provide insights into how the grade 10 learners were engaging with the ICT simulations. In addition, this also provided insights about the role of the teacher in the key teaching episodes towards addressing rural grade 10 learners' alternative conceptions using ICT simulations.

(iv)Reflecting

The fourth and last phase of the action research cycle is reflecting, which involves evaluating the effectiveness of the ICT-simulation-based intervention used in addressing rural grade 10 learners' alternative conceptions about waves and sound. In this stage, data were analysed, and new ideas were implemented and revisited. Given the nature of action research, the circle was repeated post the reflection stage for improvements.

3.5.2 Action Research Cycle II

The second cycle included improvements from cycle one. The activities in the revised plan were informed by the lack of understanding of the specified actual content in the concept test. It was observed that the learners experienced a challenge in understanding pulses, particularly about pulse reflection and properties of the medium. This was achieved by the evaluation of group activities during teaching and learning. Therefore, the ICT simulations formed part of the revised plan. This plan included PhET, oPhysics, and Classroom Physics simulations focused on these aspects to reconduct the lesson to observe how the learners interact and understand these concepts.

During the observation of the second cycle of action research, the data was generated through the post-test. This test was similar to the one that was used in the planning phase as a pre-test. Moreover, the post-test was analysed to determine the effectiveness of the ICT simulation-based intervention. In addition, during the reflection phase, the data was generated through the interviews to determine the rural learners' perceptions of learning through ICT simulations. The data were further analysed. The data analysis methods are discussed in the data analysis section.

3.6. Rurality context

The nature of participants refers to the characteristics and attributes of the individuals or groups who are involved in a research study (Wendler & Grady, 2008). Understanding the nature of participants is crucial for designing and conducting research effectively, as it influences various aspects of the research process, including sampling, data collection methods, and data analysis (Creswell & Creswell, 2017). The selected participants with both genders were all Africans, residing in rural communities with a low socio-economic status. The participants were in grade 10 Physical Sciences class from the same chosen school. The school is also located in a rural area. The school lacks the infrastructures for quality education. As a result, the rural education gets compromised. These demographic characteristics of the participant may help researchers understand how different groups may experience or respond to the phenomenon under study (Goodenough & Waite, 2012). The participants had more or less of the same experiences and beliefs which could influence their responses to the research questions and interventions (Punch, 2013).

3.7. Data generation

Appropriate methods are an important feature of the research (Kumar, 2018). The data generation strategies, the rationale for using such strategies, and the data analysis strategies are all considered part of the research methodology (Tsoka, 2020). Johnson (2012) argued that action research is about gathering important information during classroom lessons and making conclusions based on that information. The researcher used different data generation methods to collect data. The tools employed were pre-and post-tests, interview schedules, observation schedules, and lesson plans. The table (Table 3.3) below shows the research methodology and how and why data will be generated. Firstly, the pilot study was conducted. The following section describes how the pilot study was done. The next sections explain how instruments for the main study were utilized to generate the data.

Table 3.3: Data generation method.

Research Question	**Instrument**	**Data Generation Method**	**Data Analysis**
What are the rural grade 10 Physical Sciences learners' alternative conceptions about waves and sound?	Concept test (Appendix H)	A pre-test was administered to all rural grade 10 learners.	Memorandum, Themed
How can ICT simulations address rural grade 10 Physical Sciences learners' alternative conceptions about waves and sound?	Interview Schedule (Appendix J)	Interviews were conducted with six learners before the intervention.	Themed
	Lesson observation Schedule (Appendix N)	Video recordings were taken during the class lesson.	Thick description, Transcription, Rubric
	Post-test (Appendix H)	A post-test was administered to all rural grade 10 learners.	Excel spreadsheet and compared.
How do rural grade 10 Physical Sciences learners' perceptions of learning through ICT simulations relate to their performances?	Interview Schedule (Appendix Q)	Interviews were conducted in class with six learners	Themed

3.7.1 Pilot study

As indicated earlier, this study used the concept test to diagnose rural grade 10 alternative ideas around waves and sound. This concept test was taken from a study by Tongchai et al. (2009) see Appendix G. The concept test was made up of 22 multiple-choice questions. Questions 17, 18, 19, 21, and 22 were all two-tiered. Each question was worth two points. The concept test was then given to a pilot sample of 10 rural grade 10 who were Physical Sciences learners from a nearby school to enhance both content and face validity. The researcher then used a corresponding memorandum to mark the learners' responses. The preliminary analysis of this test identified alternative conceptions of waves and sound from the pilot sample. The questionnaire tests most of the concepts for waves and sound in grade 10. According to the constructivism theory, learners come to class with knowledge, so the pre-test identified the learners' conceptions of waves and sound. The pre-test revealed that learners have poor conceptions implying naïve and alternative conceptions that are consistent for most questions. The reflection of the questionnaire suggested that there are a few changes that need to be made to this instrument that are contextual to the South African curriculum statement. For example, the standing wave concept which is not covered in the annual teaching plan or CAPS is included in the pilot pre-test. This was replaced by the transverse and longitudinal waves from the grade 10 CAPS curriculum. These questions were taken from previous DBE standardised questions which have passed both content and face validity. The revised final version of the main study now contains 25 multiple-choice questions (Appendix H). Questions 21 to 25 are two-tier questions so that the researcher can determine the learners' alternative conceptions.

Given that the sample of this study was from a rural setting where the command of English is not satisfactory, the concept test was also given to an English teacher to check the language usage, and appropriateness for the context. Table 4 of alternative conceptions will be used to probe and support learners' understanding and the use of simulations for the main study. The preliminary analysis of the test revealed a series of learner alternative ideas on the topic, these are listed below:

1. High and low pitches have the same frequencies and the same amplitudes.
2. Equally loud sounds with low and high pitches have different frequencies and different amplitudes.
3. Sound at a higher frequency has a greater penetration.
4. The amplitude determines the speed of sound waves.
5. According to $v = f\lambda$, the speed of a sound wave is proportional to its frequency
6. For a pulse to take a shorter time, the string must be flicked faster to get a higher frequency.
7. For a pulse to take a shorter time, one must flick the string further up and down to create a pulse with a smaller amplitude.
8. For a pulse to take a shorter time, the tension in the string should be increased because the velocity increases as the tension decreases.
9. When sound is produced, the dust particle moves away from the speaker.

10. Higher pitch causes the dust particle to stay in the same position.

11. An increase in volume will cause the dust particle to stay in the same position.

12. Pulses (crests) cancel each other when they meet.

13. Pulses (crests) become smaller because they collide and lose energy when they meet.

14. When the frequency is doubled, the wavelength increases.

15. Wavelength increases as mass increases because tension increases wave speed.

3.7.2 Instruments

The following are the instruments that were used in this study.

(i) Concept test

The concept test (see Appendix H) which was adapted from Mechanical Waves Conceptual Survey (MWCS), developed by Tongchai et al. (2011) was employed to answer the first research question about identifying the learners' alternative conceptions of waves and sound. The diagnostic test is a multiple-choice question test administered to grade 10 learners. The researcher invigilated the participants to ensure an uninterrupted writing session. The concept test aimed to reveal the alternative conceptions about waves and sound topics learners bring as prior knowledge to the science classrooms. The diagnostic test addressed a constructivist approach which states that learners come to class with prior knowledge. The new knowledge was created from the existing knowledge. The researcher marked the learners' test scripts to identify the alternative conceptions. The rural grade 10 learners' alternative conceptions probed were used to prepare for the classroom lessons.

(ii) Interview schedules

The interview schedule (see Appendix J) was used as an instrument for this study. Six learners were selected randomly from the class to answer semi-structured interview questions before the intervention phase, which was about integrating ICT simulations in teaching and learning, and as the intervention strategy in addressing alternative conceptions in waves and sound. The participants were interviewed for 40 minutes. The second interview (see Appendix Q) was conducted after the intervention phase to determine rural learners' perceptions about using ICT simulations in waves and sound and their performance in the post-test.

(iii) Observation schedule

An observation tool such as a rubric (see Appendix N) was used to gather more data to answer the research questions. The classroom lessons were conducted during the normal teaching hours aligned with the CAPS notional hours. During the classroom lessons, the classroom observation data were generated through video recording (Cohen et al., 2002; Jewitt, 2012). The observation process was conducted during the observation stage through video recording, and using a rubric (see Appendix N) for meaningful learning with ICT, which was adopted from Koh (2013). The cellphone was used to take lesson videos. This observation focused on using ICT simulations in teaching and learning waves and sound.

(iv) Post-test

A concept test was later used as a post-test (see Appendix H). A post- test is a test given after a lesson or period of instruction to determine what learners have learned. The purpose of giving the same test was to find what change was brought about by the intervention toward understanding the concepts. A post-test was administered to grade 10 rural learners. The researcher marked the learners' test scripts to measure their achievement and the effectiveness of using ICT simulations.

3.8. Data analysis

Data analysis is a process that consists of a number of stages, i.e. examining, categorizing and tabulating or otherwise recombining the evidence, in order to address the objectives of a study (Rabiee, 2004). Qualitative thematic analysis analysed the qualitative data from the pre/post-tests, lesson plans, interviews, and observations (video recording and rubric). The data generated from pre, and post-tests were analysed through qualitative descriptive analysis. The pre and post-test results were also analysed through an Excel spreadsheet which compared the findings to determine the effectiveness of ICT simulations as an intervention teaching strategy. This thematic analysis enables interpreting learners' opinions (Alhojailan, 2012). Qualitative data analysis is guided by Braun and Clarke (2006) : familiarizing oneself with the information, themes are being examined, defined, and written up while seeking them. The thematic analysis was conducted in line with constructivism and conceptual change. Pre/post-tests, lesson plans, observations, and semi- structured interviews data were read, organised, and themed into categories. Clark et al. (2020) mentioned that themes and patterns must be identified during data analysis to provide accurate and robust evidence for the findings. The data generated through video recording was transcribed, read, and richly described. Video recording was transcribed to formulate a tentative understanding (Eshach & Schwartz, 2006). See Table 3.3 above, which summarises how was the data analysis executed.

The diagnostic test was administered to a sample of rural grade 10 learners to diagnose their alternative conceptions in the topics of waves and sound. The alternative conceptions were identified from the qualitative analysis of the explanations given by the learners on the pre-test of the main study (see Appendix O). Question-by-question analysis was used to determine the learners' possible alternative conceptions. See Appendix H for a complete list of multiple-choice questions (MCQs). The pre-test consisted of 25 MCQs. Questions 5, 10, 11, and 17 were all two-tiered. The reasons were provided for the two-tiered questions since the options were one-word answers. The interviews conducted before the implementation of ICT simulation intervention were analysed by categorizing the data into themes. This analysis occurred in the planning phase of the first action research cycle.

This research aimed to develop learners' conceptual understanding and thus drew on Posner's conceptual change model (CCM) (see Figure 5.3) for data analysis. In the conceptual change approach, there are four important phases described in the theoretical framework: dissatisfaction, intelligibility, plausibility, and fruitfulness (Posner et al., 1982). All the lessons conducted were analysed the same way through conceptual change theory. For the lesson observations the rubric for meaningful learning with ICT adopted from Koh (2013) was used to analyse the observations. The data from interviews conducted after the implementation of ICT simulations were read, categorized and themed. The themes are presented and discussed in chapters 3 and 4.

3.9. Research Rigour

Rigour in research entails researchers employing verification strategies and self-correction mechanisms throughout each stage of the research process (Firth et al., 2005). This active engagement aims to enhance the reliability and validity of qualitative data analysis (Mays & Pope, 1995). The study employed a qualitative action research methodology. The qualitative method involves trustworthiness to ensure reliability and neutrality (Clark et al., 2020). Trustworthiness can be achieved by demonstrating the following criteria; dependability, credibility, confirmability, and transferability (Lincoln & Guba, 1985). Dependability was achieved using the same rural grade 10 learners throughout the research. The researcher maintained the consistency of the instruments by ensuring that all learners had the same questions (Mabalane, 2019). All rural grade 10 learners had the same concept test. The data was given back to the participants to confirm the truth about their data. Lastly, an audit trail (keeping all information and proper documentation) ensured dependability.

The researcher and participants were given enough time to complete research tasks (prolonged engagement). Data generation tools, such as concept test, post-test, interviews, and observations, were utilised to gather information (triangulation). Lastly, learners were also given the results to confirm the truth (member check). The techniques mentioned above ensured credibility. Triangulation also occurs in confirmability; the data were generated and obtained from various sources (concept test, post-test, interviews, observations). The participants were all rural grade 10 learners tested using the same questions to ensure neutrality. "The research findings and claims to knowledge are much more impactful if demonstrated as trustworthy" (Clark et al., 2020, p. 104). The data generated were given to the participants to confirm and maintain the neutrality of the findings. Transferability was confirmed by using rich descriptions (the implementation process is outlined in the data generation section). Purposive sampling was employed in this study to ensure transferability. The instruments used to generate data are attached as research appendices for future use.

3.10. Ethical issues

The University of KwaZulu-Natal granted the permission to conduct research and ethical clearance. The protocol reference number is HSSREC/0005133/2022. The letters requesting permission to conduct the research study were also sent to the Department of Education and the school principal. The Department of Education granted the researcher permission to study in one selected school. The school's principal also offered permission to conduct the research study. An informed consent form was secured from each participant (Sileyew, 2019). Participation in this research study was voluntary. The participants may have quit without penalty at any time. The informed letters were also sent to parents to sign on behalf of underage learners. During the planning stage of an action research cycle, when the meeting was conducted, the purpose of the study was explained to the participants. The study aimed to identify rural grade 10 Physical Sciences learners 'alternative conceptions about waves and sound and address those through ICT simulations. The participants were informed that their information would be kept confidential and their identities would not be revealed. The information generated was used for research purposes only. The participants were also given the contact details, should they wish to know more about participants' rights.

3.11. Chapter summary

This chapter described the methodology adopted in this study. Furthermore, it highlighted the data generation methods utilising different instruments. Moreover, the data analysis was described to answer the research questions. The chapter employed a qualitative research methodology; hence it further discussed credibility and trustworthiness. In the next chapter, the researcher analyses the data generated from the concept test (pre-test) and interviews conducted before the ICT-based intervention. Furthermore, the findings from the analysis are discussed.

CHAPTER 4

PHYSICAL SCIENCES ALTERNATIVE CONCEPTIONS ABOUTWAVES AND SOUND

4.1. Introduction

The purpose of the study was to identify rural grade 10 Physical Sciences learners' alternative conceptions about waves and sound and address those conceptions through ICT simulations. The focus of this chapter is to report on the alternative conceptions held by rural grade 10 learners about waves and sound. As such, this chapter responds to the first research question that asked: *What are the rural grade 10 Physical Sciences learners' alternative conceptions about waves and sound?*

The chapter further presents the findings of the data generated throughinterviews conducted before the ICT intervention. Finally, the chapter discusses the findings of the first research question with existing literature and concludes from these reported alternative conceptions.

4.2. Rural Grade 10 Science Learner's Alternative Conceptions about Wavesand Sound

The analysis was organised into five themes in a topic in line with the National Curriculum Framework. These themes are (i) transverse pulses on a string, (ii) superposition of pulses, (iii) transverse waves, (iv) longitudinal waves, and (v) sound. In the following sub-sections, the findings from the analysis of the responses from the diagnostic test are presented. In the analysis, the boldface in the options indicated the correct answer to the question. However, during the analysis, the focus was not given to the right answers. The distribution of the option was analysed to map the nature of the alternative learners' conceptions of waves and sound. As much as a numerical count indicated the distribution of learners' responses, there were no statistical inferences and meanings made out of these numerical counts of the data presented in this work.

4.2.1 Transverse pulses on a string

In this section, the researcher examined pulse amplitude, pulse speed, string characteristics, pulse frequency, and pulse reflection. Questions 1 to 5 evaluated the conceptual knowledge of the participants in the diagnostic test. The focus of MCQ 1 was to determine the learners' understanding of the relationship between the speed of the pulse produced and the properties of the string in which the pulse travels. Table 4.1 below provides the distributions of the options chosen by the rural grade 10 learners.

Table 4.1: Distribution of learners selecting each option for MCQ 1.

Sub-topic	Options					
Speed of pulses	A	B	C	D	E	**F**
	7	16	12	8	2	**2**

Most participants chose option B implying that for a pulse to take a shorter time, one should flick the string faster to create a pulse with a higher frequency. In addition to this observation, 12 respondents chose option C which implied that a pulse with a larger amplitude can take a shorter time to reach the end. Eight participants assumed that the speed of a pulse would increase when the created pulse has a smaller amplitude. These responses show that learners had alternative conceptions of this idea.

MCQ 2 focused on understanding the relationship between the speed of the pulse and the density of the string. Table 4.2 below shows how rural grade 10 learners chose their answers.

Table 4.2: Distribution of learners selecting each option for MCQ 2.

Sub-topic	Options			
Pulse speed and properties of a string	A	B	C	D
	8	4	13	22

The majority of learners selected option D. These participants mistakenly believed that the speed of pulse on a string depends on frequency and wavelength according to $v=f.\ \lambda$. Another group of 13 participants asserted that a girl should decrease the tension in the string because the velocity increases as the tension decreases. These indicate the alternative conceptions from the correct scientific understanding of this idea

The MCQ 3 involved choosing the correct sketch that shows the complete reflection of an asymmetric pulse moving along a string to the right toward a fixed end. Table 4.3 below shows the distributions of the options selected by the rural grade 10 learners.

Table 4.3: Distribution of learners selecting each option for MCQ 3.

Sub-topic	Options				
Pulse reflection	A	B	C	D	E

	8	16	10	**8**	5

The most common alternative conception was option B, which showed a reflected pulse on the same string but without a vertical inversion. Also, 10 participants selected option C, which showed a sketch of an asymmetrical pulse with no change after reaching a fixed end. Similarly, these indicated alternative conceptions of this idea.

MCQ 4 used the same context in item 3 except that the string was tied to a free-end string. The selection of the options by the rural grade 10 learners is shown below in Table 4.4.

Table 4.4: Distribution of learners selecting each option for MCQ 4.

Sub-topic	Options				
Pulse reflection	A	**B**	C	D	E
	5	**5**	7	10	20

The most common alternative conceptions that the participants had, were options D and E. In option D, learners selected a sketch that showed a reflected pulse on the opposite side of the string and vertically inverted, while option E was the same as option D, however, the reflected pulse was not asymmetrical.

The MCQ 5 was a two-tier question. This question assessed the knowledge of the frequency of a wave when the wave reaches a boundary. The item asked learners to compare the frequency ofa wave in the light rope to the frequency of a wave in the heavy rope. The second letter represents the reason given by the learners. The table below shows the distributions of the options selected by the rural grade 10 learners.

Table 4.5: Distribution of learners selecting each option for MCQ 5.

Sub-topic	Options								
Frequency and	A-a	A-b	A-c	B-a	B-b	B-c	C-a	**C-b**	C-c

Medium	8	6	7	0	5	1	1	**5**	1

The findings show that 21 participants had a common alternative conception. The respondents believed that the frequency of a wave in the light rope is greater than in the heavy rope. However, their reasons differ. Eight learners thought that a medium with greater mass has greater inertia, and this makes fewer waves propagate through the medium. In addition to this observation, seven learners who selected A-c thought that more waves propagate through the medium. The second group of six learners suggested that the frequency of a wave is determined by its source, not by the medium's properties.

4.2.2 Superposition of pulses

In this section, the phenomenon of constructive interference was assessed. Questions 6 and 7 probed knowledge of the overlapping of the two pulses along the same medium. Moreover, learners' responses relating to constructive interference are considered for possible alternative conceptions held by learners when answering the questions. The aim of MCQ 6 was to examine the understanding of the constructive interference of two pulses. Learners were expected to choose the diagram that corresponds to the shape of the resultant pulse after 2s. The distributions of the options selected by rural grade 10 learners are shown in Table 4.6 below.

Table 4.6: Distribution of learners selecting each option for MCQ 6.

Sub-topic	**Options**					
Constructivism interference	A	B	C	**D**	E	F
	13	15	14	**3**	2	0

The correct conceptual understanding was the diagram that presented the constructive interference (superposition) of two pulses at the moment of overlap, which is the addition of displacements due to each wave pulse on a point-by-point basis. Most participants selected option B, a sketch that showed no superposition except for the peaks of the overlapped pulses. The other group of 14 participants selected the sketch that showed an enlarged amplitude of the resultant pulse as pulses overlapped. These findings indicated the alternative conceptions held by the rural grade 10 learners.

The MCQ 7 is a continuation of question 6. The item required learners to select the correct sketch and explanation that corresponds to the resultant pulse of two pulses after 5s. Table 4.7 below shows the rural grade 10 learners' choices.

Table 4.7: Distribution of learners selecting each option for MCQ 7.

Topic	Options		
Constructive interference	**A**	B	C
	27	7	13

The most relevant conceptual knowledge was the diagram that showed the two pulses that have passed through one another and retained their shape after the overlapping of two pulses to show the constructive superposition. The most frequent alternative conception was option C. These participants selected a sketch that showed pulses that had cancelled each other. The second common misunderstanding of the participants was a sketch that showed smaller pulses and the explanation was, that waves have become smaller because they have collided and therefore have lost energy.

The MCQ 8 assessed the understanding of the destructive interference of two pulses when they meet. The correct conception was the addition of displacements due to each wave pulse on a point-by-point basis. Table 4.8 below displays the distributions of rural grade 10 learners' options.

Table 4.8: Distribution of learners selecting each option for MCQ 8.

Sub-topic	Options					
Destructive interference	A	B	**C**	D	E	F
	6	10	**9**	9	10	3

Options B and E were the alternative conceptions that were indicated the most by the respondents. Option B implied that after 3s the pulses will cancel each other, while option E implied that nothing will happen, the pulses will not superpose. Another frequent alternative conception chosen by another set of participants was option D, which suggested that the pulses would meet and form pulses with smaller amplitudes.

The MCQ 9 is a continuation of item 8. Learners were required to identify the diagram and explanationthat correspond to the shape of the resultant pulse after 5s. The correct conception was the pulses that passed through one another and retained their shapes. Table 4.9 below presents the options selected bythe rural grade 10 learners.

Table 4.9: Distribution of learners selecting each option for MCQ 9.

Sub-topic	Options			
Destructive interference	**A**	B	C	D
	20	5	10	12

Most participants selected option D, which implied that after the superposition, the pulses collided with each other and turned upside down. Furthermore, option C was also selected more often, here the participants thought that after superposition, the pulses become smaller because they have lost energy.

4.2.3 Transverse waves

In this section, concepts such as the wavelength, period, and frequency of a wave, as well as in-phase and out-phase particles were assessed. Questions 10, 11, 12, 13, and 14 tested these concepts. As a result, learners' responses relating to transverse waves are analysed for possible alternative conceptions held by learners when answering the questions.

The focus of MCQ 10 was to test the period of a wave conceptual understanding. The displacement versus time graph that showed a transverse wave diagram was provided, and learners were asked to identify the wave property labelled x from the graph. Learners were also expected to give a reason for the answer. The correct concept understanding was the period, which is the time needed for the particle to complete one cycle of motion during the passage of the wave. Table 4.10 below presents the distributions of the options selected by the rural grade 10 learners.

Table 4.10: Distributions of learners selecting each option for MCQ 10.

Sub-topic	Options											
Period of a	A-a	A-b	A-c	B-a	B-b	**B-c**	C-a	C-b	C-c	D-a	D-b	D-c

Wave	0	0	0	0	0	**2**	26	3	3	**3**	3	1

The most common alternative conception was option C-a. This group of learners identified the wave property as wavelength. The learners believed that the wavelength is measured between consecutive crests, without considering the labels given for each axis of the graph. The respondents viewed the graph as representative of the transverse wave that propagates through the medium.

The MCQ 11 examined the understanding of the wavelength concept. Once again, the learners were given a graph, though the graph had a different x-axis, the graph of displacement versus distance. The item asked the learners to select the correct wave property represented by the label Y from the given graph. The wavelength was the wave property represented by label Y, which is the distance between two identical points on successive waves. Table 4.11 below shows the options distribution by rural grade 10 learners.

Table 4.11: Distribution of learners selecting each option for MCQ 11.

Sub-topic	**Options**											
Wavelength	A-a	A-b	A-c	B-a	B-b	B-c	**C-a**	C-b	C-c	D-a	D-b	D-c
	3	4	2	1	10	0	**5**	4	4	6	3	2

Most participants selected option B, with reason b, which implied that the wave property was the period, and further reasoned that period is the time needed by the wave to cover the distance between two successive points. The next alternative conception discovered was D, with the reason a. In this case, the participants selected the amplitude as the labelled wave property and described it as the distance between two identical points on successive waves.

In MCQ 12 the understanding of the relationship between the frequency of a transverse and the number of waves was tested. The learners were required to select the option that showed a direct proportionality between the frequency and the number of waves. Moreover, they were requested to perform a calculation to arrive at the correct answer. The correct conceptual understanding was that the frequency of a transverse wave is the number of waves per second, and the frequency of source B was 5 times the waves of source A. Table 4.12 below shows the distribution of learners for each option.

Table 4.12: Distribution of learners selecting each option for MCQ 12.

Sub-topic	Options			
Frequency and wave number	A	**B**	C	D
	8	**13**	7	19

The first common misunderstanding was option D, which implied that the frequency of wave B would be greater than the 80 Hz frequency of wave A. In addition to this observation, the participants selected option A, which suggested that the frequency of source B would be 8 times the frequency of source A. The last set of participants had an idea that the frequency of source B would be less than that of source A.

This MCQ (13) required students to understand the relationship between the frequency of the wave and the wavelength of the wave. The item asked how the wavelength would change if the frequency of a transverse wave was doubled. The most relevant conceptual knowledge wasif the frequency of a transverse wave is doubled while everything else stays the same, the wavelength decreases because it is inversely proportional to the frequency since the velocity doesn't change. Table 4.13 below shows how learners answered this question.

Table 4.13: Distribution of learners selecting each option for MCQ 13.

Sub-topic	Options			
Frequency and wavelength	A	B	C	**D**
	16	9	13	**9**

Most respondents selected option A which implied that the wavelength increases because it depends on the amount of energy flowing in the waves. Furthermore, another group of participants chose option C, the learners asserted that the wavelength stays the same, it depends on the length of the rope, and the frequency doesn't affect it.

In this MCQ 14, the knowledge of the particles that are in phase was examined. The item required learners to choose the correct description of the particles that are in phase. The most relevant conceptual understanding was that the particles in phase must have the same displacement and be moving in the same direction. Table 4.14 below presents the distributions of the options chosen by rural grade 10 learners.

Table 4.14: Distribution of learners selecting each option for MCQ 14.

Sub-topic	Options			
In-phase and out-phase	A	B	C	**D**
	2	10	14	**21**

The most common alternative conception was option C, which suggested that the particles in phase need only move in the same direction. In addition to this observation, 10 participants chose option B which implied that the particles in phase need only have the same position.

4.2.4 Longitudinal waves

In this section, concepts such as compression, rarefaction, wavelength of a longitudinal wave, and propagation of a longitudinal wave were examined. Questions 15, 16, and 17 tested these concepts. Furthermore, learners' responses relating to longitudinal waves are analysed for possible alternative conceptions held by rural grade 10 learners when answering the questions. The aim of MCQ 15 was to examine the understanding of the compression and rarefaction of the longitudinal waves. The learners were expected to choose the option that correspond to the correct descriptions of the compression and rarefaction. The most relevant conceptual knowledge was that Compression refers to the area of increased pressure, while rarefaction pertains to the region of decreased pressure. Table 4.15 below presents the distributions of the options selected by rural grade 10 learners.

Table 4.15: Distribution of learners selecting each option for MCQ 15.

Sub-topic	Options			
Compression and rarefaction	**A**	B	C	D
	21	5	5	4

The first group of five participants chose option B, which implied that compression was the region of low pressure and rarefaction was the region of high pressure. Another set of participants suggested that compression was the minimum displacement of particles and rarefaction was the maximum displacement of particles. In addition to this observation, four respondents selected option D, the opposite of option C, which implied that compression was the maximum displacement of particles and rarefaction was the minimum displacement of particles.

The MCQ 16 assessed the application of the longitudinal waves and used sound as an example of the longitudinal waves. Learners were required to select the option that corresponds to the type of wave that described the sound as an example. The correct conceptual understanding was that sound is the longitudinal wave that needs a medium to propagate. Table 4.16 displays the distributions of the optionschosen by the rural grade 10 learners.

Table 4.16: Distribution of learners selecting each option for MCQ 16.

Sub-topic	**Options**			
Sound wave as a longitudinal wave	A	B	**C**	D
	18	4	**18**	5

Learners' responses to this question showed option A as the most common alternative conception. Their choice described a sound wave as a transverse wave that requires a medium to propagate. MCQ 17 probed the learners' understanding of the sound waves produced by the tuning fork. In this item, learners were given a diagram of the sound waves created by the tuning fork, and they were expected to identify the wavelength of the longitudinal waves. The reasons were also provided. The correct theoretical understanding was that the wavelength of the longitudinal wave was the distance between two consecutive compressions. Table 4.17 presents the distributions of the options chosen by the rural grade 10 learners.

Table 4.17: Distribution of learners selecting each option for MCQ 17.

Sub-topic	**Options**											
Sound waves	A-a	A-b	A-c	**B-a**	B-b	B-c	C-a	C-b	C-c	D-a	D-b	D-c
	1	1	1	**0**	3	0	1	0	4	2	0	1

The most common alternative conception was option C, which showed one compression, and the reason was the time taken to complete one compression. In option B-b, learners responded correctly, however, their reasoning was incorrect, as they described label B as the distance between two consecutive rarefactions.

4.2.5 Sound

In this section, the concepts such as pitch, loudness, quality, echo, and ultrasound were examined. Questions 18, 19, 20, 21, 22, 23, 24 and 25 tested these concepts. Additionally, learners' responses relating to sound are analysed for possible alternative conceptions held by learners when answering the questions. MCQ 18 considered learners' understanding of the relationship between frequency and amplitude as they affect the pitch of the sound. The question tested whether a student understands that a person, who sings at the same volume as another person, but at a higher pitch, will generate a sound wave with the same amplitude but a different frequency. Learners were expected to relate with amplitude and volume as the same in this question. Table 4.18 shows the distributions of options selected by rural grade 10 learners.

Table 4.18: Distribution of learners selecting each option for MCQ 18.

Sub-topic	**Options**			
Pitch and loudness	A	**B**	C	D
	11	**16**	7	13

The correct conception was that the amplitude is the same since the students sing equally loud, while the frequencies are different as the students sing at high and low pitches. The qualitative analysis reveals two incorrect models which are options A and D. Most learners selected option D which suggested that the two frequencies are different, and the amplitudes are also different. Thirteen learners selected option A, which implied that the two frequencies are the same, but the amplitudes are different.

MCQ 19 aimed to test whether learners understand that the speed of sound waves in the air is independent of the frequency of the waves. In this question, learners had to compare the velocity of two sound waves with different frequencies and the same amplitude in air. The correct conceptual knowledge was that both speeds are equal since sound speed depends only on-air properties. Table 4.19 below shows how rural grade 10 learners answered this question.

Table 4.19: Distribution of learners selecting each option for MCQ 19.

Topic	**Options**			
Speed of sound waves	**A**	B	C	D

	9	18	7	12

The most frequent conception selected by the learners was option B, which indicated that the speed of the wave increases with the higher frequency, using the equation $v = f\lambda$. Another conception discovered was option D (12 learners), which suggested that the sound with a higher frequency is more penetrating.

MCQ 20 aimed to determine whether learners understand that the speed of sound waves in air is independent of the waves' frequency and amplitude. This question was very similar to Question 19, which required learners to compare the velocities of two sound waves in the air with different amplitudes but the same frequencies. Again, the correct conceptualunderstanding was that both speeds are the same. The table presents the distribution of optionschosen by rural grade 10 learners.

Table 4.20: Distribution of learners selecting each option for MCQ 20.

Topic	Options			
Speed of sound waves	**A**	B	C	D
	14	13	9	11

The most common conception selected by 14 participants was option A, due to the incorrect belief that the speed of waves depends on the amplitude. The second alternative conception similar to the one in Question 19, was option B, in which the thirteen participants believed that the speed of the waves depends on the frequency according to $v=f\lambda$. On the other hand, a set of 11 participants selected option D, which suggested that the sound wave with a larger amplitude travels faster.

The focus of MCQ 21 was to examine the understanding of the longitudinal oscillation of an air particle perturbed by sound waves. Learners were requested to explain the movement of a particle affected by a sound wave in the presence of a loudspeaker when the device is activated and emits a loud, constant-pitched tone. The most relevant theoretical understanding was that the particle would move back and forth about the same position. Table 4.21 below displays the distribution of the options chosen by rural grade 10 learners.

Table 4.21: Distribution of learners selecting each option for MCQ 21.

Sub-topic	Options

Displacement of sound waves	A	**B**	C	D	E
	1	**4**	12	25	5

Most participants selected option D, which implied that the particle would move away from the speaker due to the sound produced. Another frequent conception selected by 12 learners was option C, which implied that the particle would move up and down about the same position due to the sound produced.

MCQ 22 focused on the learners' understanding of whether or not an increase in the frequency of the sound waves will produce a faster oscillation of an air particle. This question is a continuation of the previous one and asks about the motion of dust particle if the pitch of the sound is increased but the volume remains the same. The correct conceptual understanding was that the particle would move back and forth faster. Table 4.22 shows the learners' choicesfor this question.

Table 4.22: Distribution of learners selecting each option for MCQ 22.

Sub-topic	**Options**							
Displacement of sound	A	B	**C**	D	E	F	G	H
Waves	13	6	**5**	2	6	5	5	4

The most common conception selected by the participants was option A. In this case, learners thought that an increase in frequency would cause the dust particle to stay in the same position. Furthermore, options B, D, and F revealed that the participants had conceptions that the dust particle would move further. In option E, learners believed that the particle would move up and down faster.

MCQ 23 aimed to determine whether learners understand that an increase in a sound wave's amplitude will produce a wider oscillation of a dust particle. This question is a continuation of the previous one and asks what would happen to the motion of the dust particle when the volume of sound is increased but the pitch remains constant. The correct conception was that the dust particle would move back and forth further. Only Table 4.23 below shows the distributions of the options chosen by rural grade 10 learners.

Table 4.23: Distribution of learners selecting each option for MCQ 23.

Sub-topic	**Options**

Displacement of sound Waves	A	**B**	C	D	E	F	G	H
	7	**2**	8	3	6	6	7	8

The most common alternative conceptions were options C and H, with an equal number of respondents. In option C, learners' understanding was that the dust particle would move back and forth faster. The second group of learners chose option H because they believed that the particlewould move away faster as a sine curve.

MCQ 24 assesses the understanding of the echo concept. The question had a diagram that showed a boy standing between high walls. The question further required the learners to choose the corresponding description of an echo sound. The correct conceptual understanding was that an echo is the reflected sound wave from the surface. Table 4.24 shows the distributions of options selected by rural grade 10 learners.

Table 4.24: Distribution of learners selecting each option for MCQ 24.

Sub-topic	**Options**			
Echo	**A**	B	C	D
	22	14	2	9

The most frequent alternative conception selected by participants was option B. In this case, learners described an echo as refracted sound waves. The second alternative conception was option D. In this situation, learners explained an echo as the repetitions of sound.

MCQ 25 was the last item and it examined the knowledge of the ultrasound, whether learners know the difference between the sound heard by animals and humans. The question asked the learners to choose the option that correspond to the reason why a dog can hear a dog whistle but the owner of the dog can't. The most relevant conceptual knowledge was that dogs can detect a sound of a higher frequency than humans. Table 4.25 presents the distribution of options selected by rural grade 10 learners.

Table 4.25: Distribution of learners selecting each option for MCQ 25.

Sub-topic	**Options**			
Ultrasound	A	**B**	C	D

4	**28**	6	8

Most learners selected option D, which reasoned that dogs detect sound at a higher speed than humans. Moreover, option C was analysed as the second alternative conception. In this case, respondents maintained that dogs detect sounds of lower frequency than humans. The following is the list of alternative conceptions about waves and sound that emerged from the qualitative analysis of rural grade 10 learners' responses.

4.3. Emergent Rural Grade 10 Learners' Alternative Conceptions in Waves and Sound

The rural grade 10 Physical Sciences learners' responses showed poor conceptual understanding. The following list reveals the alternative conceptions about waves and sound identified from the learners' responses. Additionally, the alternative conceptions listed below were indicated by most participants. The alternative conceptions are arranged according to the themes.

Transverse pulse on a string

1. For a pulse to take a shorter time, one must flick the string faster to create a higher frequency or larger amplitude.
2. For a pulse to take a shorter, she should not change the properties of the string because thespeed of pulse on a string depends on frequency and wavelength according to $v=f.\lambda$.
3. When an incident pulse reaches the fixed end, a reflected pulse with no vertical inversionremains on the same side of the string.
4. The frequency of a wave in the light rope is greater than in the heavy rope.

Superposition of pulses

5. Pulses (crests) cancel each other when they meet.
6. Pulses (crests) become smaller because they collide and lose energy when they meet.

Transverse waves

7. When the frequency is doubled, the wavelength increases.
8. A period is the time needed by the wave to cover the distance between two successive points.
9. The particles in phase need only have the same position.

Longitudinal waves

10. Compression is the region of low pressure and rarefaction is the region of high pressure.
11. A sound wave is a transverse wave that requires a medium to propagate.

Sound

12. Equally loud sounds with low and high pitches have the same frequencies and different amplitudes.
13. The particle will move away from the speaker due to the sound produced.
14. An increase in frequency will cause the dust particle to stay in the same position.
15. When the volume of the sound is increased but the frequency stays the same, the particlewill move up and down faster.

4.4. Interviews Before the Implementation of ICT Simulation Intervention

The analysis of the interviews revealed that the participants responded with quick, short, and obvious answers. Some of the responses weresingle-word or phrase answers. Some responses indicated that the participants had difficulty understanding the questions. Some of the significant and appropriate questions are offered below regarding themes that developed during participants' interviews (Choudhury & Pattnaik, 2020). The emerged themes were (i) conceptual understanding, (ii) conceptual difficulties, and (iii) support. This section presents and further explains the emerged themes as follows:

(i) Conceptual understanding

Conceptual understanding refers to the grasping the underlying concepts and relationships rather than just memorizing facts. It enables learners to apply their knowledge in solving problems. When the rural grade 10 learners were asked about what they knew about mechanical waves and sound. The 'conceptual understanding' emerged as a theme. Most of the participants had the same conceptual understanding of mechanical waves and sound. The participants' responses reflected partial understanding. They had a clue about what these two concepts were about. Learners referred to the medium when describing the mechanical waves. Their knowledge was not complete. The interviewees' responses were:

Learner15: *These are waves that can be propagated through air.*

Learner 35: *Mechanical waves need a medium to be created on.*

Learner 40: *These are the waves that move energy through a medium by vibrating` particles.*

Furthermore, the respondents described the sound as a vibration. The participants' answers were:

Learner 15: *Sound is an example of a longitudinal wave it can vibrate parallel*.

Learner 28: *Vibration of particles that move forward and backward till they are detected by a person's ear*.

Learner 40: *This is the energy that is made by vibrations, it is slower than light.*

(ii) Conceptual difficulties

Conceptual difficulties refer to the challenges that learners encounter in understanding the abstract concepts dues to existing alternative conceptions. These difficulties require strategies, such as encouraging active engagement of learners to develop deeper understanding. The second theme that emerged was conceptual difficulties. Again, some of the participants showed conceptual difficulties when answering the questions about mechanical waves and sound. Most learners revealed the alternative conceptions they had about waves and sound. Thefollowing are the participants' responses about mechanical waves:

Learner 4: *Mechanical waves are waves that are used in the machines of hospitals to check whether a person is alive or not.*

Learner 15: *These are waves that can be propagated through air.*

Learner 28: *Movement of particles that forms waves in mechanical tools.*

One participant described the sound as follows:

Learner 13: *Is sound waves, radio, and the sound of the baby crying?*

Support

ICT is the support system that enhances teaching and learning. During the qualitative analysis of the interviewees' responses, help also emerged as a theme. When learners were asked what they like about ICT simulations, their responses indicated thatthe simulations help them learn. Learners know about ICT; however, they all indicated that they have not used ICT simulations in class. The interviewees' responses were:

Learner 4: *What I like about ICT is that it makes our lives as students better to understand what we are learning. The reason I like ICT simulations is thatwe understand the particular topic we are learning at that time.*

Learner 13: *I like that ICT simulations allow you to learn more information, it is because it helps children to study easily and get information not strugglewith one thing.*

Learner 28: *It makes learners understand the topics more if they see it displayed on screen than being it is explained to you.*

Learner 35: *It helps us understand and have a better understanding of what we are learning.*

The interviews' thematic analysis confirmed the conceptual difficulties of the rural learners. The findings showed the need for the intervention. After the interviews were conducted, the interviews' findings and concept test results were used to prepare for ICT-based interventions. The next section discusses the findings from the pre-test and interviews.

4.5. Discussion

4.5.1 Rural Grade 10 Learners' Alternative Conceptions about Waves and Sound

The first research objective of this study was to identify rural grade 10 Physical Sciences learners' alternative conceptions of waves and sound. Consequently, this section discusses the rural grade 10 learners' alternative conceptions about waves and sound identified above. The findings of the current study are discussed focusing on the five themes, namely, transverse pulse on a string, superposition of pulses, transverse waves, longitudinal waves, and sound.

The topic of transverse pulses on a string was underperformed by the participants. Learners had the alternative conception that moving the string faster with a higher frequency or larger amplitude would produce a faster pulse. The findings are similar to the study of Olaniyan (2022) which reasoned that the alternative conception stems from their confused understanding of the effect of how fast the string is flicked, the height of the flick, and the thickness of the string on the pulse produced. When Bolat and Kocacan (2018) investigated the effect of using multiple methods for teaching sound topics in a secondary school curriculum on student achievement, the authors mentioned that students associated flicking the string faster and the height of the flick with the pulse produced. Another common alternative conception was that, for a pulse to take a shorter, a girl should not change the properties of the string because the speed of pulse on a string depends on frequency and wavelength according to $v=f.\ \lambda$. The finding was in agreement with the study of Barniol and Zavala (2016). The authors reasoned that students, probably thinking of the equation $v = f\lambda$, held the incorrect conception that the speed of waves on strings depends on frequency.

In MCQ 2, one of the alternative conceptions was that one should use a heavier string under the same tension. Tongchai et al. (2011) also noted that in their study students (80%) chose option B without having a complete understanding by guessing. Questions 3 and 4 focused on the reflected pulses when the end was firm or loose. The most common alternative conception showed a reflected pulse on the same side of the string but with no vertical inversion. This finding was similar to the study by Kryjevskaia et al. (2011) that investigated students' difficulties with the sequence of two or more pulses. The researchers found that students used a simple rule-based approach instead of a reflection model.

The rural grade 10 Physical Sciences learners demonstrated a lack of understanding of constructive interference and destructive interference. The alternative conceptions that were observed were that pulses (crests) cancel each other when they meet, and pulses (crests) become smaller because they collide and lose energy when they meet. The observation is similar to the work of Wittmann (2002) as the researcher found that learners tend to describe the superposition as if it were a collision between objects. Learners failed to relate the movement of pulses A and B within a given distance in a specific time with the nature of the resultant wave formed when they are superimposed. This indicated that learners' conceptual understanding of the principle of superposition of two pulses during and after overlap is poor. This may be because the students are not familiar with practical applications related to concepts as projected in the diagrams Olaniyan (2022).

This section assessed the relationship between the period, frequency, and wavelength of the transverse wave, as well as the particles that were in-phase or out-phase. The learners demonstrated a lack of conceptual understanding since the alternative conceptions wereprobed. The respondents believed that the frequency decreased as the number of waves increased. The incorrect conception was due to the wrong calculation performed. When learners were assessed through a wave diagram, the most common alternative conception wasthat the learners believed that the wavelength is measured between consecutive crests, withoutconsidering the labels given for each axis of the graph. The respondents viewed the graph as representative of the transverse wave that propagates through the medium. This is in agreementwith Caleon and Subramaniam (2010) when the nature of alternative conceptions was investigated.

A set of participants also identified the wave property as wavelength, however, the reasoning, that the wavelength is the distance between any two points where maximum displacement of the particle occurs was incorrect. This indicated that learners lack an understanding of the wavelength conception. The last group had difficulty recognising the wave property presented in a graph. Hence, the learners identified the wave property as the amplitude. Furthermore, they described an amplitude as wavelength. This proves that the learners cannot measure an amplitude from the graph. This is in line with Tumanggor et al. (2020) when the alternative conceptions about mechanical waves were detected. On the other hand, learners believed that the wave property was the period, and further reasoned that period is the time needed by the wave to cover the distance between two successive points. Once again, learners use a transverse waveform to measure the period, and they know that the period is time, as a result, they select a reason that relates to time.

This section reviews the alternative conceptions that relate to the longitudinal waves. Once again, the rural grade 10 learners indicated difficulties in their responses. Firstly, the learners described the compression and rarefaction of the longitudinal waves differently. Furthermore, the participants viewed compression as the low region of pressure, and rarefaction as the high region of pressure. Additionally, the respondents described a sound wave as a transverse wave that requires a medium to propagate. The answer also reflected their difficulty in dealing with the properties of longitudinal waves. This finding is the same as the results of the investigation by Caleon and Subramaniam (2010) on the use of diagnostic tests to assess alternative conceptions about mechanical waves. The author reasoned that the misunderstanding of the longitudinal waves is perhaps due to the greater emphasis given to transverse waves than to longitudinal waves during class discussions and in textbook presentations. The last alternative conception was that sound waves are longitudinal waves that do not require a medium for propagation. This error may be because the air particles are not visible to the learners. They knew that sound is a longitudinal wave, however, it travels in space. The participants had a memory lapse of previous learning (Caleon & Subramaniam, 2010).

Sound is the last topic assessed through a diagnostic test. The analysis of the results indicated that the rural grade 10 learners have alternative conceptions about sound concepts. Analyzing why learners chose the more incorrect model which is option A, implied that amplitudes are different (equal loudness) of sounds while frequencies are the same (sounds with low and high pitches). Learners did not understand that the same volume implies the same amplitude with sound, and the pitch is proportional to frequency (Saparini et al., 2021). Learners' conceptual understanding was found to be related to DiSessa's theory of knowledge in the piece and organization of physics knowledge. The analysis once again revealed the alternative conception that the speed of the wave increases with the higher frequency, using the equation $v = ff\lambda$. These learners did not realize that the speed of sound in air is independent of the frequency of the wave. They assumed the relationship between frequency, speed, and wavelength, from $v = ff\lambda$.Since the frequency is different, learners thought that the speed would be different because, according to the equation it depends on frequency. The findings regarding this question are similar to the study by Nurfazliana and Jumadi (2023) when the study investigated the student's mastery of concepts.

The analysis revealed another common alternative conception that the particle will move up and down about the same position. In this case, learners considered the particle only, and not the sound wave propagation. This is the same as the Wittmann et al. (2003) findings when the author reported that the particle would oscillate transversally. In addition to the analysis of the previous observation, the faster movement of the dust particle is similar to the study of Hrepic (2011) in the investigation of students' understanding of sound propagation when alternative concepts about sound were identified.

4.5.2 Interviews Before the ICT Simulation-based Intervention

The participants were interviewed before the ICT simulation-based intervention. The responses indicated that learners always have prior knowledge. They had their knowledge about mechanical waves and sound. However, they described the mechanical waves by referring to the medium, which was mostly an alternative conception they had. This indicates that learners had alternative conceptions that needed to be corrected in the classroom. The participants showed conceptual difficulties when answering the interview questions. There are some scientifically correct concepts in the learner's conceptual framework that the learner knows. For example, some learners described the sound as a vibration. It is the responsibility of the teacher to create a favourable condition (Hanson, 2020) and help the learner consciously throw away the alternative conceptions, and actively learn the scientifically correct concepts. Hence, teachers need appropriate support to employ simulations to help learners comprehend abstract concepts and improve learners' thinking skills (Falloon, 2019). The author argued that teachers should be well prepared when considering to use of simulations to ensure the abstract concepts are clear to learners. The researcher interviewed the learners to prepare for the intervention. The learners' responses indicated that they know ICT and its benefits in teaching and learning. Learners described ICT as a strategy that helps understand the topics easily and better. All participants liked the idea of using ICT simulation to learn waves and sound in their class. Nevertheless, they all indicated that they had never used ICT simulations in class. Learners believed that the ICT simulations would help them understand better, as referenced above from the study of Falloon (2019). The participants believed that ICT simulations could address their alternative conceptions.

4.6. Chapter summary

This chapter presented the data generated through the concept test. The pre-test aimed to answer the first research question and identify the rural grade 10 learners' alternative conceptions about waves and sound. These alternative conceptions were grouped into five themes. Furthermore, the researcher presented the data from the interviews conducted before the ICT intervention. The researcher discussed the five themes that emerged from the data sources. These findings were discussed in support of dissimilarities to the literature reviewed. In the next chapter, the second and third research questions will be answered through the analyses and discussions of the data generated.

CHAPTER 5

USING ICT SIMULATIONS TO DEVELOP SCIENTIFIC CONCEPTIONS

5.1. Introduction

The previous chapter has identified and discussed the possible alternative conceptions of rural grade 10 Physical Sciences learners about waves and sound in answering the first research question that asked: What are the rural grade 10 Physical Sciences learners' alternative conceptions about waves and sound? Then, this chapter presents the findings of the study when ICT simulations were used to address the learners' conceptions and develop scientific conceptions. Hence, this chapter sought to address the second research question which investigated: How can ICT simulations address rural grade 10 Physical Sciences learners' alternative conceptions about waves and sound? Furthermore, after the completion of integrating ICT simulations in the Physical Sciences grade 10 classroom, the participants were interviewed to answer the third question that examined: How do rural grade 10 Physical Sciences learners' perceptions of learning through ICT simulations relate to their performances? The chapter further discusses the findings of the second and third research questions. Finally, the chapter ends with a conclusion.

5.2. Developing Rural Grade 10 Physical Sciences Learners' Understanding of Waves and Sound through ICT Simulations

The conceptual test findings identified the learners' alternative conceptions (section 4.3). This was crucial in informing the researcher to prepare the lessons to be conducted to engage the observed alternative ideas. The intervention teaching strategy was constructive and informed by the integration of ICT simulations (PhET, Physics Classroom, JavaLab, and oPhysics) in Physical Sciences. Due to limited resources in the hosting school and the strict rules on learners' cell phones, the intervention was conducted utilizing a projector, researcher's laptop, and display screen to demonstrate the concepts of waves and sound. The next section presents the findings from the ICT simulation-based interventions using two action research cycles (see Figure 5.1).

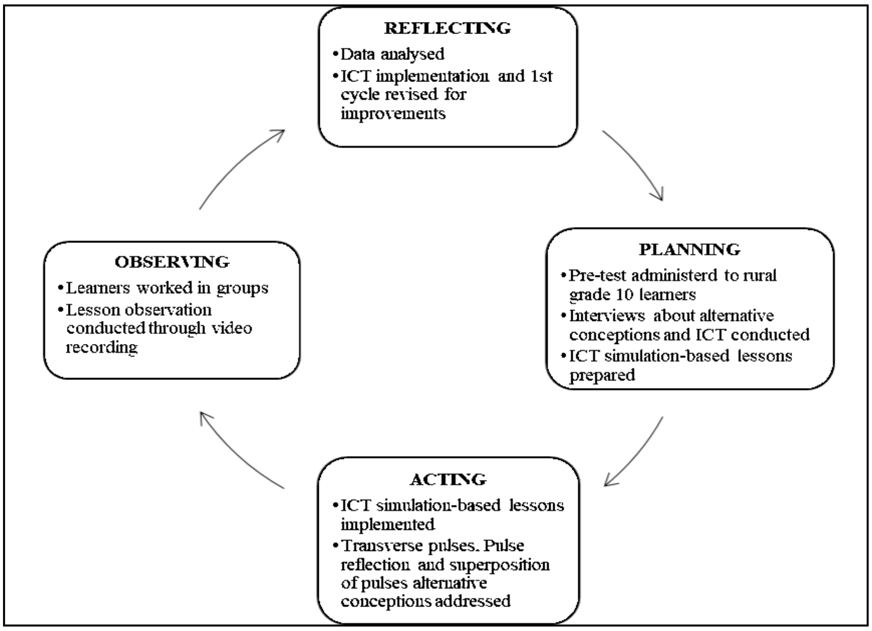


Figure 5.1: The first action research cycle employed to address learners' alternative conceptions.

The first action research cycle had 6 lessons, these are (i) Transverse Pulses, (ii) Transverse Waves, (iii) Longitudinal Waves, (iv) Sound Quality, and (v) Ultra-sound. In the second action research cycle (Figure 5.2), the transverse pulses and sound quality lessons were repeated.

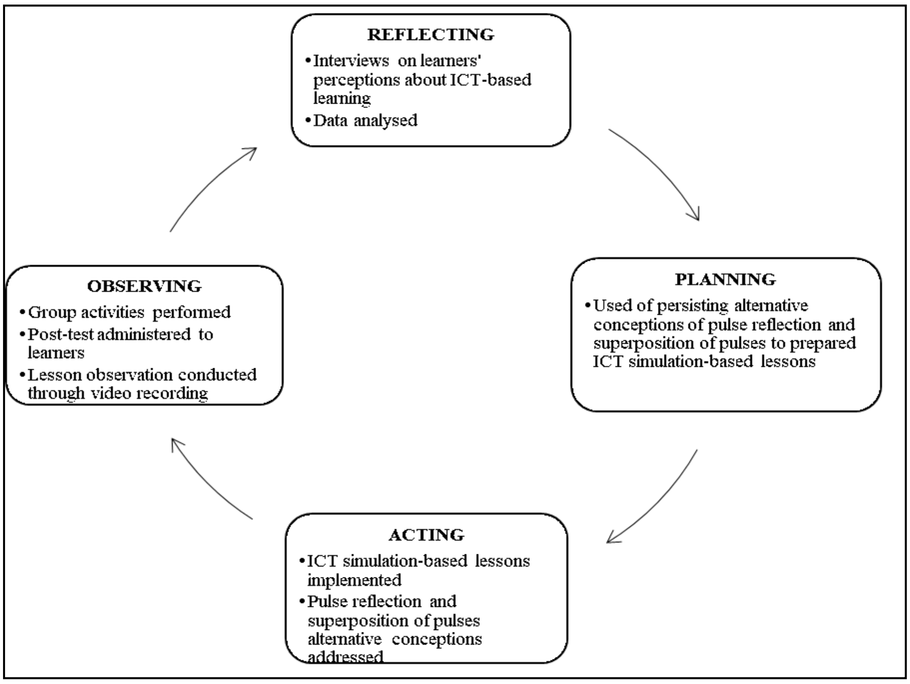


Figure 5.2: The second action research cycle addressed alternative conceptions.

5.2.1 Implementing the ICT Simulation Intervention: Action Research Cycle I

In the action phase of the first action research cycle, the intervention lessons were conducted through ICT simulations. The video recordings were then used to analyse the intervention, to answer the research question of this study. This research aimed to develop learners' conceptual understanding and thus drew on Posner's conceptual change model (CCM) (see Figure 5.3) for data analysis. In the conceptual change approach, there are four important phases described in the theoretical framework: dissatisfaction, intelligibility, plausibility, and fruitfulness (Posner et al., 1982). All the lessons conducted were analysed the same way through conceptual change theory.

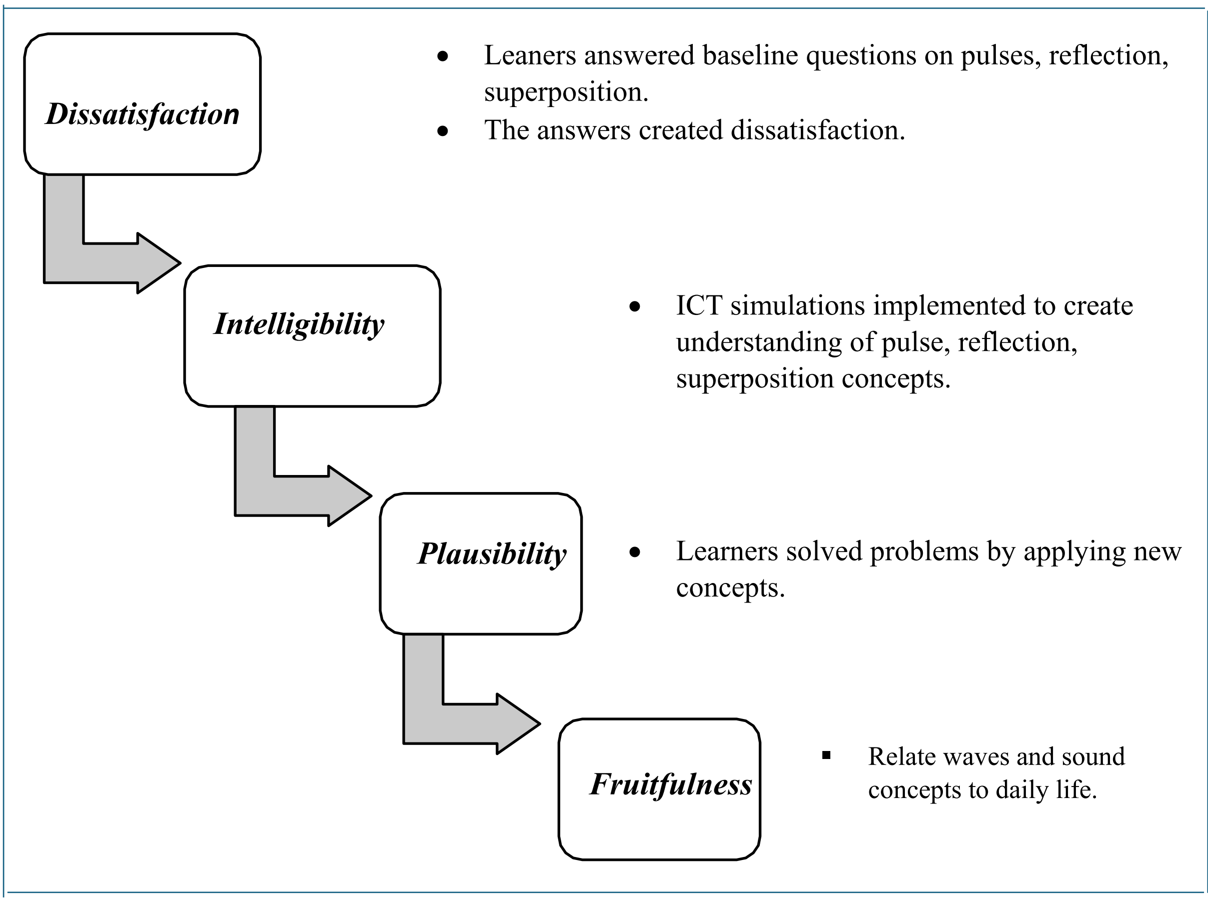


Figure 5.3: Conceptual change theory guided the development of scientific concepts through ICT simulations.

(i) Dissatisfaction

To implement the ICT intervention, lesson plans were developed to explicitly show the inclusion of teaching with ICT simulation as a resource. Appendix K shows one signature lesson (Pulses) that describes the quality of implementing ICT simulations in the first action research cycle. During the lesson, the conceptual change theory guided the intervention, which was how this state of dissatisfaction was created when learners were asked the following questions:

Q1: *Define pulse and amplitude.*

Q2*: Draw a labelled pulse.*

Q3: *Explain a pulse reflection.*

Q4: *Describe what happens when the slinky spring reflects from a fixed end and a loose end.*

Q5: *Define the principle of superposition.*

The researcher then wrote on the chalkboard to engage learners on these questions, Figure 5.4 shows a researcher writing these questions:

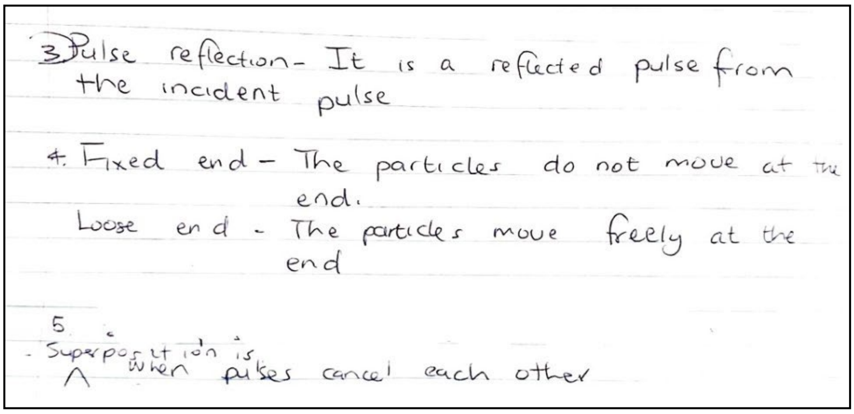
Figure 5.4: The researcher assessed learners' dissatisfaction.

Learners were instructed to work in groups. There were seven groups formed in the class. Each group consisted of six learners. The group work helps build a positive and encouraging atmosphere in a class. Moreover, learners become more effective as they can participate and solve problems quickly (Salvaña & Potane, 2023). Learners were given 10 minutes to discuss the questions in groups and answer the questions as shown in Figure 5.5.

Figure 5.5: Participants worked in groups to activate and reveal their conceptions.

Questions 1 and 2 were fairly answered. Learners were able to correctly describe the pulse and amplitude. In questions 3, 4, and 5, learners had alternative conceptions. They gave incorrect answers (see Figure 5.6). The following groups answered the questions about pulses as follows. These quotations were rewritten to ensure legibility.

Group 4:



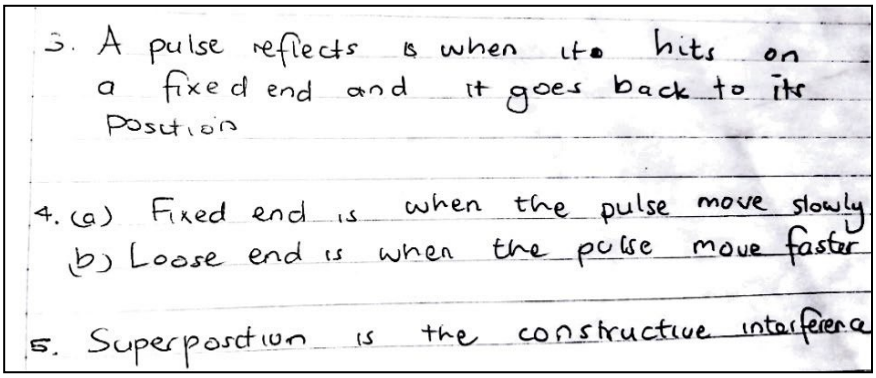
3. Pulse reflection- It is a reflected pulse from the incident pulse

4. Fixed end – The particles do not move at the end.

Loose end - The particles move freely at the end

5. Superposition is when pulses cancel each other

Group 5:



3. A pulse reflects is when its hits on a fixed end and it goes back to its position

4. (a) Fixed end is when the pulse move slowly

b) Loose end is when the pulse move faster

5. Superpostion is the constructive interference

Figure 5.6: The extracts from learners' activities.

During this phase, the researcher first reminded learners about their earlier conceptions from the pre-test related to the transverse pulses on a string. Then, the corrections for baseline questions were done together as a class. One of the groups described the pulse reflection as a reflected pulse from the incident pulse. Learners could not think of the boundary as they described this conception. Also, the description of pulse reflection from fixed and loose ends was referred to as the particles' movement toward the ends. The learners were expected to explain the pulse reflection as the disturbance that returns after bouncing off the end (pole). The fourth question was also a challenge for learners. It was expected that learners would answer as the pulse reflects from the fixed end and becomes inverted (returns as a downward displaced pulse). As a result, they became uncertain about their conceptions. These conceptions were then addressed in the next phase which is discussed as follows:

(ii) Intelligibility

The dissatisfaction phase leads to an intelligible phase. Here, the learners are expected to create new scientific knowledge. It was at this stage that the new concepts were explained using ICT simulations. To address this, the researcher used ICT simulations to demonstrate and explain the concepts. Two ICT simulations were sourced from PhET (https://phet.colorado.edu/sims/html/wave-on-a-string/latest/wave-on-a-string_all.html) and oPhysics (https://ophysics.com/w2b.html) websites. The PhET simulation demonstrated the transverse pulse on a medium and pulse reflection. Whilst the oPhysics simulations demonstrated the superposition of pulses. The simulations demonstrated the formation of a pulse along a medium, transverse pulse propagation, the pulse reflection, and the superposition of pulses. The ICT simulations were used to remediate the alternative conceptions that were displayed by the learners. Figure 5.7 shows this phase.

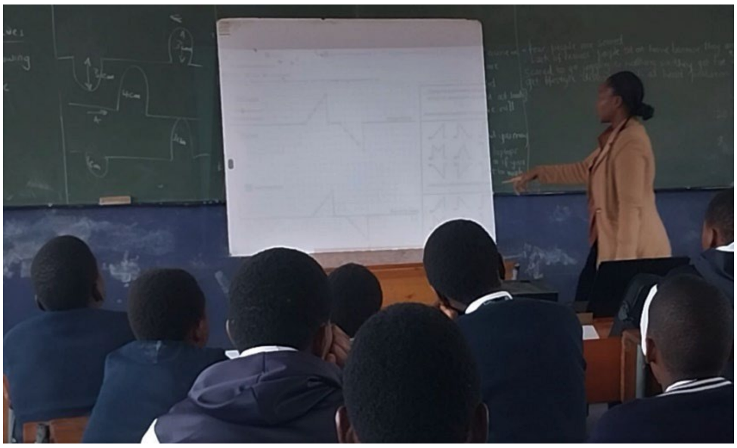


Figure 5.7: The researcher addressed the learners' conceptions in the intelligibility phase.

The transverse pulse simulation displayed on the screen (see Figure 5.8) was one of the ICT simulations that assisted in teaching and learning the waves and sound. The simulation was manipulated to observe pulse reflection at the fixed and free ends.

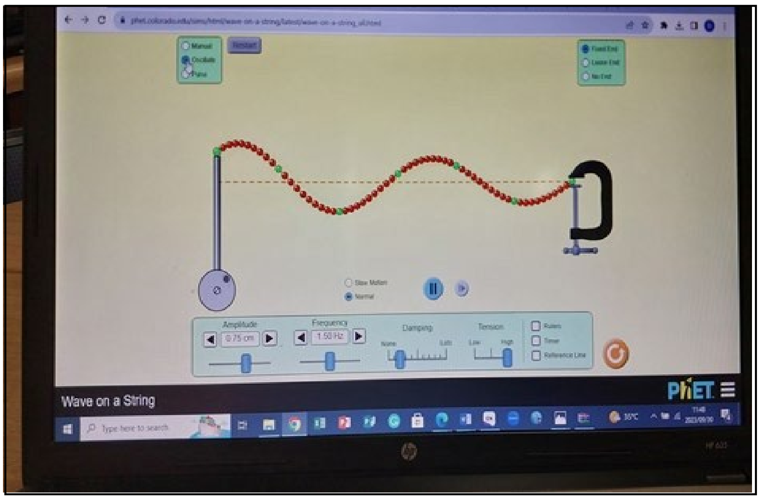


Figure 5.8: PhET simulation demonstrated pulse along a medium and pulse reflection.

After the intelligibility phase, learners were expected to have understood the concepts as they showed so much interest as they were observing the simulations. To ensure understanding. The plausible is the next phase to assess the conceptual understanding.

(iii) Plausible

Learners' new scientific concepts should make sense and be believable. A new concept about pulse reflection and superposition of waves should be applied to solve problems. This was done after observing the simulations demonstrated these concepts as shown in Figure 5.9.

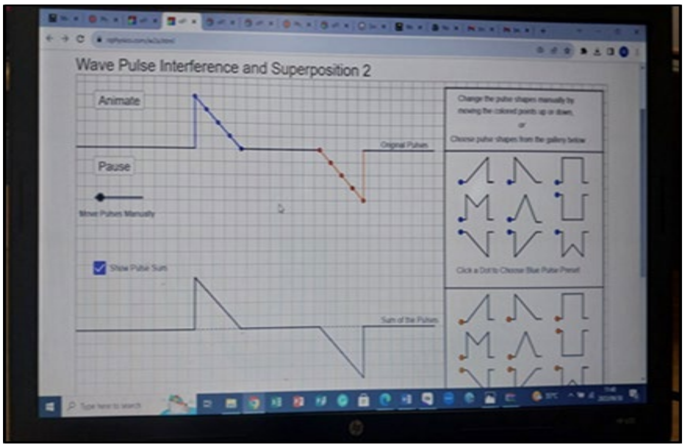


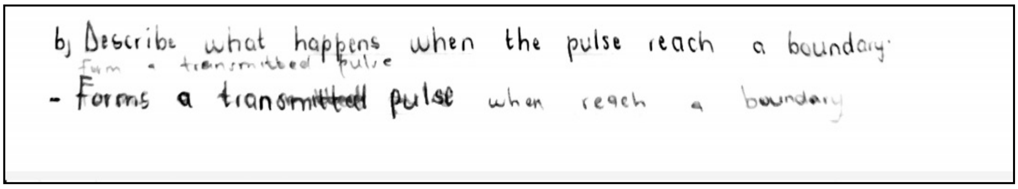
Figure 5.9: An oPhysics simulation demonstrated the superposition of pulses.

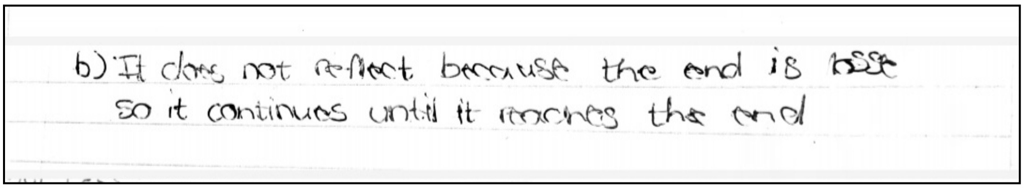
Plausibility was addressed through another group activity that required learners to solve problems by applying the new concepts. During the discussions within the groups, the learners answered (see Figure 5.10) some of the following questions with the researcher:

Q6: *Describe what happens when the pulse reaches the boundary.*

Q7: *Describe the superposition of pulses.*

The groups responded as follows:

Group1: 
b) Describe what happens when the pulse reach a boundary.
form a transmitted pulse
- Forms a transmitted pulse when reach a boundary

Group 2: 
b) It does not reflect because the end is lose
so it continues until it reaches the end

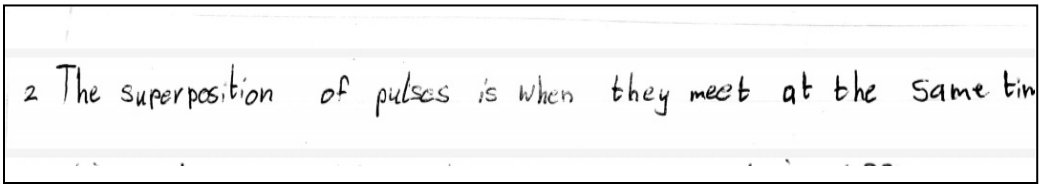
Group 3: 
2 The superposition of pulses is when they meet at the same tim

Figure 5.10: The extracts from some groups' activities during the plausibility phase.

The answers from some of the groups showed that the ICT simulations were able to demonstrate concepts such as wave at the boundary and superposition of pulses. However, some learners still had their alternative conceptions. For example, when they were asked what happens to the pulse as it reaches the boundary, they answered question 6 as follows:

"It does not reflect because the end is loose, it continues until it reaches the end'.

This indicated a poor understanding even after observing the concept with the aid of ICT simulations. The next section discusses the fruitful phase of the CCM.

(iv) Fruitfulness

For the concept to be fruitful, learners should be able to apply the new knowledge in their future lives (Denis et al., 2015). The transverse wave concepts should solve the problems at hand, and open new areas of inquiry (Posner et al., 1982). When the lesson was concluded, learners continued to discuss activities related to transverse pulses. In their discussions, learners gave examples of natural events and daily life experiences that are related to the new concepts or knowledge. The following were some of the examples discussed by the learners.

Learner 7 said*: Snakes use transverse wave motion to move through the surroundings.*

Learner 13 added*: When a stone is thrown into the water, circular waves are formed.*

To make sense of the quality at which the ICT simulation was used for meaningful learning, the researcher borrowed from the work of Howland et al. (2012) regarding the five dimensions of meaningful learning with ICT as an analytical lens. These dimensions are (i) Active, (ii) Constructive, (iii) Authentic, (iv) Intentional, and (v) Cooperative. The Active Dimension refers to the time taken by learners to engage with ICT tools in manipulating subject matter (waves and sound) (Koh, 2013). For the active dimension, there was a sporadic use of ICT tools, since the school lacked the ICT tools and learners are not permitted to use cellphones within the school premises. To measure the quality of this dimension, Table 5.1 shows an extract of the rubric that was used for this analysis: The rubric has a Likert scale of 1 – 4 indicating the progression in the quality of ICT integration for meaningful learning.

Secondly, the Constructive Dimension refers to the incorporation of Information and Communications Technology (ICT) tools in lesson activities that aim to encourage students to explore divergent aspects of a subject rather than focusing on convergent knowledge acquisition and personal reflections (Koh, 2013). Table 5.1 shows an extract from the rubric for meaningful learning with ICT that describes the constructive dimension.

Table 5.1: An extract from the rubric shows the active and constructive dimensions.

Dimension	1	2	3	4
Active	There is sporadicuse of ICT tools by learners to work with the subject matter.	Learners are using ICT to work with subject matter half the time.	Learners make substantial use of ICT to work with subject matter.	Almost all lesson time involves learners usingICT to work with subject matter.
Constructive	ICT tools areused to support the transmission and reproduction of subject matter without meaning-making.	ICT is used to support convergent knowledge expression by learners with respect to the subject matter.	ICT is used to support divergent knowledge expression by learners with respect to the subject matter.	ICT tools are used by learnersto synthesize information to construct verbal and written, expressions ofthe subject matter.

Similarly, the other dimension is authenticity, which involves the use of ICT tools in the lesson activity to engage students to represent their applications of real-world phenomena related to the subject matter being learned. The intentional dimension applies to the use of ICT tools in the lesson activity when it engages learners to self-diagnose and fix their learning gaps concerning the subject matter being learned. The cooperative was the last dimension applied from the rubric. The dimension involved the utilization of ICT tools for collaborative efforts during lesson activities and encompasses opportunities for divergent, constructive discussion on the subject matter, either in proximity to or via the computer. The greater the extent to which the activity promoted divergent communication, the more it was deemed cooperative (Koh, 2013).

To map the quality of the researcher's role in integrating ICT for meaningful learning, the rubric from Koh (2013) was used (see Appendix N). As shown in, the rubric has a Table 5.1 Likert scale of 1 – 4 indicating the progression in the quality of ICT integration for meaningful learning. During the intervention, lessons were video-recorded and analysed by the researcher for insights into the development of rural grade 10 learners' scientific conceptions. In cycle 1, all the lessons were analysed using this rubric. However, one signature lesson was chosen to represent the integration of ICT for meaningful learning. Table 5.1 presents the quality of the cycle 1 lesson.

Table 5.2: Rubric levels of performance achieved for meaningful learning with ICT.

Dimension	Level	Description
Active	1	Sporadic use of ICT simulations.
Constructive	2	ICT was used to support convergent knowledge expression by learners concerning pulse and amplitude.
Authentic	1	ICT tools were used to present examples of real-world phenomena related to transverse wave propagation.
Intentional	2	Learners' learning gaps in the understanding of pulse behaviour as it crossed the boundary were diagnosed by a teacher.
Cooperative	2	Learners worked in groups in activities that required convergent knowledge of pulse, pulse reflection, and the superposition of pulses.

5.2.2 Implementing the ICT Simulation Intervention: Action Research Cycle 2

This section presents the findings from the second action research cycle. This cycle was the remediation cycle from the observations and reflections of cycle one. Reflecting on the events of the first cycle, it was apparent that learners still had some significant fundamental alternative conceptions. These were misunderstandings in pulse reflection, pitch, and loudness of conceptions in sound. However, for the analysis purpose, only the signature lesson is presented in this study (see Appendix L). The signature lesson was an improved lesson on the transverse pulses, pulse reflection, and superposition of pulses. The ICT simulations were integrated to address the alternative conceptions from the first cycle. Once again, the conceptual change theory in support of social constructivism guided the lessons. Furthermore, the conceptual change was adopted to analyse the qualitative data (Mihas, 2019). The four phases of the conceptual change are discussed below:

(i) Dissatisfaction

The researcher made learners aware of the alternative conceptions they had from the pre-test in the first cycle, especially in the transverse pulse topic. One of the alternative conceptions is shown below.

Group 3:

> 1. The frequency of a wave in the light rope is grater than in the heavy rope.

Figure 5.11: The extract showed participants' conception resulting in the dissatisfaction phase.

The alternative conception was about the properties of the medium and the wave behaviour at the boundary. Learners believed that the frequency of a wave along a light rope was greater than the frequency of a wave along a heavy rope, without considering that the frequency is determined by the source of a wave. The learners realised that the knowledge they had about waves and sound was not scientifically correct. This concluded the first step in the conceptual change theory, dissatisfaction with the existing conceptions.

(ii) Intelligibility

To address intelligibility, the researcher used ICT simulations to demonstrate and explain the wave behaviour at the boundary and superposition of waves. This time around three ICT simulations were sourced from PhET, Physics Classroom, and oPhysics websites. The PhET simulations demonstrated the pulse along a medium and pulse reflection. Physics Classroom demonstrated the boundary behaviour of pulses and the superposition of pulses, and the oPhysics simulations showed the propagation of a pulse (see Figure 5.12).

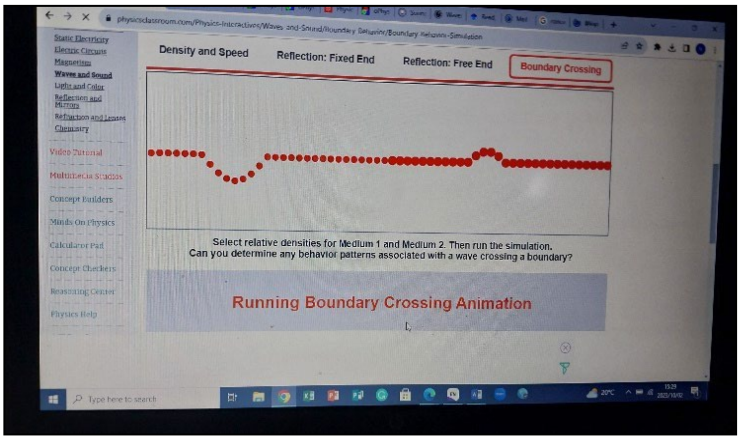


Figure 5.12: Classroom Physics simulation demonstrated the pulse as it reached the boundary.

The ICT simulations were used to address the alternative conceptions. The researcher described the behaviour of the pulse as it travels along from the light rope to the heavy rope, and vice versa. Furthermore, the researcher manipulated the simulations to demonstrate the frequency and speed of the waves as the waves travel through different media. While learners were observing the demonstrated concepts, the researcher was also applying the question-and-answer method, asking questions question and learners answering questions. Some learners were also taking notes without the researcher's instruction.

Figure 5.13: Rural grade 10 learners observed the pulse as it reached the boundary.

The lesson was concluded by making learners understand the concepts through ICT simulations supported by the next phase, plausibility, as described below.

(iii)Plausible

Plausibility was addressed through another group activity that required learners to solve problems by applying the new concepts. Learners were allowed to work among themselves for 10 minutes through social constructivism. Social constructivism refers to the creation of knowledge from the existing knowledge through learners' interactions (Kalina & Powell, 2009). Learners were allowed to collaborate without the researcher's assistance, and later, they were offered assistance to promote conceptual understanding (see Figure 5.14).

Figure 5.14: The researcher assisted learners through scaffold during group discussions.

Learners discussed the problems and solved them as groups. After the interactions within the groups, the learners discussed the following questions with the researcher:

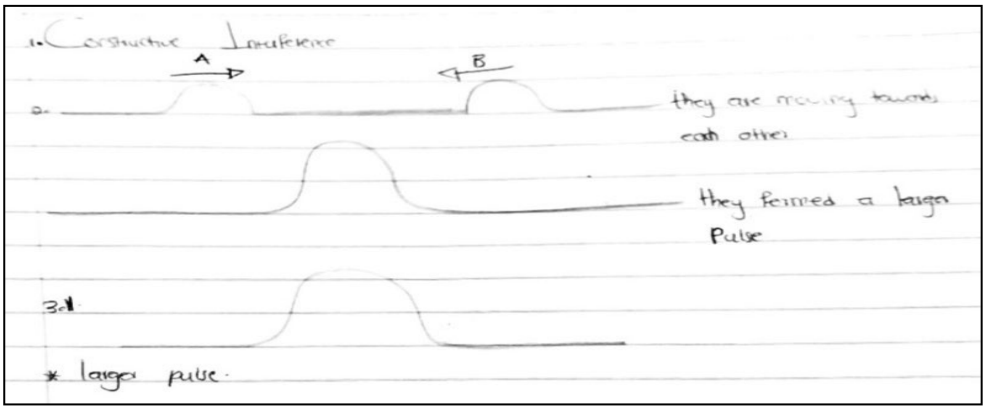
Q8: *Use a diagram to show constructive interference.*

Q9: *Draw a diagram as the pulse moves from the lighter medium to the heavier medium.*

Q10: *The frequency of the transmitted pulse will be (greater than, less than, or the same as) the frequency of the incident pulse. Explain your answer.*

The learners showed improvements in the second cycle. More time was allocated to the use of ICT simulations. This gave learners more time to observe the concepts through ICT simulations. Some learners even requested to manipulate and change the variable to understand it better. They understood and believed in themselves. They were able to give scientifically correct answers. The groups responded as follows:

Group 2:



Group 3:

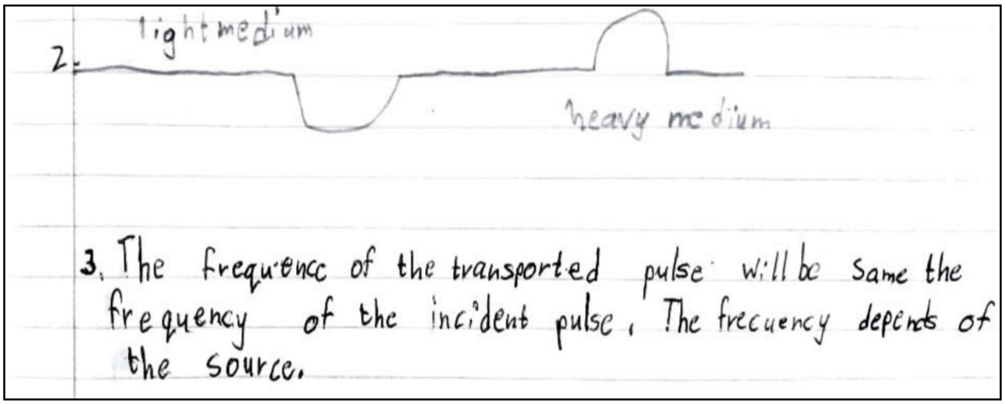


Figure 5.15: The extract of scientifically accepted conceptions in the plausibility phase.

(iii)Fruitfulness

Learners continued to discuss activities related to waves and sound. In their discussions, learners gave examples of natural events and daily life experiences that are related to the new concepts or knowledge. The following are the examples discussed by the learners and researcher:

Learner 17 said: *The sea waves are the transverse waves.*

Learner 31 said: *Playing a skipping rope tied at one end shows pulse reflection.*

The same rubric for assessing meaningful learning (see Appendix N) was used to analyse the learners' engagement and performance toward the integration of ICT simulations during teaching and learning. The table below presents the summary of the rubric levels of performance achieved by learners in the second action research cycle.

Table 5.3: Rubric levels of performance achieved for meaningful learning with ICT (AR Cycle II).

Dimension	Level	Description
Active	1	Sporadic use of ICT simulations.
Constructive	3	ICT tools were used by learners to synthesize information to construct verbal and written expressions of the pulse reflection and medium properties.
Authentic	3	ICT tools supported in investigating real-world phenomena or problems related to transverse wave propagation.
Intentional	3	Learners used ICT tools during the intelligibility phase to diagnose and fix learning gaps related to pulse reflection and properties of the medium.
Cooperative	4	Learners worked in groups through the computer in activities that required some degree of divergent knowledge expression of pulse reflection and properties of the medium.

5.3. Understanding post-ICT-based interventions

After the completion of the ICT simulations-based intervention, a post-test was administered to learners. This post-test was similar to the pre-test (Appendix H). The post-test was used to determine whether grade 10 learners underwent the conceptual change and therefore had a reduction in the number of identified alternative conceptions about waves and sound. After marking the test, the results (see Appendix P) were recorded in Microsoft Word and analysed through Microsoft Excel.

5.3.1 Comparing the results of the pre-test and post-test

The data generated from the post-test was analysed to compare learners' understanding of waves and sound concepts. The performance of the learners from pre-test to post-test was used as a measure of whether the ICT simulations teaching approach was a success in teaching waves and sound to rural grade 10 Physical Sciences learners. There was a significant difference in the marks of the participants after the intervention was implemented. Learners' performance in the pre-test was at an average of 30%. It appeared that the understanding of learners concerning the concept of waves and sound through ICT simulations improved as they achieved an average of 53%. The themes that emerged in the pre-test were also used to analyse the post-test findings. Table 5.4 compares the results of the pre- test and post-test.

Table 5.4: Comparison of pre-test and post-test.

Theme	Question	Pre-test (correct responses)	Post-test (correct responses)
Transverse pulse on a String	1	2	7
	2	8	14
	3	8	16
	4	5	13
	5	5	5
Superposition of Pulses	6	15	11
	7	13	19
	8	9	14
	9	20	25
Transverse waves	10	26	22
	11	10	8
	12	13	13
	13	9	12
	14	21	21
Longitudinal waves	15	21	26
	16	18	23
	17	0	5
Sound	18	16	14
	19	9	7
	20	9	9
	21	4	14
	22	5	15
	23	2	4
	24	22	23
	25	28	27

In the post-test, the analysis was done per question, in comparison with the pre-test. Some questions indicated a positive response and a few questions indicated a negative response. Table

5.3 shows an improvement in the post-test after the integration of ICT simulations in waves and sound lessons. The post-test results showed an increase of 23% compared to the pre-test. Questions 4, 6, 7, 9, 15, 16, 21, and 22 were the most improved as they received an increase in the number of learners with the correct responses. The concepts assessed and showed an improvement after ICT simulation intervention were pulse reflection (loose end), constructivism interference, and destructive interference.

The questions that examined the displacement of sound waves also indicated an improvement since the number of learners who answered correctly increased. The findings are similar to the responses given by the participants interviewed after the intervention, as they revealed the concepts that they understood better (see section 5.4). The qualitative analysis revealed that questions, 1, 2, 3, 8, 13, 17, and 23, showed a little improvement. Few learners answered these questions. The concepts examined were transverse pulse, transverse wave, and sound, as shown in Table 5.3.

The results of the post-test indicated that there was an improvement in conceptual understanding of waves and sound. However, some questions showed negative responses. These questions (5, 12, 20, and 24) indicated no change even after exposure to ICT simulations. The number of learners who answered these questions did not change. This was an indication that learners' alternative conceptions about the frequency of a pulse in different media, frequency, and number of waves relationship and echo sound persists. In addition, questions 10, 11, 14, 18, 19, and 25 also showed a negative response, since the number of participants achieved decreased. The items assessed transverse wave period, wavelength, in-phase and out-phase, pitch and loudness of sound, and ultrasound. These concepts were revealed by the participants when the interviews about their perceptions were conducted. These are the concepts in which learners still hold alternative conceptions. The results of the post-test are further discussed in the discussion section.

5.4. How do rural grade 10 Physical Sciences learners' perceptions of learning through ICT simulations relate to their performance?

After the two action research cycles were complete. The interviews were conducted to gain insight into the perceptions of rural grade 10 learners about integrating ICT in teaching and learning of waves and sound, and Physical Sciences subject as a whole. And also how their perceptions relate to their performances. The researcher randomly selected six rural grade 10 learners to answer interview questions. According to Kiger and Varpio (2020) the qualitative data reveal emerging themes. The emerging themes after the ICT simulations-based intervention of this study were (i) learner engagement, (ii) enjoyment, (iii) teaching and learning support, (iv) better conceptual understanding, (v) ICT for rural schools, and (vi) conceptual difficulties. The next section presents and further explains the emerged themes as follows:

(i) Learner engagement

When the participants were interviewed, they all showed an interest. The 'learner engagement' emerged as the theme when learners were asked if they liked to learn using ICT simulations. The following are some of the participants' responses:

Learner 4: *Yes, it provides a more interactive and engaging experience.*

Learner 15: *The lesson was very interesting and meaningful because we experience many things through the practical or when we see what we are learning.*

Learner 27: *Yes, it helps us concentrate and analyse each topic well.*

The use of ICT simulations evoked their interest. The ICT simulations made learners active in the classroom. Furthermore, the simulations gave visual stimulation and caught and sustained the learners' attention and concentration.

(ii) Enjoyment

When the rural grade 10 learners were asked if they enjoyed the ICT simulation-based lessons, all learners had positive responses, as they all stated that they enjoyed the ICT simulation-based lessons. The second theme that emerged during interviews was enjoyment. The interviewees' responses were:

Learner 27: *Yes, I enjoyed the lessons because we sat in groups, and it was easy to help each other understand better.*

Learner 30: *Yes, I enjoyed, and I did participate fully during the lesson since I understood what was learned.*

Learner 34: *I did enjoy although the learning environment was negative since we were short on some equipment the environment was welcoming and friendly.*

(iii) Teaching and learning support

Learner engagement and enjoyment are an indication of positive results of ICT simulations as a teaching and learning strategy. The 'teaching and learning support' theme emerged when the participants answered the interview question, which was about the use of ICT simulations as a good choice. The learners responded as follows:

Learner 12: *As for my class I don't know but to me the lesson was okay. The way the teacher has taught us, she was patient and she made us understand and gain more information.*

Learner 30: *The use of ICT simulations is a good choice because it helps me to be able to understand the lesson and to gain more information.*

The participants also believed that the ICT simulations can be used in teaching and learning other Physical Sciences topics, as well as other subjects since they make abstract concepts clear and understandable.

(iv) Improved conceptual understanding

The literature has revealed that ICT improves students' learning. The use of ICT helps learners to learn with ease and retain them in their memory for a very long period (Mirzabek et al., 2022). The ICT simulations used had pause and slow-motion keys that were manipulated to ensure learners' conceptual understanding. Moreover, the question-and-answer method was employed when simulations were run to evaluate learners' understanding. These findings relate to this study's post-test analysis as the number of correct responses increased. The learners were interested and paying attention; hence they understood the content better. All the participants responded that they did understand some of the concepts taught. The concepts include pulses and sound. The 'improved conceptual understanding' emerged as the theme from the answers provided by the learners during the interviews. Some of the participants' responses were:

` Learner 12: *The topic of pulses because when the teacher explained it to us it sounded easier.*

Learner 15*: Transverse pulses, because we were able to see it through the simulations.*

Learner 30*: Sound waves topic. It is because when I saw the ICT simulations it made me understand it better than before because I didn't understand the way I understand it now.*

Learner 34: *Sound waves, I understood it better because it is more familiar.*

The learners' responses indicated that the ICT simulations motivated them and encouraged them to think. The researcher allocated time for reflections and discussions after experimenting with simulations. These discussions led to deeper learning. In addition, in most answers, the participants indicated that they understand better when learning through ICT simulations.

(v) ICT for rural schools

When the rural grade 10 learners were asked if any improvement was there for the lessons. Some of their responses were not based on the lessons provided, instead, they answered relating to the rural schools. The participants' responses were:

> Learner 13*: Yes we need to improve the ICT usage in the rural schools so that learners can improve their knowledge about something that they don't understand.*
>
> Learner 27: *We need to teach rural learners how ICT works and what technologies we need to have access to it.*
>
> Learner 39: *Rural schools can be better if we have more computers.*

These participants' quotations indicate that they realised that the rural schools lack resources and they believed that the ICT simulations could be integrated to improve and develop rural schools.

(vi) Conceptual difficulties

Learners have difficulty developing conceptual understanding of waves and sound (Muliyati et al., 2019). This is because physics concepts are abstract and unseen. Another cause might be a lack of time for learners to learn about and understand topics such as longitudinal waves. Furthermore, Que (2021) asserted that the adoption of ICT in rural regions has been associated with socioeconomic, geographical, political, and cultural challenges. The presence of learners' smartphones may have influenced conceptual understanding. The final emerging subject was conceptual difficulties. This theme emerged when participants responded to the question, "Which topic did you understand the least?" Why? The students' responses were as follows:

> Learner 4: *Ultrasound, because the examples that were provided in the class confused me a bit.*
>
> Learner 12: *The wave's topic because I still cannot identify the pitch, frequency.*
>
> Learner 13*: The pulses and longitudinal wave because I struggled to identify the difference between compression and rarefaction and its frequency.*

Learner 39: *The lesson about the longitudinal waves, and the difference between rarefaction and compression*.

These quotations revealed the rarefaction and compression of longitudinal waves, pitch, and frequency of sound and ultrasound as concepts that learners misunderstood. This is an indication that learners' conceptions were not addressed. However, the learners' perceptions about ICT simulation-based teaching and learning relate to the post-test performance of learners. The positive impact of the ICT simulation was shown through the results of the post-test. The next section discusses the findings of this study that are presented in this chapter to answer the research questions.

5.5. Discussion

5.5.1 Implementing ICT Simulation-based Intervention

The researcher introduced the lesson by asking baseline questions as highlighted above in section 5.2.1. Learners were working in groups, supported by social constructivism. The researcher allocated learners into groups of six learners. The lesson started by discussing the questions given by the researcher. This learning theory allowed learners to interact, and learn from each other. Through social constructivism and the zone of proximal development, the learners were allowed to answer the questions on their own, and after group interactions, the researcher together with the class discussed the answers, and the learners realised the incorrect conceptions they made. Hence, they were dissatisfied. The researcher demonstrated the concepts through using PhET, Physics Classroom, JavaLab, and oPhysics simulations. However, the lessons analysed used PhET, Physics Classroom, and oPhysics simulations. The PhET simulations were the most used. They have many features, such as the ruler to measure the amplitude, and the properties of the medium which could be changed, and the user could be the source of a wave. The oPhysics that demonstrated the superposition of pulses allowed the user to draw his diagrams, and calculate the amplitude of the resultant pulse. The JavaLab offered the simulations with the audible sound. These simulations made it easy for learners to understand the concepts. However, the user had to use different websites since the waves and sound simulations were not offered on one website.

After demonstrations and observations in the intelligibility phase of the conceptual change theory, the learners were given another activity, to determine whether conceptual understanding developed from the learners in the plausibility phase. The participants showed positive responses. This indicated that the ICT simulations addressed the pulses, transverse waves, longitudinal waves and sound alternative conceptions that learners held. A similar finding to the study by Njoko (2020) when the researcher investigated the use of ICT in teaching sound, waves, and light in grade 10. The author stated that she had previously struggled to assist learners in understanding transverse waves until the researcher taught the topics through PhET simulations. The author also claimed that using the PhET simulation made it easier for learners to understand because they could only observe the particle going up and down while the wave was created horizontally.

As highlighted above, this study was guided by the conceptual change theory, supported by social constructivism. The researcher integrated ICT simulations into the teaching and learning of waves and sound. The learners were instructed to work in groups through social constructivism. But again, the lessons were observed by the researcher using the five dimensions, namely; active, constructive, authentic, intentional, and cooperation (see Table 5.2) of meaningful learning with ICT in a rubric developed by Koh (2013). The analysis of the observation through the rubric indicated that the learners were engaged and participated in the integration of ICT simulations during teaching and learning. However, there were some learning difficulties that learners were experiencing. This is shown by the rubric levels of learners' performances above in Table 5.2 and Table 5.3.

In the first action research cycle, the active dimension showed that there was sporadic use of ICT tools by learners to work with the subject matter. This was because of the lack of ICT tools, and learners were not permitted to use their cellphones. In the second cycle, the researcher observed that the ICT simulations were used more frequently, to ensure that learners' alternative conceptions were addressed. The researcher used the slow-motion key for learners to grasp the concepts. The researcher allocated more time for post-simulation discussions to reflect on what they learned from simulations.

The constructive dimension was in line with social constructivism, as it allowed participants to learn through group interactions in a social setting (Vygotsky & Cole, 1978). During the teaching and learning, the researcher used the ICT simulations to support convergent knowledge expressed by learners for the transverse pulse on a string, pulse reflection, and superposition concepts. Furthermore, the learners became more engaged as the researcher used ICT simulations more often to describe the waves and sound concepts. The ICT simulations caused learners to be interested and involved in class activities. The results of the study by Bentaleb et al. (2022) reported that ICT motivates students to engage in classroom activities. Moreover, in the authentic dimension, learners were able to improve their understanding and relate the concepts to daily life experiences. For example, snakes use transverse wave motion to move through the surroundings. Such concepts were reported above in the fruitfulness condition of the conceptual change theory. The learners related the propagation of transverse waves to the motion of the snake, and the longitudinal wave propagation to the motion of the worm. These conceptions result from a better conceptual understanding of wave propagation. The rubric for meaningful learning with ICT was the appropriate tool to assess whether learners' conceptions were addressed through ICT simulations.

The findings indicated a positive response as learners underwent the conceptual change, from their alternative conceptions to the scientifically correct conceptions. As the conceptual change phases were explained in chapter two, the dissatisfaction ensured that were dissatisfied with their alternative conceptions, such as: Pulse reflection is when the pulse moves slowly and when the pulse moves faster, and when a pulse reaches the boundary, it disturbs the particles of the rope. The researcher used ICT simulation from PhET, and oPhysics websites to address intelligible. The simulations were visual and animated so that learners could easily observe the concepts demonstrated. In addition, the ICT simulations were interactive to address the problems instantly. After learning through ICT simulations, the participants were able to give correct answers (see plausible section above), which was an indication that ICT simulations addressed the rural grade 10 alternative conceptions. As a result, plausibility was also addressed. The fruitfulness was also addressed, as learners were to relate, for example, one learner mentioned that the pulse reflection is created along a skipping rope when one end is fixed.

Based on the findings, observations, and reflections from the first action cycle, some of the alternative conceptions were addressed. The following are some alternative conceptions addressed; for a pulse to take a shorter time to reach a pole, she should not change the properties of the string because the speed of pulse on a string depends on frequency and wavelength according to $v=f. \lambda$ and when the frequency is doubled, the wavelength increases. However, there were still misunderstandings in pulse reflection and sound conceptions from other groups. These include; when an incident pulse reaches the fixed end, a reflected pulse with no vertical inversion remains on the same side of the string. This was an indication that learners had a belief that the reflected pulse would not change the side. 'Pulses (crests) cancel each other when they meet', was another conception of learners even after the first cycle. The participants could not think of the types of interferences that occur as a result of a superposition of pulses. They assumed that pulses cancel each other, regardless of the directions.

The same rubric for assessing meaningful learning was used to analyse the learners' engagement and performance toward the integration of ICT simulations during teaching and learning. The results from the rubric were discussed above. The learners were dissatisfied with some of the alternative conceptions. To address the intelligible aspect, the researcher sourced

ICT simulations from PhET, Physics Classroom, oPhysics, and JavaLab websites. The simulations demonstrated the creation of pulse boundary and pulse reflection. The Classroom Physics simulation had relative densities for two media along which the pulse travelled to determine its behaviour as it entered the different medium. The densities for the two media can be changed to observe more about the pulse reflection. The researcher together with the class discussed the answers to address the rural grade 10 learners' alternative conceptions.

5.5.2 Post-ICT Simulation-based Intervention

The present section offers an analysis of the post-test results. The examination of the most improved questions (4, 6, 7, 9, 15, 16, 21, and 22) reveals that participants demonstrated a clearer understanding of the conceptions following the integration of ICT simulations. These questions align with the findings of Barniol and Zavala (2016) who identified them as highly performed questions. As a result, six incorrect conceptions about interpreting sound wave's frequency, speed, and amplitude were effectively addressed. While questions 1, 2, 3, 8, 13, 17, and 23 elicited positive responses from participants, fewer individuals answered these questions correctly. The study identified four alternative conceptions related to transverse pulse, transverse waves, and sound waves, which may have contributed to the difficulty in conceptual understanding. The current findings corroborate those of Barniol and Zavala (2016) who reported that participants experienced challenges in interpreting sound waves' frequency, speed, and amplitude.

The analysis of items (5, 12, 20, and 24) of the post-test indicated that there was no difference in the number of correct responses. The same number of participants could not answer these questions. The learners still indicated confusion as they misunderstood that as the waves propagate through the boundary the frequency remained the same (question 5). In this study, the same number of participants from the pre-test expressed an understanding of the relationship between wave source and frequency. Similarly, Menchen and Thompson (2005) reported that the pre-service teachers associated the wave frequency with a medium instead of a source. The participants still hold alternative conceptions of the frequency and medium and echo sound, such as the frequency of a wave in the light rope is greater than in the heavy rope. Questions 10, 11, 14, 18, 19, and 25 also showed a negative response, since the number of participants achieved decreased compared to the pre-test. In questions 10 and 11, learners still confused the wavelength with the period. The learners identified the crest-crest gap in displacement versus time graph as wavelength instead of the period. The findings were also observed in the study of Caleon and Subramaniam (2010). The study of Barniol and Zavala (2016) also revealed that learners experienced conceptual difficulties when answering these questions. The concepts assessed included pitch, loudness, amplitude, and frequency of sound waves. In addition, Kanyesigye et al. (2022) argued that researchers such as Wittmann (2002) reported that one of the pupils' issues in topic waves was found as a lack of cognitive parts of knowledge offered by Bloom's taxonomy. The questions with follow-up of the reason such as items 5, 10, 11, and 17 showed a negative response as the majority of learners indicated a decrease in comprehending these concepts. Hence, from the identified rural grade 10 Physical Sciences learners' alternative conceptions about waves and sound out of 15, 11 were addressed through ICT simulations.

5.5.3 Learners' perceptions of ICT simulation-based Intervention

The primary aim of this study was to investigate the perceptions of rural Grade 10 Physical Sciences learners regarding their learning experiences through the use of ICT simulations. To achieve this, the researcher conducted and analysed interviews with these learners. The first theme to emerge from the analysis was learner engagement. According to the literature review conducted by the researcher, when learners are engaged in ICT-based classrooms, they tend to exhibit extreme excitement about the prospect of using computers (Hartley & Treagust, 2006). This excitement could be attributed to the ICT simulations that were new to the participants. Some learners indicated that they were learning through ICT simulations for the first time. Furthermore, learners become cognitively involved with ICT simulations (Almasri, 2022), which means that they pay attention to what is being learned through ICT simulations.

Additionally, ICT simulations help learners retain concepts in their memories for a long period (Mirzabek et al., 2022). The learners even took notes during the lessons, indicating that some of them were thoughtful. During the lessons, the participants engaged in group discussions, which promoted participation through social constructivism. The noise level increased during these group discussions and classroom interactions, but it was more productive than disruptive noise. ICT makes learners active and motivates them to effectively engage in learning (Bentaleb et al., 2022). This was also an indication of learner engagement, as the learners participated fully in their groups. This aligns with the findings of Mirzabek et al. (2022), who discovered that ICT attracts learners, makes them active in class, and promotes learner interactions during the learning process (see Appendix M).

The second theme to emerge from the participants' interviews was their enjoyment of ICT simulation-based lessons. All participants responded positively, expressing delight in incorporating ICT simulations into their waves and sound lessons. They found the technology to be enjoyable and exciting, as evidenced by their physical expressions of enjoyment, such as smiling and laughter. During teaching and learning, the participants were attentive and engaged when the researcher demonstrated and described concepts through ICT simulations. They were even willing to assist the researcher in connecting the ICT tools. The noise level in the classroom increased when the researcher asked a question, indicating a fun and exciting atmosphere.

Learner engagement and enjoyment are indicators of positive ICT simulation results as teaching and learning strategies. The theme of "teaching and learning support" emerged when the participants were asked about the effectiveness of ICT simulations as a teaching and learning tool. The learners agreed that ICT simulations are an effective teaching and learning strategy, as stated by Almasri (2022) who argues that ICT simulations are an ICT tool used as a pedagogical tool for teaching and learning. ICT simulations are used to simplify abstract physical concepts, making them easier to understand. According to current literature, simulations are a clearer and more effective strategy than textbooks and real equipment. Furthermore, Abou Faour and Ayoubi (2017, p. 65) investigated the effects of using a virtual laboratory on grade 10 students' conceptual understanding and attitudes toward physics and found that "learners who learned through computer simulations performed better than learners who were taught through traditional methods."

During the interviews, the learners indicated that they were asked to explain what they understood during the lessons. A majority of the participants stated that transverse pulses and sound were the concepts they found most comprehensible. This perception of the learners suggested that the integration of ICT simulations in class lessons eliminated alternative conceptions among rural grade 10 learners, a finding that resonates with the research conducted by Ramnarain and Moosa (2017). The utilization of ICT simulations facilitated a better understanding of the observed concepts among learners. According to the existing literature, Wilson (2016) posited that computer simulations simplify the process of comprehending new concepts compared to traditional teaching methods. Similarly, Falloon (2019) argued that simulations make abstract scientific concepts tangible and comprehensible. In a study conducted by Chumba et al. (2020) it was recommended that learning should incorporate computer simulations as they foster positive attitudes. Higher levels of positive attitudes are associated with improved academic performance.

This study has revealed that learners have demonstrated an improved conceptual understanding of waves and sound concepts. However, it has also emerged that certain concepts continue to pose challenges for the participants. The participants' quotations have highlighted areas of confusion, including the concepts of rarefaction and compression in longitudinal waves, pitch and frequency of sound, and ultrasound. These findings suggest that the learners' misconceptions were not adequately addressed. This result is consistent with previous research by Abdul and Akhilesh (2008) who reported that rural learners tend to have more alternative conceptions than their urban counterparts. The literature has indicated that conceptual difficulties may stem from a limited understanding of the English language, abstract concepts, and textbooks used during teaching and learning. In this study, learners experienced confusion with the concepts of rarefaction, compression, and the propagation of longitudinal waves. These findings align with those of Coombs (2007) who investigated students' understanding of sound as a longitudinal wave. The authors emphasized that longitudinal waves are not well comprehended, and students struggled to relate them to transverse waves. This misunderstanding may be attributable to the fact that longitudinal waves are represented by dots, whereas transverse waves are illustrated using a sine curve diagram. A study by Tumanggor et al. (2020) also identified students' alternative conceptions of the properties of longitudinal waves, such as the wavelength as the distance between compression and rarefaction, and the challenge of distinguishing between compression and rarefaction. These concepts indicate a profound conceptual difficulty.

5.6. Chapter summary

The researcher presented and discussed the data from observation lessons, intervention, post-test, and interview results. Firstly, the researcher presented the interview results before intervention. Moreover, the chapter presented the findings from the ICT simulation-based lessons. The second and third research questions were answered in this chapter. Finally, perceptions of rural grade 10 learners were revealed. All the findings analysed in this chapter were discussed in the last section. The recommendations and conclusions of this study are presented in the next chapter.

CHAPTER 6

CONCLUSIONS AND RECOMMENDATIONS

6.1. Introduction

The purpose and focus of the study, as well as the study's background, were presented in chapter 1. The chapter also addressed the research questions that guided this investigation. The relevant body of literature was reviewed in chapter 2. In addition, the theoretical frameworks that led this study were discussed in the same chapter. The research design and methodology adopted in this study were discussed in chapter 3. In chapter 4, the researcher presented and discussed the pre-test results to answer the first research question. In chapter 5, the data from interviews, observation, and post-test, were presented and further discussed to address the second research question and third research question. This chapter begins by presenting the study's findings according to the research questions. The second section discusses the contributions of this study to the body of knowledge. Limitations arising from this study are presented in the third section. In the fourth section, the researcher presents a critical reflection on the research methods. Recommendations are offered at the end of the chapter in light of these results.

6.2. Summary of Findings

6.2.1 What are the rural grade 10 Physical Sciences learners' alternative conceptions about waves and sound?

The results of the questionnaire revealed that the rural grade 10 Physical Sciences learners had a poor conceptual understanding, and many of the commonly identified alternative conceptions were similar to those reported in the current literature. These alternative conceptions are discussed in detail in Section 4.3 of this study. The ultimate goal of this research was to identify and address the alternative conceptions of waves and sound held by rural grade 10 learners using ICT simulations. The identified alternative conceptions were utilized to develop an ICT simulation-based intervention.

6.2.2 How can ICT simulations address rural grade 10 Physical Sciences learners' alternative conceptions about waves and sound?

The group activities were used to assess plausibility, while the learners applied the knowledge acquired in other phases to address fruitfulness. The learners worked in groups, supported by social constructivism, which allowed them to interact and learn from one another. After a designated time for group discussions, the teacher, together with the class, discussed the waves and sound concepts using simulations from PhET, Physics Classroom, Java Lab, and oPhysics. These simulations were animated, interactive, and had slow-motion keys to facilitate the understanding of abstract concepts of waves and sound. The lessons were observed by the researcher using the five dimensions of meaningful learning with ICT in a rubric developed by Koh (2013). The analysis of the observation through the rubric indicated that the learners were actively engaged and participated in the integration of ICT simulations during teaching and learning.

During this intervention, a post-test was administered to all participants, and the results demonstrated that ICT simulations were an effective instructional strategy. The findings revealed that the most improved questions (4, 6, 7, 9, 15, 16, 21, and 22) indicated that the participants had a comprehensive understanding of the concepts after the integration of ICT simulations. These questions assessed transverse pulses, superposition of pulses, longitudinal waves, and particle movement due to sound-produced concepts. A positive response was shown for questions 1, 2, 3, 8, 13, 17, and 23, although only a few learners answered these questions correctly. The concepts examined were wave speed, transverse waves, and sound waves. However, the post-test results also revealed difficulties in understanding even after the intervention. Items (5, 12, 20, and 24) of the post-test indicated no change, and questions 10,

11, 14, 18, 19, and 25 showed a negative response since the number of participants decreased compared to the pre-test. The learners still demonstrated confusion, as they misunderstood some of the waves and sound concepts, such as medium properties, wavelength, period, sound pitch, and loudness. The analysis of these findings indicated that ICT simulations were a successful intervention that improved the academic performance of rural learners.

6.2.3 How do rural grade 10 Physical Sciences learners' perceptions of learning through ICT simulations relate to their performances?

The third objective of this study was to investigate the perceptions of rural Grade 10 Physical Sciences learners regarding their learning experiences through the use of ICT simulations. The initial analysis revealed the theme of learner engagement. The learners exhibited enthusiasm before the intervention, which may have been attributed to the novelty of the ICT simulations. Participants were actively engaged in group discussions, fostering participation through social constructivism. The learners expressed their enjoyment of ICT- based learning, emphasizing that technology makes learning more enjoyable and exciting.

The learners opined that ICT simulations are an effective teaching and learning strategy due to their ability to simplify abstract physical concepts. Additionally, the participants reported having a better conceptual understanding. This study suggests that incorporating technology, such as ICT simulations, in the classroom can enhance the quality of instruction, particularly in addressing alternative conceptions. This finding indicates that ICT simulations can improve the understanding of waves and sound alternative concepts. Most of the participants indicated that they had a better grasp of transverse pulses and sound concepts. However, the participants also identified difficulties in understanding longitudinal waves and sound concepts. The participants' quotes highlighted the misunderstanding of the longitudinal wave and sound concepts.

6.3. Contributions to Body of Knowledge

The existing body of literature has revealed very limited studies on the utilization of simulations to address alternative conceptions related to waves and sound, particularly in rural schools. Most of the existing research studies have emphasized the integration of ICT simulations in rural schools in teaching and learning physics concepts, as they are abstract and complex (Mwapwele et al., 2019; Tsoka, 2020). The literature suggests that rural schools face challenges in accessing technology (Jones, 2018). Based on the identified gaps, the study's contributions to the literature are as follows: Firstly, the research identified alternative conceptions about waves and sound among rural grade learners, which have not been extensively studied previously. The results revealed that the integration of ICT simulations to address rural grade 10 learners' alternative conceptions was more effective than traditional teaching methods. This contribution advances the existing literature by providing a novel approach to employing conceptual change theory through social constructivism to enhance the performance of rural learners. Furthermore, the findings provide insights that can inform policies and practices for improving the academic success of rural learners. Second, limited previous studies have been conducted in a rural setting, as most of the existing research has focused on townships and urban schools. The related findings will contribute in the rural education context.

6.4. Limitations of the study

The present study was conducted in a single rural school situated within the Zululand district in the province of KwaZulu-Natal. As such, the findings cannot be generalized to all rural schools; however, they are consistent with existing literature. The study provides insights into how ICT simulations could be employed to address alternative conceptions of science held by rural Grade 10 learners. Additionally, the findings add to the existing body of literature on rural science learners' alternative conceptions of waves and sound, and the use of ICT simulations to correct these conceptions.

The study was limited in several ways, including the English science language used that was difficult for learners. The study was conducted in English, and learners were expected to respond and cooperate in English. As a result, some learners did not respond due to language barriers. Furthermore, the instruments used may have had some problems. The pre-test used to identify alternative conceptions contained some answers that were guessed, as revealed in Chapter 4, which limited the instrument's ability to measure performance. Additionally, the study used 25 items, which may have introduced fatigue as a factor in answering test questions, leading to participants guessing.

Furthermore, the awareness of participants that they were being studied may have limited the study, reducing the possibility of recording true behaviour and generating authentic data. Moreover, the lack of ICT tools to engage learners limited the study, as learners could not work independently. Additionally, cellphones were not used due to the strict rules of the hosting school.

6.5. Critical Reflections on the Research Methods

The researcher came to understand the issue while examining the outcomes for each term. The role of the instructor in resolving the issue was recognized. Consequently, research questions were formulated to guide the investigation. The study's results were closely tied to the calibre of primary data and the appropriate choice of methodology. Hence, the study utilized a qualitative methodology. Reflection is a crucial aspect of qualitative research as it helps comprehend the participants (Mohan, 2020). The researcher also utilized an action research design, which allowed the researcher to act as both a researcher and a participant. The study was pilot-tested to guarantee feasibility and likelihood to success. The data was obtained from rural Grade 10 learners. Moreover, the data was examined through thematic analysis. The methods used ensured fair data analysis and conclusions.

6.6. Recommendations of the study

This study aimed to identify and address alternative conceptions held by rural grade 10 Physical Sciences learners through the use of ICT simulations. The findings indicated that learners developed a strong conceptual understanding of waves and sound after participating in ICT simulation-based interventions. Therefore, it is essential for teachers to be aware of these alternative conceptions and to integrate ICT simulations into their day-to-day teaching to reduce misunderstanding of school science concepts. Additionally, regular workshops should be conducted for teachers to develop their knowledge and skills in ICT integration, including software and hardware usage and how to teach using ICT tools. Furthermore, it is recommended that school stakeholders actively encourage and empower teachers to use ICT simulations that are accessible on mobile platforms to support a learner-centred approach to science concepts. Access to the Internet is crucial for rural schools, and the Department of Basic Education should offer assistance to those who cannot afford to pay for Internet services. In rural schools where technology integration is a challenge, teachers should attempt to use ICT tools and improve learners' positive attitudes towards the Physical Sciences subject. Language plays an important role in teaching and learning, and rural schools should reconsider their language of learning and teaching (LoLT) to promote maximum participation of learners and improve their academic performance. Future research is needed to investigate the effect of ICT simulations on the retention of waves and sound concepts among rural grade 10 Physical Sciences learners, as well as to explore other topics in greater depth.

6.7. Conclusion

The Department of Basic Education has expressed significant concern regarding the underperformance of learners in grade 12 Physical Sciences. It is imperative that educators consistently refine their teaching methods to accommodate the unique needs of learners. The employment of ICT simulations has been demonstrated to be a successful teaching strategy for addressing alternative conceptions and enhancing learners' academic performance. Through the use of ICT simulations, learners were able to gain a more profound comprehension of scientific principles. The learners were motivated, and their academic performance improved as a result. This suggests that ICT simulations possess the potential to enhance both teaching methodologies and learning outcomes.

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Appendices

Appendix A: Gatekeeper's Permission from the Department of Education

KWAZULU-NATAL PROVINCE

EDUCATION
REPUBLIC OF SOUTH AFRICA

OFFICE OF THE HEAD OF DEPARTMENT

Private Bag X9137, PIETERMARITZBURG, 3200
Anton Lembede Building, 247 Burger Street, Pietermaritzburg, 3201 **Email:** Phindile.duma@kzndoe.gov.za
Tel: 033 392 1051

Enquiries: Mrs B.T. Ntuli **Ref.**:2/4/8/77363

Miss Nokubonga Fortunate Mzolo
P.O. Box 10081
ULUNDI
3838

Dear Miss Mzolo

PERMISSION TO CONDUCT RESEARCH IN THE KZN DoE INSTITUTIONS

Your application to conduct research entitled: **"RURAL GRADE 10 PHYSICAL SCIENCES LEARNERS' ALTERNATIVE CONCEPTIONS ABOUT WAVES AND SOUND THROUGH INFORMATION AND COMMUNICATIONS TECHNOLOGY SIMULATIONS:"**, in the KwaZulu-Natal Department of Education institutions has been approved. The conditions of the approval are as follows:

1. The researcher will make all the arrangements concerning the research and interviews.
2. The researcher must ensure that Educator and learning programmes are not interrupted.
3. Interviews are not conducted during the time of writing examinations in schools.
4. Learners, Educators, Schools and Institutions are not identifiable in any way from the results of the research.
5. A copy of this letter is submitted to District Managers, Principals and Heads of Institutions where the Intended research and interviews are to be conducted.
6. The period of investigation is limited to the period from **14th November 2022 to 31st March 2025**.
7. Your research and interviews will be limited to the schools you have proposed and approved by the Head of Department. Please note that Principals, Educators, Departmental Officials and Learners are under no obligation to participate or assist you in your investigation.
8. Should you wish to extend the period of your survey at the school(s), please contact Miss Phindile Duma at the contact numbers above.
9. Upon completion of the research, a brief summary of the findings, recommendations or a full report/dissertation/thesis must be submitted to the research office of the Department. Please address it to The Office of the HOD, Private Bag X9137, Pietermaritzburg, 3200.
10. Please note that your research and interviews will be limited to schools and institutions in KwaZulu-Natal Department of Education.

[redacted]

Mr GN Ngcobo
Head of Department: Education
Date: 14 November 2022

GROWING KWAZULU-NATAL TOGETHER

Appendix B: Ethical Clearance Certificate

UNIVERSITY OF KWAZULU-NATAL™
INYUVESI YAKWAZULU-NATALI

31 January 2023

Nokubonga Fortunate Mzolo (206516153)
School Of Education
Edgewood Campus

Dear NF Mzolo,

Protocol reference number: HSSREC/00005133/2022
Project title: Rural grade 10 Physical Sciences learners' alternative conceptions about waves and sound through information and communications technology simulations
Degree: Masters

Approval Notification – Expedited Application

This letter serves to notify you that your application received on 08 December 2022 in connection with the above, was reviewed by the Humanities and Social Sciences Research Ethics Committee (HSSREC) and the protocol has been granted **FULL APPROVAL**.

Any alteration/s to the approved research protocol i.e. Questionnaire/Interview Schedule, Informed Consent Form, Title of the Project, Location of the Study, Research Approach and Methods must be reviewed and approved through the amendment/modification prior to its implementation. In case you have further queries, please quote the above reference number. PLEASE NOTE: Research data should be securely stored in the discipline/department for a period of 5 years.

This approval is valid until 31 January 2024.
To ensure uninterrupted approval of this study beyond the approval expiry date, a progress report must be submitted to the Research Office on the appropriate form 2 - 3 months before the expiry date. A close-out report to be submitted when study is finished.

HSSREC is registered with the South African National Health Research Ethics Council (REC-040414-040).

Yours sincerely,

[redacted]

Professor Dipane Hlalele (Chair)

/dd

Humanities and Social Sciences Research Ethics Committee
Postal Address: Private Bag X54001, Durban, 4000, South Africa
Telephone: +27 (0)31 260 8350/4557/3587 **Email:** hssrec@ukzn.ac.za **Website:** http://research.ukzn.ac.za/Research-Ethics

Founding Campuses: Edgewood Howard College Medical School Pietermaritzburg Westville

INSPIRING GREATNESS

Appendix C: School Principal Letter

Miss N.F Mzolo

P.O Box 10081

Ulundi

3838

07 November 2022

Ntabasuka High School

P.O Box 436

Ulundi

3838

Dear Principal

REQUEST FOR PERMISSION TO CONDUCT RESEARCH

My name is Nokubonga Mzolo. I am studying for a Master of Education degree in the school of education at the University of KwaZulu-Natal, Edgewood campus. I humbly request permission to use the school facilities and involve grade 10 Physical Sciences learners from the school to conduct a research study based on science education.

The research project will focus on identifying rural grade 10 Physical Sciences learners' alternative conceptions about waves and sound and addressing them through Information and Communications and Technology (ICT) simulations. The results of the study will improve my pedagogy with the use of ICT in science teaching. It will expose learners to ICT and also prepare them for tertiary education and the workplace.

The research will entail collecting data from learners. Data will be collected through pre and post-tests, interviews, discussions, classroom lessons, and video recording during working hours. Participants will be asked to give their written consent before the research begins. All the data from this study will be kept as private as possible. School names will not be disclosed, and pseudonyms will be used instead of learners' real names. The information gathered will be used for research purposes only.

The participants will be assured that they can withdraw from the study at any time without any penalty. There are no foreseeable risks in participating in this study. I would like to assure you that the research will not interfere in any way with the functioning of the school.

The research study will be conducted under the supervision of Professor Nadaraj Govender and Mr Bongani Prince Ndlovu. If you have questions regarding this research, do not hesitate to contact the researcher and the supervisors at the contact details below.

Researcher: Ms. NF Mzolo

Contact no.: [redacted]

[redacted]

Supervisor: Prof N Govender

Contact no.: [redacted]

[redacted]

Co-supervisor: Mr B.P Ndlovu

Contact no.: [redacted]

[redacted]

Thank you in advance for your contribution to this study.

Yours sincerely

Nokubonga Mzolo

____

Appendix D: Gatekeeper's Permission from the School Principal

NTABASUKA HIGH SCHOOL

P.O.BOX 436, Ulundi, 3838

EMIS: 500 238 983

Ntabasuka High School

P.O Box 436

Ulundi

3838

15/11/2022

Dear Mzolo NF

I am delighted to hear that you are advancing yourself in Physical sciences. I always like to see young enthusiastic ladies brightening their future as you do. **Keep up the good work.** As your principal I allow you to conduct your research to our school as long as your research won't interfere with your co-duty i.e teaching and learning.

I wish you all the best in your studies.

[redacted]

~~DEPUTY~~ PRINCIPAL
DEPT OF EDUCATION
NTABASUKA HIGH SCH
P. O. BOX 436
ULUNDI
3838
DATE: 15/11/2022

Appendix E: Parent Consent Letter

UNIVERSITY OF
KWAZULU-NATAL
INYUVESI
YAKWAZULU-NATALI

INFORMED CONSENT LETTER

Dear Parents/Guardians

My name is Nokubonga Mzolo. I am a Master of Education student from the Science and Technology Cluster, School of Education, College of Humanities, University of KwaZulu-Natal. I am conducting research titled **'Rural Grade 10 Physical Sciences Learners' Alternative Conceptions about Waves and Sound through Information and Communications Technology Simulations'.**

I have observed that rural learners are not performing well in physical sciences, particularly in waves and sound. The literature review has suggested the integration of information and communications technology in teaching and learning, hence simulations will be used to address alternative conceptions about waves and sound.

I will be doing action research, thus I am also involved in participation. The research study will gather information through daily lesson plans, tests, interviews, audio/video recordings, and discussions with learners. I, therefore, invite your child to participate in this research study since the child is in grade 10 Physical Sciences class.

Please note the following:

- Your child's confidentiality will be guaranteed. All data from this study will be kept as private as possible. Pseudonyms will be used instead of your child's real names.
- The discussion and interview may last for about an hour
- The information gathered will be used for research purposes only.
- The collected data will be stored in secure storage and destroyed after 5 years.
- Your child's participation in this research study is voluntary. A child may quit without penalty at any time.

- Your child’s involvement is purely for academic purposes only, and there are **no financial** benefits involved. However, it is expected that the findings will help us gain a better understanding of the content.

My contact details are as follows:

[redacted]

This study will be supervised by Prof Nadaraj Govender and Mr Bongani Prince Ndlovu. They are located at the School of Education, College of Humanities, Edgewood Campus, University of KwaZulu-Natal. Prof Govender can be contacted at [redacted] Mr Ndlovu can be contacted at [redacted]

You may also contact the Research Office at:

University of KwaZulu-Natal

Humanities and Social Sciences Research Ethics

Govan Mbeki Centre

[redacted]

Thank you for reading this document about this research. Thank you for your contribution to this research study.

Yours faithfully

………………………

DECLARATION OF CONSENT

I ……………………………………………………………………………… (Full names of the parent/guardian) hereby confirm that I have been informed about the study titled **"Rural Grade 10 Physical Sciences Learners' Alternative Conceptions about Waves and Sound through Information and Communications Technology Simulations'**. **I understand the contents of this document and the nature of the research project, and I consent for my child to participate in the research project. I also consent to the following data collection tools (please tick):**

	Yes	No
Pre/post-tests		
Interviews		
Audio/Video recording		
Discussions		

……………………………………… ……………………………………

Signature of Parent/Guardian **Date**

Appendix F: Assent to Learners

UNIVERSITY OF
KWAZULU-NATAL
INYUVESI
YAKWAZULU-NATALI

ASSENT TO LEARNERS

Dear Participant

My name is Nokubonga Mzolo. I am a Master of Education student from the Science and Technology Cluster, School of Education, College of Humanities, University of KwaZulu-Natal. I am conducting research titled **'Rural Grade 10 Physical Sciences Learners' Alternative Conceptions about Waves and Sound through Information and Communications Technology Simulations'.**

I have observed that rural learners are not performing well in physical sciences, particularly in waves and sound. The literature review has suggested the integration of information and communications technology in teaching and learning, hence simulations will be used to address alternative conceptions about waves and sound.

I will be doing action research, thus I am also involved in participation. The research study will gather information through daily lesson plans, tests, interviews, audio/video recordings, and discussions with learners. I therefore invite you to participate in this research study since you are in grade 10 Physical Sciences class.

Please note the following:

- Your confidentiality will be guaranteed. All data from this study will be kept as private as possible. Pseudonyms will be used instead of your real names.
- The discussion and interview may last for about an hour
- The information gathered will be used for research purposes only.
- The collected data will be stored in secure storage and destroyed after 5 years.
- Your participation in this research study is voluntary. You may quit without penalty at any time.

- Your involvement is purely for academic purposes only, and there are **no financial** benefits involved. However, it is expected that the findings will help us gain a better understanding of the content.

My contact details are as follows:

[redacted]

This study will be supervised by Prof Nadaraj Govender and Mr Bongani Prince Ndlovu. They are located at the School of Education, College of Humanities, Edgewood Campus, University of KwaZulu-Natal. Prof Govender can be contacted at [redacted] Mr Ndlovu can be contacted at [redacted]

You may also contact the Research Office at:

University of KwaZulu-Natal

Humanities and Social Sciences Research Ethics

Govan Mbeki Centre

Tel [redacted]

[redacted]

Thank you for reading this document about this research. Thank you for your contribution to this research study.

Yours faithfully

………………………

DECLARATION OF CONSENT

I ……………………………………………………………………………… (Full names of the participant under 18 years of age) hereby confirm that I have been informed about the study titled **"Rural Grade 10 Physical Sciences Learners' Alternative Conceptions about Waves and Sound through Information and Communications Technology Simulations'**. **I understand the contents of this document and the nature of the research project, and I consent to participate in the research project. I also consent to the following data collection tools (please tick):**

	Yes	No
Pre/post-tests		
Interviews		
Audio/Video recording		
Discussions		

……………………………………… ……………………………………

Signature of Participant **Date**

Appendix G: Pilot Pre-test

Sound and Waves

Standardised test (Pre-test)

1. Two students sing equally loudly. Student **X** sings at a high pitch, student **Y** sings at a lower pitch. Which of the following is true?

    A. The two frequencies are the same, but the amplitudes are different.
    B. The two amplitudes are the same, but the frequencies are different.
    C. The two frequencies are the same, and the amplitudes are also the same.
    D. The two frequencies are different, and the amplitudes are also different.

Consider the following description and answer questions 2 - 3.

Students **X** and **Y** are standing 50 meters apart and yell "Yo!" at each other at exactlythe same time.

2. They yell at each other with the same loudness, but **Y** yells with a higher pitch than **X** does.Who will hear the other's sound first?

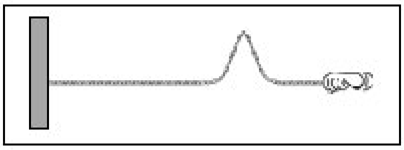
    A. They will hear each other at exactly the same time because the speed of sound waves depends on the properties of the air.
    B. **X** will hear the sound first because the speed of sound waves depends on frequency according to $v=f.\lambda$
    C. They will hear each other at exactly the same time because the speed of sound waves depends on amplitude.
    D. **X** will hear the sound first because sound with a higher frequency is more penetrating.

3. Student **Y** yells louder than **X**, but they yell at each other with the same pitch. Who will hear the other's sound first?

    A. **X** will hear the sound first because the speed of the waves depends on the amplitude of the sound.
    B. They will hear each other at exactly the same time because the speed of the waves depends on the frequency according to $v=f.\lambda$
    C. They will hear each other at exactly the same time because the speed of the waves depends on the properties of the air.
    D. **X** will hear the sound first because the wave with the larger amplitude travels further.

1

Consider the following description and answer questions 4 – 5.
One end of a long taut string is tied to a distant pole while the other end of the string is held by a girl (see figure below). This girl quickly flicks her hand up and down to create a pulse moving towards the pole.



4. She now wants to produce a pulse that takes a shorter time to reach the pole. How can she do this?

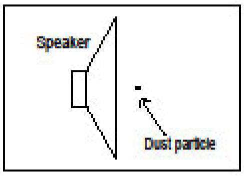
    A. Flick the string harder to push more force into the pulse.
    B. Flick the string faster to create a pulse with higher frequency.
    C. Flick the string further up and down to create a pulse with larger amplitude.
    D. Flick the string a shorter distant up and down to create a pulse with smaller amplitude.
    E. Wait until the first pulse is reflected back then flick again to add the pulses together.
    F. None of the above would produce a pulse that takes a shorter time to reach the pole.

5. She still wants the pulse to reach the pole in a shorter time by changing the properties of the string. How can she do this?

    A. She should use a lighter string, under the same tension, because the velocity increases as the density decreases.
    B. She should use a heavier string, under the same tension, because the velocity increases as the density increases.
    C. She should decrease the tension in the string because the velocity increases as the tension decreases.
    D. None of the above would produce a pulse that takes a shorter time because the speed is determined by frequency and wavelength according to $v=f.\lambda$

Consider the following description and answer questions 6 - 8.

A dust particle hovers in front of a silent loudspeaker (see figure below). The loudspeaker is turned on and plays a loud tone at a constant pitch.



6. How will the dust particle move?

   A. It will stay in the same position.
   B. It will move back and forth about the same position.
   C. It will move up and down about the same position.
   D. It will move away from the speaker.
   E. It will move away as a sine curve.

For questions 7 and 8, choose the description from **A through H** which best answers each question.

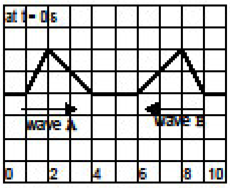
   A. It will stay at the same position.
   B. It will move back and forth further.
   C. It will move back and forth faster.
   D. It will move up and down further.
   E. It will move up and down faster.
   F. It will move away further.
   G. It will move away faster.
   H. It will move away faster as a sine curve.

7. The pitch of the sound is increased but the volume stays the same. **What happens to the motion** of the dust particle?

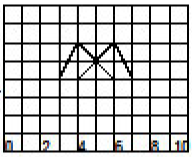
8. The volume of the sound is increased but the pitch stays the same. What happens to the motion of the dust particle?

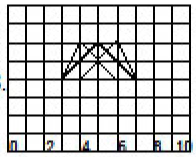
Consider the following description and answer questions 9-10.

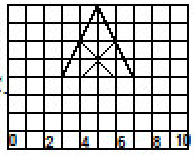
Two pulses are moving towards each other. Each pulse has a speed of 1 cm/s. The figure on the right shows the pulses at time t = 0 s. Each square width corresponds to 1 cm x 1cm. The dashed lines indicate the correct positions of the individual pulses after 2 s.

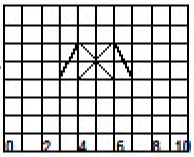


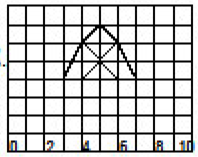
9. Select the drawing that corresponds to the shape of the resultant pulse after **2** s.

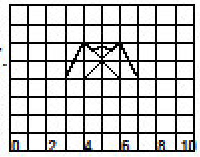
A. 

B. 

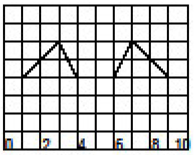
C. 

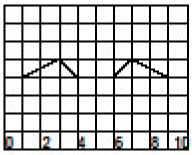
D. 

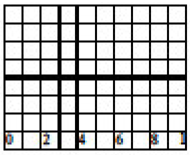
E. 

F. 

10. Select the drawing and explanation that corresponds to the shape of theresultant pulse after **5** s.







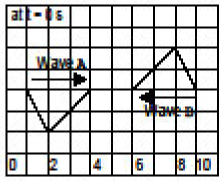
A. Waves have passed through one another and retained their shapes.

B. Waves have become smaller because they have collided and so lost energy.

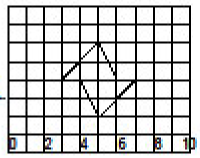
C. Waves have cancelled each other.

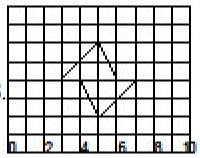
Consider the following description and answer questions 11-12.

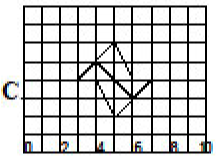
Two pulses are moving towards each other. Each pulse has a speed of 1 cm/s. The figure on the right shows the pulses at time t = 0 s. Each square width corresponds to 1 cm x 1cm.

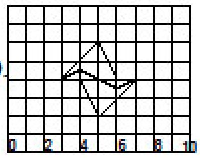


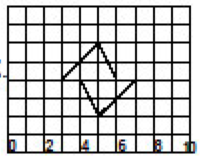
11. Select the drawing that corresponds to the shape of the resultant pulse after 3 s.

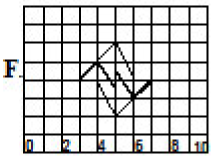
A.


B.


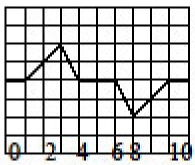
C.


D.


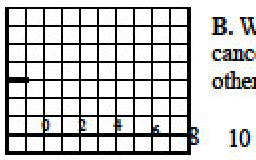
E.


F.


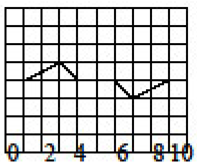
12. Select the drawing that corresponds to the shape of the resultant pulse after 5 s.



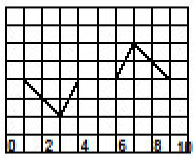
A. Waves have passed through one another and retained their shapes.



B. Waves have cancelled each other.



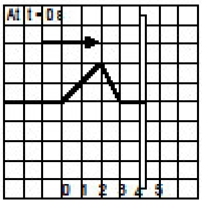
C. Waves become smaller because they have collided and so lost energy.



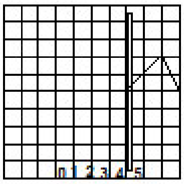
D. Waves have collided with each other and turned upside-down.

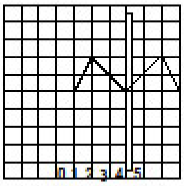
Consider the following description and answer questions 13-14.

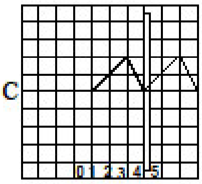
A girl is demonstrating wave motion on a string attached to a pole. The string can be either ***firmly*** attached so that the end cannot move or tied to a ring that can move ***loosely*** up and down on the pole. The girl flicks the string creating an ***asymmetric*** pulse moving towards the pole. The pulse has a speed of 1 cm/s. Each square in the figure corresponds to 1 cm x 1 cm. The figure on the right shows the pulse at t = 0 s.

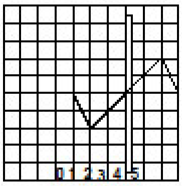


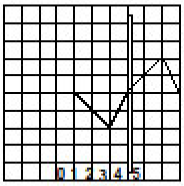
For questions 13 and 14, choose the drawing from **A** through **E** which best answers each question.

A


B


C


D


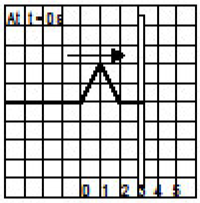
E


13. Select the drawing that corresponds to the shape of the resultant pulse after 4 s, assuming the string is ***firmly*** attached to the pole.

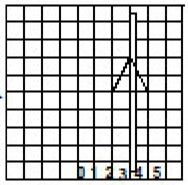
14. Select the drawing that corresponds to the shape of the resultant pulse after 4 s, assuming the string is tied to a ring that can move ***loosely*** up and down on the pole.

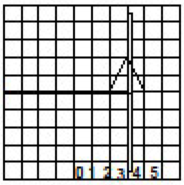
Consider the following description and answer questions 15-16.

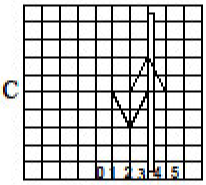
A girl is demonstrating wave motion on a string attached to a pole. The string can be either ***firmly*** attached so that the end cannot move or tied to a ring that can move ***loosely*** up and down on thepole. The girl flicks the string creating a ***symmetric*** pulse moving towards the pole. The pulse has a speed of 1 cm/s. Each square in the figure corresponds to 1 cm x 1 cm. The figure on the right shows the pulse at t = 0 s.

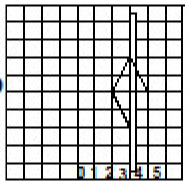


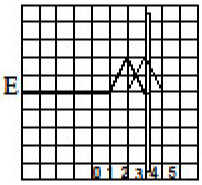
15. Select the drawing that corresponds to the shape of the resultant pulse after **2** s, assuming the string is ***firmly*** attached to the pole.

A


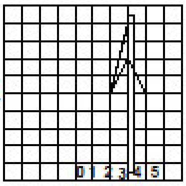
B


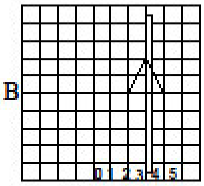
C


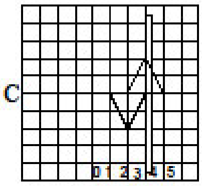
D


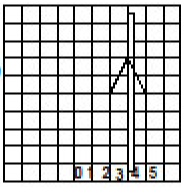
E


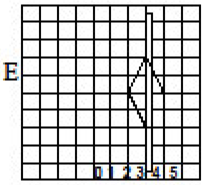
16. Select the drawing that corresponds to the shape of the resultant pulse after **2** s, assuming the string is tied to a ring that can move ***loosely*** up and down on the pole.

A


B


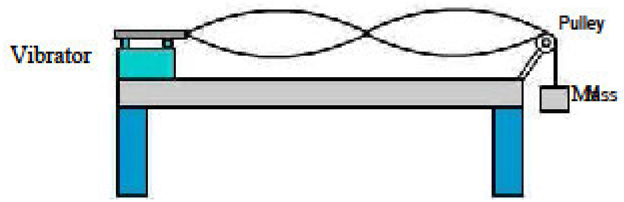
C


D


E


Consider the following description and answer questions 17-19.

A standing wave is produced with a fixed length string, one end of which is attached to a vibrator, the other end of which is placed on a pulley and hung with a mass. Using the vibrator, the second harmonic standing wave is created (see figure below). The length between the vibrator and the pulley does not change.



17. If the frequency of the vibrator is doubled while everything else stays the same, a different harmonic standing wave is created. How would the wavelength of the new harmonic standing wave change?

Answer:

A. Increase
B. Decrease
C. Stay the same

Reason:

1. The wavelength depends on the amount of energy flowing in the waves.
2. The wavelength is proportional to frequency since the velocity doesn't change.
3. The wavelength depends on the length of the rope the frequency doesn't affect the wavelength.
4. The wavelength is inversely proportional to the frequency since the velocity doesn't change.

18. If the mass is increased by a factor of four while everything else stays the same, a different harmonic standing wave is created. How would the wavelength of the new harmonic standing wave change?

Answer:

A. Increase
B. Decrease
C. Stay the same

Reason:

1. The wavelength depends only on the length of the rope.
2. The wavelength is inversely proportional to the frequency.
3. As the tension increases, the speed of the wave increases.
4. As the tension increases, it is harder to get the string to vibrate.

1

19. If a thicker (more mass) rope is used while everything else stays the same, a different harmonic standing wave is created. How would the wavelength of the new harmonic standing wave change?

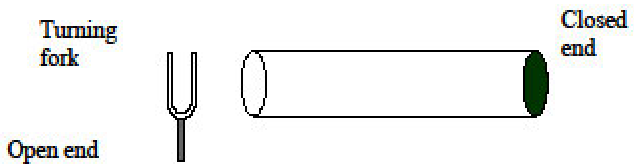
Answer:

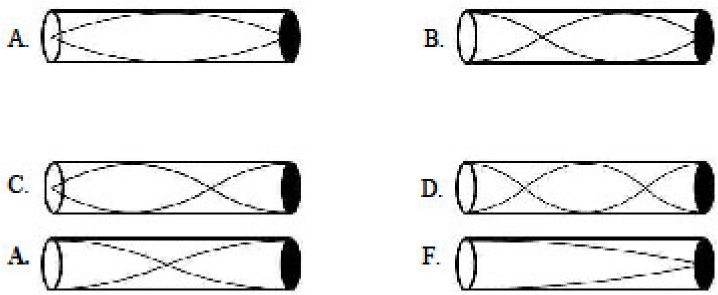
A. Increase
B. Decrease
C. Stay the same

Reason:

1. The wavelength depends only on the length of the rope.
2. The wavelength is inversely proportional to the frequency.
3. As the rope becomes heavier, the speed of the wave decreases.
4. As the rope becomes heavier, the amount of energy flowing in the waves is different.

20. A tuning fork is hit and held in front of a one open-ended cylinder. The first harmonic resonance (the fundamental) is generated. Which diagram best describes the pattern of the displacement of air molecules inside the tube.





21. Two tubes have the same diameter and length. One has two open ends, and the other has only one open end. The fundamental frequencies of these two tubes are…

Answer:

A. the same
B. greater in the tube with one open end
C. greater in the tube with two open ends

Reasons:

1. There is more air pressure in the tube with one open end.
2. The two tubes contain the same number of air molecules.
3. The two tubes have the same size and the ends do not matter.
4. The wavelength in the tube with one open end is longer than in the other one.
5. The wavelength in the tube with one open end is shorter than in the other one.

22. Air is blown across the top end of a bottle filled one third with water, creating a sound. How would the pitch of the sound be changed if more water were added to fill the bottle to half full? The pitch would…

Answer:

A. stay the same
B. become higher
C. become lower

Reasons:

6. Each bottle has its own constant frequency.
7. The air column becomes shorter and the wavelength changes.
8. There is a shorter air column, so the air molecules have less space to vibrate.
9. There is a shorter air column, so there is higher air pressure inside the bottle.
10. There is a longer column of water which absorbs more energy from the sound

1

Appendix H: Main Study Pre-test

Sound and Waves

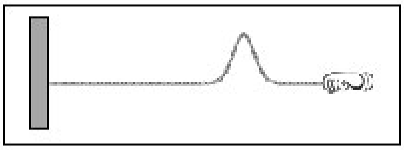
Pre-test

Name: .... **Date:** ....

Class: .... **Marks:** ....

Instruction: Answer the following questions by circling the correct option.

Consider the following description and answer questions 1 – 2.
One end of a long taut string is tied to a distant pole while the other end of the string is heldby a girl (see figure below). This girl quickly flicks her hand up and down to create a pulse moving towards the pole.



1. She now wants to produce a pulse that takes a shorter time to reach the pole. Howcan she do this?

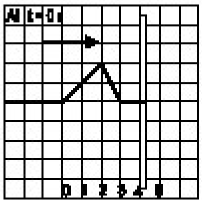
   A. Flick the string harder to push more force into the pulse.
   B. Flick the string faster to create a pulse with a higher frequency.
   C. Flick the string further up and down to create a pulse with a larger amplitude.
   D. Flick the string a shorter distance up and down to create a pulse with a smalleramplitude.
   E. Wait until the first pulse is reflected back then flick again to add the pulsestogether.
   F. None of the above would produce a pulse that takes a shorter time to reach thepole.

2. She still wants the pulse to reach the pole in a shorter time by changing the properties of the string. How can she do this?

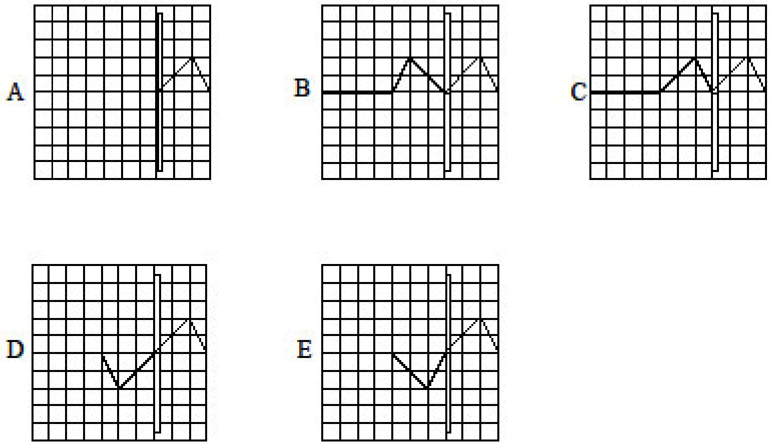
   A. She should use a lighter string, under the same tension, because the velocity increases as the density decreases.
   B. She should use a heavier string, under the same tension, because the velocity increases as the density increases.
   C. She should decrease the tension in the string because the velocity increases asthe tension decreases.
   D. None of the above would produce a pulse that takes a shorter time because the speed is determined by frequency and wavelength according to $v = f. \lambda$

Consider the following description and answer questions 3-4.

A girl is demonstrating wave motion on a string attached to a pole. The string can be either ***firmly*** attached so that the end cannot move or tied to a ring that can move ***loosely*** up and down on the pole. The girl flicks the string creating an ***asymmetric*** pulse moving towards the pole. The pulse has a speed of 1 cm/s. Each square in the figure corresponds to 1 cm x 1 cm. The figure on the right shows the pulse at t = 0 s.

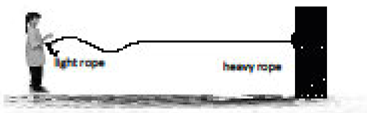


For questions 3 and 4, choose the drawing from **A** through **E** that best answers each question.



3. Select the drawing that corresponds to the shape of the resultant pulse after 4 s, assuming the string is ***firmly*** attached to the pole.
4. Select the drawing that corresponds to the shape of the resultant pulse after 4 s, assuming the string is tied to a ring that can move ***loosely*** up and down on the pole.

5. Mary tied end-to-end two similar ropes of equal length but **different masses**. She fastened the end of the heavier rope to a wall. She held and pulled the other end of the lighter rope until the rope system was taut. She jerked the end of the lighter rope up and down at a **fixed frequency** to create a wave train while maintaining constant tension in the ropes. The setup is shown in the diagram below.



The frequency of the waves in the light rope is……… than in the heavy rope.
A. greater than
B. less than
C. the same as

Reason:

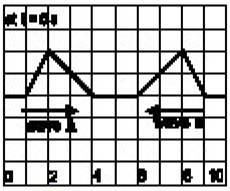
a) A medium with greater mass has greater inertia. Its particles gain speed more slowly when acted upon by a given force. Fewer waves can propagate through it in a given time.

b) The frequency of a wave depends on the source of the wave, and not on the properties of the medium. The same source created the waves in both ropes.

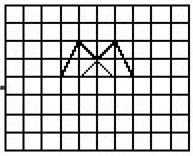
c) A medium with greater mass has greater inertia. Its particles gain speed more quickly when acted upon by a given force. More waves can propagate through it in a given time.

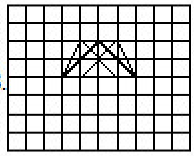
Consider the following description and answer questions 6-7.

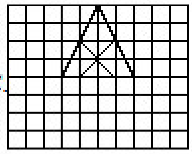
Two pulses are moving toward each other. Each pulse hasa speed of 1 cm/s. The figure on the right shows the pulses at time t= 0 s. Each square width corresponds to 1 cm x 1cm.The dashed lines indicate the correct positions of the individual pulses after 2 s.

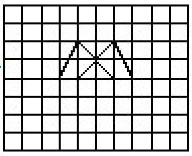


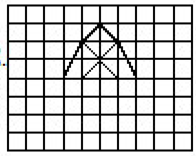
6. Select the drawing that corresponds to the shape of the resultant pulse after **2** s.

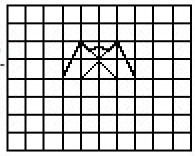
A. 

B. 

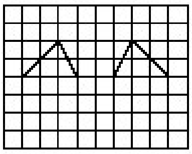
C. 

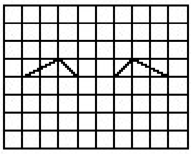
D. 

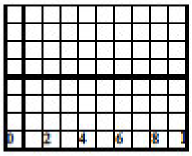
E. 

F. 

7. Select the drawing and explanation that corresponds to the shape of the resultant pulse after 5s.







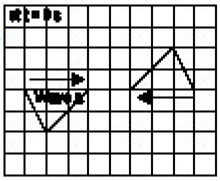
a. Waves have passed through one another and retained their shapes.

b. Waves have become smaller because they have collided and so lost energy.

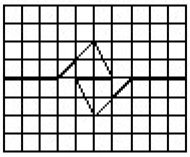
c. Waves have cancelled each other.

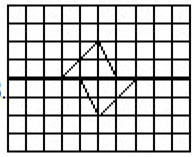
Consider the following description and answer questions 8-9.

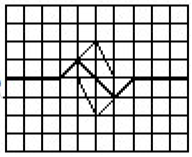
Two pulses are moving toward each other. Each pulse has aspeed of 1 cm/s. The figure on the right shows the pulses at time t = 0 s. Each square width corresponds to 1 cm x 1cm.

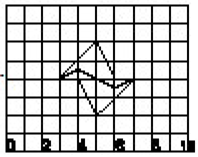


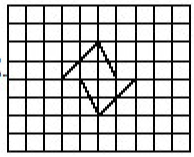
7. Select the drawing that corresponds to the shape of the resultant pulse after 3 s.

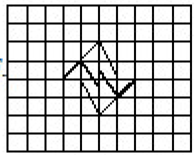
A. 

B. 

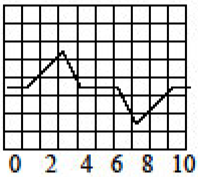
C. 

D. 

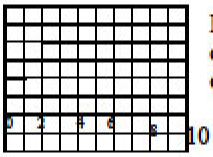
E. 

F. 

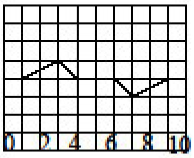
8. Select the drawing that corresponds to the shape of the resultant pulse after 5 s.



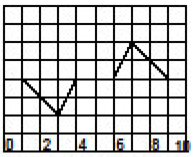
A. Waves have passed through one another and retained their shapes.



B. Waves have cancelled each other.

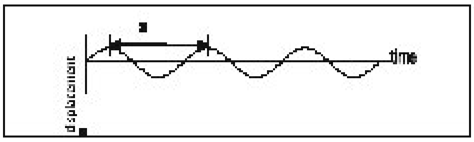


C. Waves become smaller because they have collided and so lost energy.



D. Waves have collided with each other and turned upside-down.

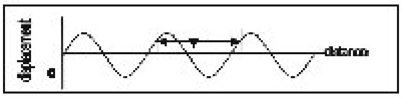
10. The graph below shows the displacement of a particle in a medium against time as a wave propagates through the medium. What property of the wave is represented by the interval shownby X?



A. Frequency
B. Period
C. wavelength
D. amplitude

Reason:
a) It is the distance between two successive crests of the wave.
b) It is the distance between any two points where the maximum displacement of the particle occurs.
c) It is the number of complete waves that pass the particle in a given time.

11. A wave propagates through a rope. The graph below shows the displacement against the horizontal distance of the particles of the rope at a particular time. What property of the wave is represented bythe interval shown by Y?



A. Frequency
B. Period
C. Wavelength
D. Amplitude

Reason:
a) It is the distance between two identical points on successive waves.
b) It is the time needed by the wave to cover the distance between two successive points whichhave the same displacement from their undisturbed positions.
c) It is the number of complete waves that pass the particle in a given time.

12. Two sources, A and B produce a transverse wave. Source A produces a transverse wave having a frequency of 40 Hz. If source B produces 1600 waves in 8 seconds, its frequency will be…

A. 8 times the frequency of source A.
B. 5 times the frequency of source A.
C. Less than the frequency of source A.
D. Greater by 80 Hz frequency of source A.

1

13. If the frequency of a transverse wave is doubled while everything else stays the same. How would the wavelength of the wave change?

    A. The wavelength increases because it depends on the amount of energy flowing in the waves.
    B. The wavelength increases because it is proportional to frequency since the velocity doesn't change.
    C. The wavelength stays the same, it depends on the length of the rope the frequency doesn't affect the wavelength.
    D. The wavelength decreases because it is inversely proportional to the frequency since the velocity doesn't change.

14. Particles in phase

    A. need only have the same displacement.
    B. need only have the same position.
    C. need only move in the same direction.
    D. must have the same displacement and be moving in the same direction.

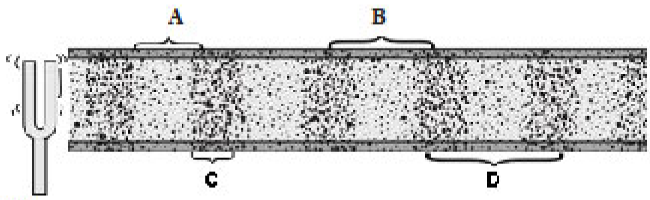
15. Which one of the combinations below concerning longitudinal waves is correct?

Compression	**Rarefaction**
A. Is a region of high pressure.	A. Is a region of low pressure.
B. Is a region of low pressure.	B. Is a region of high pressure.
C. Is the minimum displacement of particles.	C. Is the maximum displacement of particles
D. Is the maximum displacement of particles.	D. Is the minimum displacement of particles.

16. The sound waves produced are

    A. transverse and require a medium for propagation.
    B. transverse waves and do not require a medium for propagation.
    C. longitudinal waves and require a medium for propagation.
    D. longitudinal waves and do not require a medium for propagation.

17. Which letter, A, B, C, or D, correctly shows one wavelength of the sound wave producedby the tuning fork?



Reason:

a) It is the distance between two consecutive compressions.
b) It is the distance between two consecutive rarefactions.
c) It is the time taken to complete one compression.
d) It is the time taken to complete one rarefaction

1

18. Two students sing equally loudly. Student **X** sings at a high pitch, and Student **Y** sings at a lowerpitch. Which of the following is true?

A. The two frequencies are the same, but the amplitudes are different.
B. The two amplitudes are the same, but the frequencies are different.
C. The two frequencies are the same, and the amplitudes are also the same.
D. The two frequencies are different, and the amplitudes are also different.

Consider the following description and answer questions 19 - 20.

Students **X** and **Y** are standing 50 meters apart and yell "Yo!" at each other at the same time.

19. They yell at each other with the same loudness, but **Y** yells with a higher pitch than **X** does.Who will hear the other's sound first?

A. They will hear each other at the same time because the speed of soundwaves depends on the properties of the air.
B. **X** will hear the sound first because the speed of sound waves depends on frequency according to $v=f\lambda$
C. They will hear each other at the same time because the speed of soundwaves depends on amplitude.
D. **X** will hear the sound first because sound with a higher frequency is morepenetrating.

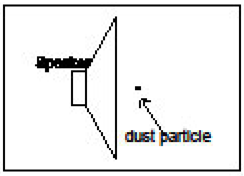
20. Student **Y** yells louder than **X**, but they yell at each other with the same pitch. Who willhear the other's sound first?

A. **X** will hear the sound first because the speed of the waves depends on theamplitude of the sound.
B. They will hear each other at the same time because the speed of the waves depends on the frequency according to $v=f\lambda$.
C. They will hear each other at the same time because the speed of thewaves depends on the properties of the air.
D. **X** will hear the sound first because the wave with the larger amplitude travels further.

1

Consider the following description and answer questions 21 - 23.

A dust particle hovers in front of a silent loudspeaker (see figure below). Theloudspeaker is turned on and plays a loud tone at a constant pitch.



21. How will the dust particle move?

    A. It will stay in the same position.
    B. It will move back and forth about the same position.
    C. It will move up and down about the same position.
    D. It will move away from the speaker.
    E. It will move away as a sine curve.

For questions 22 and 23, choose the description from **A** through **H** that best answers eachquestion.

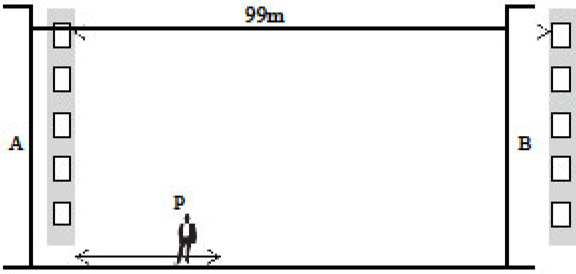
A. It will stay in the same position.
B. It will move back and forth further.
C. It will move back and forth faster.
D. It will move up and down further.
E. It will move up and down faster.
F. It will move away further.
G. It will move away faster.
H. It will move away faster as a sine curve.

22. The pitch of the sound is increased but the volume stays the same. **What happens to themotion** of the dust particle?

23. The volume of the sound is increased but the pitch stays the same. What happens to themotion of the dust particle?

1

24. A boy stands between two tall buildings which are 99 m apart from one another. He stands 33m from Building A, as shown in the diagram below. He claps his hands once and hears several echoes. An echo is the…



A. Sound waves are reflected from a surface.
B. Refracted sound waves.
C. Characteristics of loudness of sound.
D. Repetitions of sound.

25. Why can a dog hear a sound produced by a dog whistle, but its owner cannot

A. Dogs detect sounds of less intensity than humans.
B. Dogs detect sounds of higher frequency than humans.
C. Dogs detect sounds of lower frequency than humans.
D. Dogs detect sounds at a higher speed than humans.

1

Appendix I: Memorandum

1. F
2. A
3. D
4. B
5. C,b
6. D
7. A
8. C
9. A
10. C,a
11. B,b
12. B
13. D
14. D
15. A
16. C
17. B,b
18. B
19. A
20. C
21. B
22. C
23. B
24. A
25. B

Appendix J: Interview Questions (Before the ICT Simulations Intervention)

1. What do you know about mechanical waves?

2. What do you know about sound?

3. What do you know about ICT simulations?

4. What do you like about ICT simulations? Why?

5. What don't you like about ICT simulations? Why?

6. Have you ever used ICT simulations before in your learning?

7. What do you think is different from learning ICT simulations in Physical Sciences?

8. What do you know about alternative conceptions?

9. Can ICT simulations address the rural learners' alternative conceptions about waves and sound in class? Explain.

10. How does living in a rural area affect the learning of waves and sound topics in physics?

Appendix K: Lesson Plans

ARC 1 Lesson plan

<table>
<tr><td>Teacher: NF Mzolo</td><td>Subject: Physical Sciences</td><td>Grade: 10</td></tr>
<tr><td>Time</td><td colspan="2">3 Hours</td></tr>
<tr><td>Knowledge area</td><td colspan="2">Waves, sound, and light</td></tr>
<tr><td>Topic</td><td colspan="2">Transverse pulses on a spring or string</td></tr>
<tr><td>Lesson objectives</td><td colspan="2">• Define a pulse
• Sketch a pulse diagram/graph
• Define a transverse pulse
• Describe the reflection of a pulse
• Define incident pulse, reflected and transmitted pulse
• Explain the effects of medium change on the pulse
• State the principle of superposition of pulses
• Differentiate between constructive and destructive interferences</td></tr>
<tr><td>Resources</td><td colspan="2">Textbook, Projector, Answer sheet, ICT simulations</td></tr>
<tr><td>Teaching methods</td><td colspan="2">Presentation, Demonstration, Observation, Question and answer</td></tr>
<tr><td colspan="2">Teacher activities</td><td>Learner activities</td></tr>
<tr><td colspan="2">Introduction:
• Introduce the lesson by asking the baseline questions.
• Write the following questions on the board:
1. Define pulse and amplitude.
2. Draw a labelled pulse.
3. Explain a pulse reflection.
4. Describe what happens when the slinky spring reflects from a fixed end and a loose end.
• Do corrections on baseline questions and clear learners’ conceptions.
Body:
• Define a pulse as a single disturbance in a medium and illustrate the meaning of medium in Physical Sciences.
• Draw a pulse diagram and describe each part (amplitude, pulse length, crest, displacement, and speed).
• Describe the propagation of a transverse pulse.
• Use PhET simulation to demonstrate the transverse pulse along a medium.
• Define the reflection of a pulse and explain that the reflected pulse has an equal pulse length and amplitude to the incident pulse.
• Explain that a pulse reflects from the free end and is not inverted. It becomes inverted from a fixed end.</td><td>• Work in groups to answer the baseline questions.

• Observe and take notes.</td></tr>
</table>

• Explain that at the boundary some pulse is transmitted and some is reflected from less medium to heavier medium, but the reflected pulse gets inverted from denser medium to less dense. • Use PhET simulations to demonstrate pulse reflection from fixed end, free end, and at boundary. • Define superposition of pulses as the pulses that occupy the same space at the same time. • Describe the interference as the behaviour of pulses coming together and their sum of amplitude changes. • Give two interferences, constructive and destructive interferences. • Use oPhysics simulations to demonstrate the superposition of pulses, constructive and destructive interferences. • Give learners a group activity with the following questions: 1. Describe what happens when the pulse reaches the boundary. 2. Describe the superposition of pulses. • Do correction with groups, provide clarity where needed. **Conclusion:** • Ask learners to explain few applications of the lesson in daily life.	• Discuss and answer questions • Do corrections • Give few applications and discuss those with the teacher.

ARC 2 Lesson Plan

Teacher: NF Mzolo	**Subject:** Physical Sciences	**Grade:** 10
Time	2 Hours	
Knowledge area	Waves, sound and light	
Topic	Transverse pulses on a spring or string	
Lesson objectives	• Describe reflection of a pulse • Define incident pulse, reflected and transmitted pulse • Explain the effects of medium change on the pulse • State the principle of superposition of pulses • Differentiate between constructive and destructive interferences	
Resources	Textbook, Projector, Answer sheet, ICT simulations	
Teaching methods	Presentation, Demonstration, Observation, Question and answer	

Teacher activities	**Learner activities**
Introduction: • Introduce the lesson with an explanation of the components of the pulse from the previous lesson • Remind the learners about their incorrect conceptions • Address those incorrect conceptions though a class discussion. **Body:** • Define reflection of a pulse and explain that e reflected pulse has equal pulse length and amplitude to the incident pulse. • Explain that a pulse reflect from the free end and is not inverted. It becomes inverted from a fixed end. • Explain that at the boundary some pulse is transmitted and some is reflected from less medium to heavier medium, but the reflected pulse gets inverted from denser medium to less dense. • Use PhET simulations to demonstrate pulse reflection from fixed end, free end • Use Classroom Physics simulations to demonstrate the behaviour at the boundary. • Define superposition of pulses as the pulses that occupy the same space at the same time. • Describe the interference as the behaviour of pulses coming together and their sum of amplitude changes. • Give two interferences, constructive and destructive interferences. • Use oPhysics simulations to demonstrate the superposition of pulses, constructive and destructive interferences.	• Discuss the incorrect conceptions with the teacher • Observe and take notes. • Discuss and answer questions

• Give learners a group activity with the following questions: 1. Use a diagram to show constructive interference. 2. Draw a diagram as the pulse moves from the lighter medium to the heavier medium. 3. The frequency of the transmitted pulse will be (greater than, less than, or the same as) the frequency of the incident pulse. Explain your answer. • Do correction with groups, provide clarity where needed. **Conclusion:** • Summarises the main aspects of the lesson, such as pulse reflection, pulse behaviour at boundary and superposition of pulses. • Ask learners to explain few applications of the lesson in daily life.	• Do corrections • Give few applications and discuss those with the teacher.

Appendix L: Reflective Journal

Lesson: Transverse pulse on a string

Date: 11-12 May 2023

Time: 2 Hours

The lessons aimed to address the rural learners' conceptions of waves and sound through ICT simulations. However, this lesson in particular was meant to develop a conceptual understanding of a transverse pulse along a medium, pulse reflection, and superposition of pulses. Learners seemed to show excitement as soon as they saw the setup that involved the laptop screen through the projector. Their faces were intrigued by what was about to take place. This was an indication that ICT tools keep learners' attention. During their group discussions, the researcher moves around the class. This removed the idea from their minds that the teacher should always be talking and that for them was to listen and copy down notes. Everyone was involved. Learners were not just passive but active participants. There was noise, but the productive one. Learners showed attentiveness and participation which were different from the way they are normally taught. They usually show uninterested faces. The learners provided good responses to questions like; defining pulse and amplitude and drawing a labelled pulse diagram. However, the learners also showed alternative conceptions such as pulse reflection is when the pulse moves slowly and when the pulse moves faster, and when a pulse reaches the boundary it disturbs the particles of the rope.

The ICT simulations used kept learners engaged in the lesson. They showed an interest in what they observed. At times, the researcher felt that some of the ICT simulations used were a bit difficult to understand because of fast movement. Luckily, the simulations had a slow-motion option manipulated by the researcher for learners to understand. The learners seemed to enjoy the lesson. Some of the learners were even jotting down notes. However, the researcher did not instruct the learners to take notes. At the end of the lesson, learners were able to give the application of the lesson to real-life situations. They also appreciated the use of ICT simulations, as they had not used such an approach before. What I have learned is that learners prefer this approach to the normal one. Moreover, in the second action research cycle, the researcher plans to add one more simulation from Classroom Physics simulations to show the pulse behaviour at the boundary.

Appendix M: Observation Rubric for assessing meaning learning with ICT

Dimension	0	1	2	3	4
Active	Learners passively receive subject matter from ICT all the time	There is sporadic use of ICT tools by learners to work with subject matter	Learners are using ICT to work with subject matter half the time	There is substantial use of ICT by learners to work with subject matter.	Almost all lesson time involves learners using ICT to work with subject matter.
Constructive	ICT tools used for transmission of subject matter rather than meaning-making.	ICT tools used to support reproduction of subject matter or convergent knowledge expression by learners.	ICT used to support some degrees of divergent knowledge expression by learners with respect to the subject matter.	ICT tools used by learners to synthesize information in order to construct verbal and written, expressions of the subject matter.	ICT tools used by learners to articulate their personal reflections of subject matter in the form of verbal, written and visual expressions.
Authentic	No representations of real-world phenomenon or problems related to the subject matter are presented with ICT tools.	ICT tools used to present examples of real-world phenomena related to the subject matter of learners.	ICT tools support learners to investigate real-world phenomena or problems related to the subject matter.	A problem associated with a real-world phenomenon related to the subject matter is used to anchor the activity and learners investigate the real-world phenomenon with ICT tools in order to propose solutions.	Learners represent their personal experiences of the real-world phenomenon/ problem related to the subject matter with ICT tools
Intentional	Learners do not use ICT tools to support them in diagnosing, strategizing about or improving their learning gaps of the subject matter.	Learners' learning gaps in the subject matter are being diagnosed by teachers or peers.	Learners self-diagnose their learning gaps in the subject matter by using ICT tools/resources.	Learners use ICT tools/resources to self-diagnose their learning gaps in the subject matter. Thereafter, they are to fix these learning gaps.	Learners continually use ICT-based tools/resources to self-diagnose and fix their learning g
Cooperative	No cooperative activity over ICT platforms/tools or ICT tools/platforms are used to share information and resources related to the subject matter but no online discussion occurs	Learners work together either around the computer or through the computer in activities requiring convergent knowledge expressions of the subject matter.	Learners work together either around the computer or through the computer in activities requiring some degree of divergent knowledge expression of the subject matter.	Learners work together either around the computer or through the computer in activities requiring a large degree of divergent knowledge expression of the subject matter.	Learners work together either around the computer or through the computer in activities requiring primarily divergent knowledge expression of the subject matter

Appendix N: Learners Results

Pre-test

QUESTION	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
ANSWER	**F**	**A**	**D**	**B**	**C,b**	**B**	**C**	**C**	**A**	**C,a**	**B,b**	**B**	**D**	**D**	**A**	**C**	**B,a**	**B**	**A**	**C**	**B**	**C**	**B**	**A**	**B**
Learner 1	F	D	A	E	B,c	C	A	C	D	C,a	D,b	B	B	B	A	C	C,c	B	B	B	D	H	G	A	D
Learner 2	A	C	A	D	B	A	B	D	C	C	A	B	A	B	A,D	B	D	A		D	E	H	A	A	B
Learner 3	C	D	E	C	A,a	A	A	B	A	C,a	B,a	D	B	C	A	C	a	A	B	B	E	F	H	B	B
Learner 4	C	D	C	A	B	C	C	F	D	C,b	B,b	B	D	A	C	A,D	C,c	D	B	B	C	E		A	B
Learner 5	C	C	C	E	A,c	C	A	C	A	C,a	B,b	C	A	C		C	A,a	B	B	C	D	G	D	B	B
Learner 6	B	D	D	C	B	D	C	E	D	D,c	C,a	A	D	C	A	C	D,a	A	A	B	C	C	F	D	B
Learner 7	B	D	C	D	C,c	C	C	C	B	C,c	A,b	D	C	B	A	C	d	D	A	D	D	G	A	A	B
Learner 8	A	D	B	C	B,a	C	A	A	A	C,c	B,b	D	B	D		A	B,a	D	D	D	C	D	H	A	A
Learner 9	B	D	D	E	C	A	C	D	A	A	C,a	D	C	D	D	C	a	C	D	A	E	A	H	D	B
Learner 10	B	D	C	D	A,b	E	C	F	D	C,a	C,b	A	D	D	D	A	d	B	B	D	C	E	F	D	B
Learner 11	D	A	D	C	A,a	B	A	C	A	C,a	A,a	A	C	D	B	A	B,b	B	C	B	D	F	C	D	B
Learner 12	B	A	D	E	B,b	B	C	A	D	C,a	A,b	D	A	D	D	A	a	B	B	D	B	A	E	A	B
Learner 13	B	D	C	E	A,a	B	A	D	A	C,a	C,b	D	A	D	A	C	C,a	C	C	D	D	C	G	D	B
Learner 14	D	D	C	A	A,c	A	B	A	A	D,b	C,c	D	A	D	A	A	a	C	C	C	D			A	D
Learner 15	C	D	E	B	C,b	A	B	E	D	C,a	B,a	C	B	D	A	C	a	B	D	C	D	C	E	A	D
Learner 16	B	D	C	E	A,b	C	A	B	C	C,a	B,b	D	B	D	A,B	A	a	A	D	D	D	A	H	A	C
Learner 17	A	D	E	D	B	B	B	C	B	B,c	D,a	A	C	D		A	b	A	D	C	C	A	F	A	B
Learner 18	C	A	B	E	A,c	D	A	E	A	D,b	C,a	D	C	B	A,B	C	b	B	B	C	C	E	H	A	B
Learner 19	B		E	B	A,b	C	A	B	C	C,a	B,b	D	C	D	C,D	B	C,c	A	B	A	E	F	A	A	C
Learner 20	C	A	A	C	C,a	A	B	C,E	A	C,a	A,a	D	C	C	B	A	a	D	B	B	E	A	G	C	D
Learner 21	E	C			A,b	B	A	C	D	B	A,b	C		C			a	C	A	B	B	F	A	B	B
Learner 22	B	D			A,c	B	A	E	A	D,b	D,a	B	A	C	A	B	D,d	A	C	D	B	A	E	B	B
Learner 23	C	B	B	D	B,b	C	A	A	A	C,a	D,c	B	B	B	A	A	d	C	B	C	C	A	G	D	B
Learner 24	A	A	B	A	C,b	A	C	B	C	C,a	A,c	D	D	C	C	C	A,b	C	D	C	C	A	H	A	

Learner 25	C	C	B	E	A,a	D	A	D	D	C,a	D,a	D	A	C	B	A	B,b	B	B	B	C	C	H	B	B
Learner 26	B	D	B	D	B,b	A	C	B	D	C	B,b	D	C	B		A	d	B	C	A	D	B	H	B	C
Learner 27	B	A	B	D	C,b	B	C	E	A	C,c	B,b	A	A	C	A	C	A,c	A	D	A	B	C	E	A	B
Learner 28	D	C	A	E	B,a	B	C	C	B	C,a	B,b	B	B	D	C	C	d	D	D	A	D	D	G	B	B
Learner 29	D	D	C	E	A,a	A	A	B	D	C,a	D,b	D	C	B	A	A	a	D	D	C	D	H	D	D	D
Learner 30	A	D	C	B	B	B	E	A	A	C,a	D,a	A	A	C	C	D	a	D	D	A	A	B	C	D	A
Learner 31	C	D	A	E	C,b	C	A	B	A	D,a	A,c	D	B	D	A	A	D,c	D	B	B	D	H	F	B	B
Learner 32	B	C	C	E	B,a	B	C	E	B	C,a	B	B	D	D		A	C,c	B	D	A	C	E	B	A	B
Learner 33	B	B	D	B	A,b	C	A	E	C	C,a	B,b	D	A	C	A	A	B,a	B	A	A	C	E	A	A	B
Learner 34	E	D	A	C	B,a	C	A	B	B	C,a	D,c	B	A	C	A	C	B,a	D	D	D	D	G	C	C	A
Learner 35	F	D	A	D	A,a	C	A	D	C	C,a	C,c	B	C	D	B	D	a	B	C	C	D	A	F	A	C
Learner 36	A	C	B	A	B	B	C	A	A	C	D,a	C	B	D	D	A	b	D	A	D	C	A	G	B	B
Learner 37	A	C	B	C	B,b	C	A	D	A	D,a	C,b	C	D		C	C	a	B	A	A	D	B	E	B	D
Learner 38	C	C	B	D	A,c	C	A	B	A	C,b	C,a	C	A	B	A,B	A	B,b	B	A	A	D	G	A	B	B
Learner 39	D	B	D	E	B,b	E	B	F	A	B,c	C,c	D	C	D	A	D	c	D	B	A	D	B	C	B	D
Learner 40	D	B	D	E	B,a	A	C	E	C	C,b	B,b	C	A	B	A	D	c	D	B	A	D	B	C	D	B
Learner 41	B	D	B	E	B,a	B	A	E	D	C,a	C,c	B	A	C	A	C	b	A	A	B	D	G	E	B	B
Learner 42	B	C	A	E	A,a	B	A	B	C	C,a	D,a	A	D	A	A	C	a	D	B	B	D	A	G	A	A
Learner 43	B	C	B	D	A,b	A	A	E	D	C	A,b	D	A	B	A	C	a	A	B	D	D	B	C	A	B
Learner 44	D	A	D	E	C,b	B	A	C	A	C,a	A,a	B	C	D	B	A	c	B	B	B	D	E	C	B	C
Learner 45	C	A			A,a	A	A	D	C	C,a	D,b	A	C	D		D	a	A	A	A	D	A	F	A	C
Learner 46	D	C	E	B	A,c	B	A	C	A	C,a	C,a	B	D	D	A	C	D,a	B	C	B	D	A	C	A	B
Learner 47	C	D	B	A	A,c	A	B	D	C	D,a	C,b	B	D	D	A	B	b	C	B	A	D	F	B	A	D

Post-test

QUESTION	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
ANSWER	**F**	**A**	**D**	**B**	**C,b**	**B**	**C**	**C**	**A**	**C,a**	**B,b**	**B**	**D**	**D**	**A**	**C**	**B,a**	**B**	**A**	**C**	**B**	**C**	**B**	**A**	**B**
Learner 1	D	C	D	B	C,a	C	A	C	A	B,b	C,a	A	D	C	A	B	B,a	A	D	B	B	D	H	A	B
Learner 2	A	B	B	D	A,b	C	C	C	C	C,a	C,a	B	A	C	D	B	B,a	C	D	A	B	F	G	A	D
Learner 3	C	D	E	C	A,a	A	A	B	A	C,a	A,c	C	D	D	A	C	A	D	C	B	E	D	H	D	B
Learner 4	C	B	A	A	B,b	C	C	B	A	C,a	C,a	B	C	C	A	B	B,a	C	A	B	B	C	A	A	B
Learner 5	F	C	D	E	A,c	E	A	C	D	C,a	B,b	B	A	C	B	C	A,a	C	B	A	D	G	D	A	C
Learner 6	B	D	A	B	B,b	D	C	B	A	D,a	C,a	D	D	A	A	C	B	A	B	B	B	C	F	A	B
Learner 7	C	A	B	A	C,b	C	C	C	D	B,b	C,a	A	C	A	A	C	D,a	D	B	D	B	F	G	D	B
Learner 8	A	D	B	C	B,a	C	A	B	A	C,a	C,a	D	D	D	B	D	B,c	B	A	B	B	D	H	A	D
Learner 9	D	A	A	E	C,b	E	A	C	B	C,c	C,a	D	C	C	A	C	B,c	C	C	B	E	G	B	B	B
Learner 10	B	D	E	B	C,a	E	C	B	C	B,c	C,a	B	D	D	A	A	A,a	B	A	D	B	E	F	A	A
Learner 11	B	A	C	C	A,a	B	A	C	A	C,a	C,a	A	B	D	B	A	A	A	B	C	D	F	C	A	B
Learner 12	F	A	D	B	B,b	A	C	B	C	B,a	C,a	C	D	D	C	C	B	A	B	B	C	D	A	C	D
Learner 13	B	D	E	E	A,b	B	C	B	A	C,a	B,b	B	B	D	A	C	B		B	D	D	C	G	A	B
Learner 14	D	D	C	A	A,c	C	C	B	A	A,b	B,b	D	A		A		A	A		C	D		C	D	B
Learner 15	C	D	E	C	B,b	A	B	C	D	C,a	C,a	B	D	D	C	C	C	B	D	A	D	C	B	C	C
Learner 16	B	D	C	D	A,b	C	C	B	A	B,a	C,a	A	B	D	A		A,a	B	B	C	D	G	D	A	B
Learner 17	F	A	D	D	B,a	B	B	C	A	C,a	C,a	D	C	D	B	C	D,a	A	C	B	C	A	F	D	A
Learner 18	C	C	B	E	A,c	D	C	B	A	C,a	C,a	C	B	C	A	C	A	C	B	A	B	C	G	A	B
Learner 19	B	D	C	B	C,a	C	A	B	D	B,c	C,a	B		D	A	C	B			C	B	D	E	A	B
Learner 20	C	A	D	A	C,a	A	B	E	A	C,a	A,c	D	A	C	B	B	B,b	D	B	D	E	A	G	C	D
Learner 21	E	C	B	D	A,a	B	C	C	A	B,c	C,a	A	B	D	A	C	C,a	B	C	B	B	F	A	A	B
Learner 22	B	D	B	D	A,c	B	C	B	A	D,a	C,a	A	D	C	A	D	D,a	A	C	B	G	B	B	B	D
Learner 23	F	D	C	D	C,c	C	B	A	A	C,a	D,c	B		A	A	A	D	B	B	B	D	A	G	D	B
Learner 24	A	A	D	B	A	C	D	C	B	A,c	C,a	C	D	A	C	C	A,a	A	A	C	C	C	A	A	A
Learner 25	D	D	D	E	A,c	C	A	C	A	B	C,a	D	B	C	A	A	A	B	B	A	C	C	E	A	B

Learner 26	B	D	B	E	C,a	A	C	B	B	D,a	B,b	D	C	B		A	D	A	B	A	C	F	H	B	C
Learner 27	C	A	D	C	A	C	C,a	B	D	A,c	C,a	B	B	A	A	C	A,a	D	A	B	B	C	E	A	B
Learner 28	A	D	E	B	A,a	C	C	C	A	B,a	C,a	B		B	C	C	B,b	B	B	C	D	C	F	B	B
Learner 29	F	D	D	E	C,b	A	A	B	C	C,a	D,b	D	A	C	B	C	D,a	B	D	B	D	C	D	D	D
Learner 30	A	C	C	B	B	A	C	A	A	C,a	D,a	A	A	C	A	D	A	D	D	A	A	B	C	A	A
Learner 31	B	D	A	E	B,c	C	A	B	A	C,a	B,b	D	B	D		C	B,a	B	D	B	D	C	A	A	B
Learner 32	D	D	D	C	C,b	B	C	B	B	B,a	C,b	B		C	A		C,a				C	D	C	C	B
Learner 33	B	A	D	D	A,b	C	A	E	C	C,a	B,b	D	A	D	A	C	B	A	B	A	C	E	A	A	B
Learner 34	E	B	A	D	A,a	B	C	B	A	C,a	D,c	C	D	B	D	A	B,c	D	C	B	D	C	F	A	A
Learner 35	F	A	A	B	B,c	C	A	B	A	B,b	C,a	A	C	B	A	C	C,a	B	A	C	B	C	D	D	A
Learner 36	A	A	D	A	B,b	B	C	B	C	C,a	C,a	D	B	D	D	D	A,a	B	B	B	D	B	G	D	B
Learner 37	A	D	B	C	B,a	C	A	B	C	C,a	C,a	D	D	D	B	C	B,a	D	A	B	D	F	G	D	B
Learner 38	C	C	B	B	A,c	C	C	B	A	B,a	C,a	C	A	C	C	C	B,c	A	C	B		A	B	B	B
Learner 39	D	B	A	E	C,a	B	A	B	D	B,b	C,a	B	A	C	A		C,c	D	B		D	B	D	D	D
Learner 40	A	B	C	B	B,a	A	B	E	C	C,b	B,b	C		B	A	D	C	B	B	A	D	B	C	D	B
Learner 41	B	A	D	E	C,a	D	B	A	C	C,a	A,c	C	C	D	A	B	D,a	D	C	B	A	G	D	A	C
Learner 42	B	D	A	B	A,a	C	A	B	C	C,a	B,b	A		C	C	C	A,a		B	C	B	A	G	C	B
Learner 43	F	D	D	E	C,c	A	D	B	B	A,c	C,a	A	C	D	D		C,a	B		D	B	G	E	B	A
Learner 44	D	A	A	D	C,b	B	A	C	A	C,a	A,a	B	C	D	B	A	C		D	B	D	E	C	B	B
Learner 45	C	B	D	B	A,a	C	A	B	C	A,c	C,a	C	D	D	A	D	A,a	D	C	B	E	C	D	A	D
Learner 46	A	A	B	A	B,b	B	A	C	A	B,b	C,a	D	A	A	C	A,a	B		B	B	G	B	A	A	B
Learner 47	C	D	D	E	C,a	C	A	B	A	A,c	C,a	A	D	D	A	C	C,a	A	B	C	D	C	D	A	D

Appendix O: Interview Questions (Post ICT Simulation Intervention)

1. Tell me about the experiences of lessons we had.
2. Is there any improvement needed in our lessons?
3. Did you learn or understand something? What is it?
4. Did you enjoy the use of ICT simulations during our lessons?
5. Is the use of ICT simulation a good choice?
6. Was the learning environment positive, welcoming, and friendly?
7. Did you participate fully during the lesson?
8. Would you like to use ICT simulations in other physics lessons?
9. Would you like to learn using ICT simulations in all subjects?
10. Which topic did you understand the most? Why?
11. Which topic did you understand the least? Why?

Appendix P: Turnitin report