Developing Junior Secondary Learners' understanding of the Atomic Theory using Information and Communications Technology Simulations

A dissertation submitted to the Faculty of Humanities, University of KwaZulu-Natal

by

Nobuhle Mvundla

(211528133)

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Supervisor

Dr. B.P Ndlovu

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Declaration

Submitted in fulfilment / partial fulfilment of the requirements for the degree of Masters in Education, in the Graduate Programme in School of Education, Science and Technology, University of KwaZulu-Natal, Durban, South Africa under the supervision of Dr B.P. Ndlovu

Ethical clearance was granted for this study by University of KwaZulu-Natal Research Office. The ethical clearance approval number is: HSSREC/00005317/2023

I, **Nobuhle Mvundla**, declare that

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Dedication

This thesis work is dedicated to my loving family which has been a constant source of support and encouragement during challenging times. And to you, Almighty God, I am nothing without you.

Acknowledgement

I would like to express my sincere gratitude to my supervisor, Dr Bongani Prince Ndlovu, whose invaluable advice and guidance made this project a success. Doing research is no easy task but his guidance, encouragement, and feedback through the research kept me going even in the most challenging times.

Besides, I am thankful to all the grade 10 participants for their willingness to share their time and insights. They came with enthusiastic and positive energy that made the data generation process manageable. This study would not have been possible without their contribution to this challenging research project that demanded time off their normal school hours to write tests and participate in interviews. I am truly grateful. I hope that they will gain from this research and realise the value of their contribution to understanding the topic of atomic theory better.

Moreover, I acknowledge and express gratitude to my school principal for allowing me to conduct this research and use the school's resources that were helpful in my research.

Abstract

The role of Information and Communications Technology (ICT) in teaching has received so much attention in science education research. In South Africa, the education department has pushed the digitisation of teaching through the White Paper on e-Education. However, as much as a lot has been researched in this field, there is still a gap in knowledge about developing the conceptual understanding of fundamental concepts in science through the meaningful use of ICT in teaching, particularly the use of ICT simulations. As a result, this study reports on constructive use of ICT simulations to develop the junior secondary learners'(JSLs') understanding of the atomic theory concepts following the qualitative research. Two research questions guided the study. (i) What are the JSLs' prior understanding of the atomic theory? (ii) How can JSLs' understanding of the atomic theory be developed through integrating ICT simulations?

The study was theoretically underpinned by the Technological and Pedagogical Content Knowledge (TPACK) and the Activity Theory (AT) to explore how JSLs were pedagogically supported to develop their understanding of atomic theory. The researcher followed the action research approach with a group of 30 JSLs to investigate how their prior understanding of the topic developed through the integration of ICT simulations. These JSLs were conveniently sampled from a township school in Umlazi district. The results generated prior to the ICT-based intervention indicated that JSLs have a considerable number of misconceptions about the atomic theory concepts. During the intervention, the use of ICT for meaningful learning was measured through the active, constructive, authentic, intentional, and cooperative dimensions adopted from the TPACK rubric. The ICT intervention was found to be successful in developing and improving their understanding of the topic. The study concludes by recommending further in-depth research, including different forms of ICT tools across all grades to teach abstract concepts in Chemistry.

Keywords

Atomic theory, Information and Communications Technology simulations, Technological Pedagogical and Content Knowledge, Activity Theory, Junior Secondary Learners

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CHAPTER 1

1. BACKGROUND OF THE STUDY

1.1 Introduction

A good understanding of the atom and its structure is fundamental for an effective conception of many abstract Chemistry topics that are central to Chemistry curricula (Tilahun & Tirfu, 2016). In the South African context, Chemistry is combined with Physics, together forming a subject called Physical science. Learners are introduced to Physical science for the first time in Grade 10 (junior secondary level) as per the South African Curriculum and Assessment Policy Statement (CAPS) stipulations.

Heeralal (2014) pointed out that the sub-microscopic nature of the atom means difficulty in grasping Chemistry concepts which subsequently affects the overall performance in Physical Science subject. These findings are in line with the work by Taber and Adbo (2013) that discussed the challenges students have with the particulate model of matter, highlighting the difficulty of reconciling the macroscopic world with the microscopic level. Similarly in Turkey, Niaz and Coştu (2009) research explored students 'difficulties in understanding the concept of atoms and molecules. They found that students struggle to visualize these abstract entities, impacting their grasp of chemical reactions. Additionally, in the study that investigated factors affecting high school students' achievement in chemistry Sibomana et al. (2021) identified the abstract nature of atomic and molecular structures as a significant hurdle for students. However, the increasing availability of Information and Communications Technology (ICT) tools for teaching and learning creates affordances and opportunities to gain a conceptual understanding of abstract Chemistry concepts such as atomic theory and its structure without the necessity of a physical laboratory, which is often a challenge in South African schools (Dunn & Ramnarain, 2020). Hence, there is a need to conduct research that focuses on the meaningful use of ICT simulations to develop the junior secondary learners' (JSLs) understanding of difficult concepts associated with the atomic structure.

This chapter introduces this study and provides an overview of the problem statement for the study followed by a detailed purpose and rationale of the study. The chapter then highlights the main objectives and provides the critical research questions of this study that guided this research. It concludes by expressing the positionality of the researcher, stating relevant terms, and providing the outline of the whole research dissertation.

1.2 Problem statement

International research has shown that learners at the junior secondary level (grade 10) generally have poor understanding and difficulties in conceptually grasping the concepts of atomic theory and its structure (Chamizo, 2015; Suryelita et al., 2019). A study reported by Suryelita et al. (2019) from Indonesia found that a higher percentage of learners in grade 10 do not understand or have misconceptions about atomic structures and the periodic table. Table 1.1 shows some of the data pointing to this problem.

Table 1.1: Students' learning difficulties on atomic structure and periodic table.

Learning Indicator	Category of students' answers per indicator				Learning difficulties per learning indicator (M+G+DU)	Category
	Understand (U)	Have misconception (M)	Guess (G)	Do not understand (DU)		
1	8.77%	0.9%	0.9%	89.5%	91.2%	Very high
2	86.9%	1.75%	0%	11.4%	13.2%	Very low
3	13.7%	2.46%	4.4%	81.4%	88.3%	Very high
4	49.1%	-	3.5%	47.34%	51%	Moderately high
5	59.6%	-	-	70%	70%	high
6	35.9%	-	-	64%	64%	High
7	8.7%	-	-	84%	84%	Very high
8	19.3%	-	5.3%	75.4%	81%	Very high
9	25%	-	5.7%	69.29%	74.99%	High

Similarly, in the South African context, there has been a reported poor performance in the exit-level examinations in Chemistry topics. This is particularly reflected in the overall diagnostic performance of grade 12 candidates. The National Senior Certificate (NSC) diagnostic report (2021, pg. 210-235) indicated a continuous underachievement in Chemistry. Whilst noting this challenge, this study holds a similar view by Potgieter et al. (2005) that the atomic theory and structure form the 'basis' of understanding secondary school Chemistry. Hence the lack of understanding of this key topic has a direct effect on all the topics and leads to overall poor performance by learners as the diagnostic report suggests.

The Department of Basic Education (DBE) reports show that even though a significant number of learners can pass Chemistry examinations, however, the performance of the candidates over the threshold of 50% is still significantly low as observed in the past four years.This reflects a challenge faced by most South African schools especially in disadvantaged areas.

A study conducted by Heeralal (2014) found that the main reason cited by South African learners for poor performance in the subject was that they experienced difficulty in grasping basic science concepts such as atomic theory and its structure in the earlier grade. Heeralal's study also showed that even though these topics are taught in the junior years of secondary science, learners still struggle to answer questions related to these in the exit NSC examination. This observation implies that the poor conceptual understanding of concepts in lower grades has a direct impact on performance in senior certificate examinations. In an attempt to explore this problem in-depth, this study aims to explore ways in which the understanding of concepts in atomic theory can be developed through the utilisation of ICT simulations.

1.3 Context of the Research

Chandra et al. (2014) acknowledged the importance of ICT competence in this century. They pointed out that ICT use in classrooms in developed countries has become a norm while it is still often beyond the reach of many schools in developing countries. Howie and Blignaut (2009) conducted a study which assessed South Africa's readiness to incorporate ICT into mathematics and science education in secondary schools by comparing it to other nations like Chile, Thailand, and Norway. Chile and Thailand shared similar contexts and conditions with South Africa while Norway as a developed country had different conditions. The study revealed significant disparities in the use of ICT in education between countries with ample resources and advanced technologies and those with limited access to such technologies. The findings from Howie and Blignaut (2009) study revealed the majority of schools in South Africa are in the early stages of ICT implementation. This means that they are in the process of acquiring ICT resources and developing the skills and knowledge necessary to use ICT effectively in teaching and learning. Despite these challenges, the study found that there is a growing awareness of the potential benefits of ICT in education, and there is a commitment to using ICT to improve teaching and learning outcomes.

According to Johnson et al. (2016), science education research has demonstrated that technology-integrated learning can aid in addressing the challenges of learning and understanding difficult and abstract concepts. Raja (2018) maintained that there is no doubt that the existence of modern technologies has made the task of visual representation of abstract information possible and easily accessible. This easy access to information implies that many previous restrictions and difficulties in science instruction no longer apply in teaching the subject, and according to Das (2019), this has been seen as one of the many advantages provided by educational technologies in teaching. Before that, Taber (2018) in particular, suggested that animations, stop motion videos, computer-generated simulations, and virtual reality provide a shift in the perspective of scientific imagination and teaching. Additionally, Taber (2018) highlighted that non-verbal representations in classrooms were historically restricted by the possibilities of a printed page or a teacher's whiteboard drawings. However, with the integration of ICT into teaching practice, pedagogy can shift from teacher-centred to learner-centred since learners can explore and actively engage in their learning process (Kapur, 2019). Given the affordances of ICT in education, this research aimed to explore the development of JSLs' understanding of the Atomic Theory using ICT simulations in a school located in a disadvantaged context.

1.4 Purpose of the study

The overall purpose of this study was to develop JSLs' understanding of atomic theory using ICT simulations. Various kinds of ICT simulations were incorporated into the study. These include voice-annotated simulations, video animations, ChemThink simulations by Public Broadcasting Service (PBS) learning media and Physics Education Technology (PhET)simulations by Colorado University. This study intended to use the visualisation of abstract and complex concepts associated with the atomic theory in developing the JSLs' understanding of atomic theory and related concepts through the utilisation of mentioned ICT simulations. Within this overall purpose, three objectives guided this research study. These are reflected in the next paragraph.

1.5 Objectives of the Study

The objectives of this study were:

1. To diagnose the JSLs' prior understanding of the atomic theory before the ICT intervention.
2. To develop the JSLs' understanding of the atomic theory through the integration of ICT simulations.
3. To determine the JSLs' views on ICT simulations integration in teaching atomic theory.

1.6 Research questions

The critical questions for this study are:

1. What are the JSLs' prior understanding of the atomic theory before the ICT intervention?
2. How can JSLs' understanding of the atomic theory be developed through integrating ICT simulations?
3. What are the JSLs' views on ICT simulations integration in teaching atomic theory?

1.7 Rationale

The motivation behind conducting this study is the observation of teaching atomic theory, coupled with personal experiences to learners at the junior secondary level (grade 10). Learners experience learning challenges on this topic since they mostly rely on teachers to present and elaborate the abstract concepts without any assistance tools as noted by Kumpha et al. (2014). It is imperative to determine how transitioning from traditional teaching methods to modern, engaging learning methods will impact the learners' understanding. Related studies in the field have enacted the role of ICT incorporation in different contexts. However, the significance of this study is heightened by the socio-economic context of the study site where education is predominantly hindered by a shortage of resources and poor science infrastructure. Thus, this study aimed to contribute to the existing knowledge and fill existing gaps in the teaching and learning of the atomic theory and its structure employing attributes of ICT.

1.8 Significance of the Study

South Africa's 2004 White Paper on e-Education aimed to achieve universal ICT proficiency among learners and integrate ICT into teaching and learning practices by 2013 (Lekgothoane & Thaba-Nkadimene, 2019). The National Integrated ICT Policy White Paper of 2016 underscores the South African government's dedication to leveraging ICT to foster a more inclusive society, eradicate poverty, and bridge the inequality gap by 2030 (Telecommunications & Services, 2016). These policies take a holistic view of the integration of ICTs into the schooling system to provide equal opportunities for every South African citizen regardless of their socio-economic status. According to Ghavifer (2015), ICT should be incorporated into future competencies of the educational staff and learners for the development of digital educational content and for evaluating the learners' achievements, following the learning outcomes and educational objectives. This study contributes towards the strengthening of the White Paper policy on e-Education. Learners are granted an opportunity to utilise ICT resources to enrich their knowledge skills while teachers develop their pedagogical skills to match modern standards.

1.9 Researcher and Positionality

This study is conceptualised under the interpretive or constructivist paradigm. The interpretive worldview holds that reality is subjective, socially constructed, and a composite of multiple perspectives (Cohen et al., 2018; Wahyuni, 2012). In this perspective, the researcher's personal experiences and interpretations influence the research study, shaping their understanding of the observed phenomena.

As a millennial teacher who has attended a typical socio-economic disadvantaged school in South Africa, the researcher was not exposed to the use of technology until at the university level. This meant that the researcher had to solely rely on the teachers for knowledge and understanding of abstract concepts of science. Regarding the researcher's experience as a science learner, learning science requires motivation that is beyond just traditional instruction. To understand a concept, one needs to be interested in it and therefore motivated to learn the subject matter. It is a privilege that learners now have access to technology that can stimulate and motivate them. The active engagement and interactivity created by an ICT-based classroom allow the learning process to become more effective (Kapur, 2019).

The Independent Research Project at Honours level was the stepping stone for the researcher's interest in this field of research. The researcher was introduced to the knowledge of TPACK and how it can be implemented to improve both the teaching and learning experience. Literature provides evidence that learners have difficulty understanding concepts in science and relating them to their environment (Singh, 2022). The researcher is aware that it is usual for a tenth-grade learner not to explain what an atom is and what they understand about it, even though this concept is introduced as early as the eighth grade of junior secondary. These experiences collectively shaped the researcher's interest in pursuing a study that will bring about change and improvement. This study aims to provide an opportunity to display the benefits of integrating ICT in teaching and adopting the pedagogic practices that will improve the quality of learners' understanding.

1.10 Terms Relevant to the Study

The following are the terms relevant to this study:

TPACK refers to the Technological Pedagogical and Content Knowledge by Koehler and Mishra (2009) which is the theoretical framework that underpins this study

AT refers to Activity Theory, a theory developed by Leont'ev in the 1930s which is the second theoretical framework that guides this study.

TPACKTIVITY is a term developed to represent the relationship between the TPACK framework and the Activity Theory framework (Terpstra, 2015).

ICT SIMULATIONS is a term that refers to the use of computer and technology modelling to represent real-world processes, systems, or event situations.

JUNIOR SECONDARY LEARNERS is a term that refers to the sample of grade 10 learners that was researched in this study.
The last part of this chapter will briefly outline the whole structure of this research dissertation.

1.11 Thesis outline

This study contains 6 chapters. The introductory chapter provides background information regarding the significance and purpose of the study, the problem statement, the objectives, and the research questions. The background and positionality of the researcher have been included as well.

Chapter 2 highlights relevant literature to situate this research study within the relevant theoretical paradigms and uncover gaps in the areas of literature for this topic. In the same chapter, the theoretical frameworks that underpin this study, TPACK and Activity Theory are thoroughly unpacked.

Chapter 3 provides an explanation and justification for the research methodology used for this study. It consists of research design, data collection methods, and data analysis, with a focus on the scope of the sample used in the study. Rigour and ethical issues form a part of this chapter.

Chapter 4 presents the findings about the junior secondary learners' prior understanding of atomic theory from the data collected. This will respond to research question 1. The chapter also provides details about the process of developing the JSLs' understanding of atomic theory using ICT simulations. This chapter reports on the intervention and responds to research question 2 while providing an overview of JSLs' views on the integration of ICT simulations, which responds to research question 3.

In Chapter 5, there will be a discussion of the research findings in line with each research question.

Chapter 6 is composed of the contributions that this study makes. This is also accompanied by limitations of this research as well as recommendations for prospective research within the field.

CHAPTER 2

2. LITERATURE REVIEW AND THEORETICAL FRAMEWORK

2.1 Introduction

This chapter delves into a comprehensive review of the literature on ICT simulations. The chapter begins by emphasising the importance of science education in developing countries and then addresses common misconceptions about science education to establish a strong foundation for the subsequent discussion. The misconceptions in science education discussion illuminate the critical cognitive processes during learning and what is believed to result in misconceptions. A discussion on teaching atomic structure, its challenges and opportunities follow. This section explores the underlying reasons for misconceptions about atomic structure from both national and international perspectives. It then transitions to examine the role of ICT in the teaching and learning process.

In recent years, alternative and innovative teaching techniques have emerged to supplement traditional science instruction methods that have long been prevalent. The effectiveness of these instructional innovations in promoting conceptual understanding is debated, with particular attention given to justifying the use of ICT in the classroom. This chapter encompasses an extensive review of the literature exploring the advantages of incorporating ICT into teaching practices, including the students' perceptions or views on ICT in teaching and how it improves students' performance. Towards the end, this chapter discusses the theoretical positioning and justifies the theoretical framework.

2.2 Relevance of science education in developing countries

Science education has been a priority in developing countries for decades and the reasons for this urgency are not hard to find (Knamiller, 1984). Science education is believed to provide solutions to problems that mostly affect the vast majority of people living in developing countries. Knamiller (1984) pointed out that there are critical issues that affect millions of people worldwide. These issues include a lack of basic needs for survival such as water scarcity, poor sanitation, a lack of nutritious food, fuel shortage and even a lack of shelter.

These deprivations have severe consequences for health, well-being, and overall quality of life. According to Omosewo (2009), science education is essential for the development of any nation in developing or third-world countries. Reviewing the importance of science education in Nigeria, Kola (2013) posited that without science education, ICT would be impossible. Essential fields such as engineering, medicine, and architecture would be impossible without a strong foundation in the core subjects required for these courses. Similarly, South Africa as a developing country has prioritised the engagement of students in scientific enquiry within the science curriculum as a significant educational goal (Erduran & Msimanga, 2014). This is in line with the observations by Msimanga et al. (2017) that one of the objectives of the South African science curriculum is to provide equal access to science for students from all backgrounds. This would improve the quality of life for many. However, it is noted that this goal remains difficult to reach as many students from low socio-economic backgrounds continue to perform poorly in science subjects (Koopman, 2017; Msimanga et al., 2017). Therefore, there is a sense of urgency to bring about transformation to the science curriculum, specifically in Physical Science as a school subject, to liberate and empower students from disadvantaged backgrounds. This can be achieved through pedagogical practice that encourage scientific enquiry, take misconceptions that occur in classrooms into cognisance and overcome them through the use of available technologies.

2.3 Research on Students' Prior Knowledge

2.3.1. Misconceptions in Science Teaching

It is reported that in the 1970s, science educators woke to Piagetian and Vygotskian research and started acknowledging ideas that students brought into classrooms (Vosniadou, 2020). Teachers made discoveries that students had deeply held beliefs that conflicted with scientific concepts and theories. These were then labelled as misconceptions. Several scholars in science education have attempted to explore the notion of misconceptions in science and how they play a critical role in teaching and learning (Ajayi, 2017; Kaur, 2013; Taber, 2015; Treagust, 1988). For instance, Ajayi (2017) believes that misconceptions in science are preconceived notions that are based on religious and or cultural influences. Mcleod (2023) concurs from a constructivist's perspective that misconceptions could result from learners' pre-existing knowledge since they are not 'empty vessels. They build new knowledge upon the foundation of pre-existing knowledge.

In addition to the mentioned perspectives, Tomita (2009) asserted that when students enter science classrooms, they often hold deeply rooted prior knowledge or conceptions about the natural world. These conceptions influence how they come to understand their formal science experiences in school (Pines & West, 1986). Mestre (1991) noted that students bring with them a wealth of knowledge and understanding, known as prior knowledge when they enter the classroom. This knowledge can come from a variety of sources, including personal experiences, family interactions, and informal learning experiences. Some of this prior knowledge can be a valuable asset in the classroom, as it can provide a foundation for further learning (Tomita, 2009). For instance, if a student has had experience with growing plants, they may have a better understanding of the basic concepts of photosynthesis. However, some of students' prior knowledge may be incompatible with currently accepted scientific knowledge. But even if they are incompatible, they still provide teachers with important knowledge for their pedagogical reasoning (Treagust, 1988).

Despite their efforts to convey scientific concepts in the classroom, teachers are often astonished to learn that students have a challenge grasping fundamental ideas covered in class (Loughran et al., 2006). In their 2014 study, Leonard et al. (2014) observed that even some of the most academically successful students, despite providing correct answers, lacked a profound grasp of scientific concepts. Their ability to regurgitate memorised information without truly comprehending the underlying principles resulted in algorithmic thinking rather than conceptual understanding. It was revealed by the National Research Council that when students are questioned more closely, misconceptions are discovered and failure to fully understand the underlying concepts of the topic is often revealed (NRC, 1997).

In terms of physical science teaching in schools, understanding the atom is very important and forms a base for many concepts in Chemistry, and Physics subjects such as electricity and magnetism as well as molecular structures in biology (Griffiths & Preston, 2012; Kaya, 2023). Due to misconceptions and knowledge deficiencies related to the concept of atoms, learners will have difficulty understanding Physics, Chemistry, and Biology which will in turn impede further learning and affect their academic performance (Kaya, 2023). In this study, the idea of misconceptions is conceptualised according to the NRC’s framing of misconceptions. The following section provides a brief overview of basic categories of misconceptions in science:

2.3.2 Types of misconceptions in science

Misconceptions in science were categorised by the National Research Council, NRC (1997, p. 27) as follows: preconceived notions, non-scientific beliefs, conceptual misunderstandings, vernacular misconceptions, and factual misconceptions. These kinds of misconceptions are briefly unpacked below.

Firstly, preconceived notions are widely held beliefs that are often based on personal experiences and observations of the world around us (Tekin & Nakiboglu, 2006). For example, many learners believe that atoms are microorganisms since they are too small to be seen with the naked eye. A study by Papageorgiou et al. (2016) found that students in grades 8-10 often exhibit misconceptions about the nature of atoms, mistakenly attributing characteristics of living entities to these fundamental building blocks of matter. This misconception stems from a confusion between the properties of matter at the macroscopic (observable) and microscopic (atomic and molecular) levels. Students may incorrectly apply their understanding of living organisms, which exhibit growth, reproduction, and specialised functions, to atoms, which are non-living entities. The misinterpretation of the nucleus, the central part of an atom, as possessing functions similar to those of a cell's nucleus further highlights this confusion. While the cell nucleus plays a crucial role in cellular processes, the atomic nucleus is primarily responsible for maintaining the atom's structure and stability (Cokelez, 2012; Taber & Adbo, 2013).

Secondly, non-scientific beliefs encompass a broad spectrum of views and perspectives that do not align with scientific principles or evidence. These beliefs may originate from various sources, including religious teachings, cultural traditions, personal experiences, and even popular media. (Shehu, 2015). The work of Bernstein in the 1970s offered a good distinction between everyday knowledge and scientific concepts. According to Bernstein (1970), everyday knowledge is characterised by its pragmatic orientation, its reliance on personal experiences, and its embeddedness in social and cultural contexts. Knowledge is often acquired through social interactions, such as conversations with family and friends or participation in everyday activities.

Scientific concepts, on the other hand, are characterised by their abstractness, their objectivity, and their universality. They are often acquired through formal instruction, such as schooling or specialised training. For example, in a study conducted by Nodzynska (2021), it was noted that even though a large percentage of people in Poland reach a higher education level, many people believe in non-scientific knowledge. The study indicated that Polish people very often think that "synthetic" chemicals (made in a lab) are not as good for them as their "natural" equivalent (Nodzynska, 2021). This is a complete misunderstanding of the basics of Chemistry. In the African context, many Africans believe that there are two kinds of lightning: 'natural lightning' and another one at the instigation of witches to avenge a grudge or other social conflict (Trengove, 2012). All these examples are indicative of non-scientific beliefs.

Thirdly, conceptual misunderstandings arise when teaching methods fail to provoke students to question and challenge their existing beliefs and preconceptions (Laeli et al., 2020; Leonard et al., 2014). For instance, students may have a misconception that chemical equilibrium is only achieved in closed systems or under standard conditions. This may lead to difficulties in understanding concepts such as Le Chatelier's principle, open systems and equilibrium constants under non-standard conditions(Quílez-Pardo & Solaz-Portolés, 1995). Sadler and Sonnert (2016) advocated that teachers' deep understanding of the subject matter they teach is a key predictor of successful student learning. From a Mathematics perspective, Even (1990) maintained that teachers lacking subject-matter knowledge risk propagating incorrect information and misconceptions among their students, hindering their learning progress and fostering distorted understanding. This suggests that science teachers should be aware of the potential misconceptions that may arise during teaching and learning on a topic.

Fourthly, vernacular misconceptions can stem from using everyday words with different meanings in a scientific context (Shehu, 2015). The vernacular misconceptions include difficulties in understanding and interpreting vocabulary, symbols, analogies, and metaphors employed in science education (Leonard et al., 2014; NRC, 1997). One example of a vernacular misconception in science is that a vacant space is empty and this is untrue. A vacuum contains a very low density of particles such as atoms and molecules. However, due to very low pressure in a vacuum, the density of these particles is often negligible (Roth, 2012).

Rollnick (2000) pointed out that learning scientific terminology poses a unique challenge for second language learners, as it requires not only mastering new vocabulary but also comprehending the underlying concepts and their intricate relationships within abstract contexts. Moreover, teachers often overestimate students' ability to comprehend and correctly utilise scientific vocabulary. In addition, Chrzanowski et al. (2018) claim that excessive substitution of scientific terminology with everyday language can inadvertently mislead students, hindering their grasp of the precise meanings and applications of scientific concepts and symbols. The authors provide two specific examples to illustrate this point, the first one is symbol overloading, where the same symbol, such as the letter "N," can represent different concepts in different disciplines or even within the same discipline. For instance, "N" can stand for "North" in earth science, "Nitrogen" in Chemistry, and "Newton" in Physics. This can lead to confusion if students are unaware of the context-dependent meaning of the symbol. The second one is concept ambiguity: A single concept, such as "energy," can be represented by different symbols, such as "E," "Q," or "U," depending on the context. This can make it difficult for students to understand the underlying concept when they encounter different symbols for the same thing.

Fifthly, factual misconceptions are ideas or beliefs that are acquired during childhood and remain unchallenged despite their inherent inaccuracy. These misconceptions persist into adulthood, potentially hindering the acquisition of accurate knowledge (NRC, 1997). One example of a factual misconception is the notion that lightning never strikes the same place twice, but it is untrue. Lightning can and does strike the same place twice, even during the same storm. According to Helmenstine (2017), the phrase "lightning never strikes the same place twice" is not a literal statement but an idiom used to comfort people by suggesting that misfortunes are unlikely to repeat themselves in the same way for the same individual. . However, it is not factual.

To reduce the prevalence of misconceptions among students, it is advisable to equip teachers with professional development opportunities that incorporate knowledge about student misconceptions (Yizhou Qian et al., 2020). Furthermore, it is recommended that teachers receive training in utilising tools specifically designed to uncover student misconceptions, particularly those that may remain undetected through conventional methods (Yizhou Qian et al., 2020). Additionally, Prinz et al. (2022) promote the use of multimedia such as refutation texts as a useful tool to address misconceptions and improve learners' comprehension. While these suggestions are made, the use of ICT simulations has the potential to confront some of these misconceptions in science and reorganise students' understanding to correct scientific conceptions.

2.4 Teaching and learning the atomic structure: challenges and opportunities

Research in science education has demonstrated that the abstract concepts embedded within atomic structure theories pose significant obstacles for learners seeking to grasp the fundamental principles of Chemistry (Ameyaw, 2020; Braithwaite & Goldstone, 2015;

Mcleod, 2023). To elaborate on this, Penrose (1991) cited in Nkadimeng and Ankiewicz (2022) argued that atoms cannot be seen with the naked eye, as such, learners find it difficult to conceptualise the intricacies that are central to this concept. This difficulty is compounded by other abstract concepts that are tenets of the atomic structure (protons, neutrons, and electrons) (Penrose,1991 as cited in Nkadimeng and Ankiewicz (2022)). Central to this study is the assertion by Suryelita et al. (2019) that the atomic theory and its structure serve as essential conceptual frameworks that lay the groundwork for effective chemistry education.

Within the South African education system, the concepts of atomic structure and the periodic table are introduced to students in grade 8, the initial year of junior high school. At this stage, students are expected to grasp a central concepts that an atom serves as the fundamental building block of an element. The fundamental sub-atomic particles of atoms, namely protons, neutrons, and electrons, are introduced and briefly explored in grade 8, laying the groundwork for a deeper understanding of the periodic table and its elements in grade 10 (Nkadimeng & Ankiewicz, 2022). The South African Department of Education emphasises the crucial understanding of the number of protons, positively charged particles, and electrons, negatively charged particles, within an atom, must be equal, resulting in a neutral atom. Learners are expected to grasp the charge associated with each subatomic particle, and their respective locations within the atom structure, and employ mathematical calculations utilising the atomic number and mass number to determine the number of neutrons (DBE, 2011). The interrelatedness of the main objectives and aims of the curriculum at an international level can be observed. For instance, in Gilgit-Baltistan, Pakistan, Chemistry is an obligatory subject for students in grades 9 and 10 who have selected science as their primary area of study at the secondary level of high school (Ali, 2012). The Pakistan National Chemistry Curriculum states:

> *"Chemistry Curriculum builds on the vertical progression of the K-VIII science curriculum. It offers a relatively in-depth study of chemistry as a major, independent science. It focuses on content, process skill, problem-solving, inquiry, and critical and analytical thinking skills . . . The aim of the curriculum is to produce students who will be capable of doing independent thinking, asking questions, and looking for answers on their own." (p. 01)*

Even though the subject content provides endless positive opportunities for students, Johnson (2011) raises concerns regarding the abstract nature of the subject matter, particularly in

Chemistry, which may pose significant comprehension difficulties for students. The intricate relationships between atoms, molecules, and their interactions can be challenging to grasp, especially for those unfamiliar with scientific concepts. Additionally, the extensive mathematical computations and memorisation of principles associated with atomic structure may overwhelm students, particularly since science inherently involves the application of mathematics. Thus, the integration of mathematical knowledge in the study of atomic structure can pose a significant obstacle for students with numerical difficulties (Johnson et al., 2016).

Besides the abstract nature of the atomic theory concepts, factors such as disinterest and poor attention spans can further impede students' ability to grasp these concepts effectively (Braithwaite & Goldstone, 2015; Nkadimeng & Ankiewicz, 2022; Papageorgiou et al., 2016). These are regarded as affective factors rather than cognitive issues. According to Rohandi (2017), the majority of students find science challenging due to a lack of engaging activities and preconceived notions about the inherent difficulty of scientific concepts. A study conducted in Indonesia by Suryelita et al. (2019) indicated that a high percentage of grade 10 students do not understand and have misconceptions about the atomic structure and the periodic table of elements. It showed that students' learning difficulties were mostly influenced by several factors, including teaching methods, curriculum, teaching tools, and school-building conditions.

A South African study conducted by Semeon (2015) revealed that roughly 30% of grade 9 students opt to pursue Physical Science in grade 10, a combined subject encompassing Physics and Chemistry. The relatively low enrolment rate in Physical science can be attributed to prevalent misconceptions that portray the subject as challenging and overly abstract (Gadzikwa, 2018). Additionally, Heeralal (2014) pointed out that the main reason cited by learners for poor performance in the subject was that they experienced difficulty in grasping basic science concepts that were taught in the earlier years of school and thus had a challenge answering questions in the examination. The understanding of the atomic theory and structure was a largely reported area linked to poor performance. Without the proper understanding of basic connections between concepts at microscopic and macroscopic levels, learners tend to encounter challenges in creating meaningful understandings of the topic (Davidowitz & Chittleborough, 2009). Therefore, the teachers must employ creative and interactive teaching strategies for the topic such as an atom that requires the connections of bother microscopic and macroscopic representations. These include developing interactive fun games and activities, use of simulations, and integrating technology into lessons (Ippoliti et al., 2022).

Having mentioned the interactive instructional teaching methods that teachers could use to foster an understanding of the atomic structure, in this research study, the integration of ICT simulation as an intervention measure is explored. As a result, the next section elaborates on the role of ICT simulations in developing a deep understanding of the topic and inspiring them to pursue careers in science and technology.

2.5 The role of ICT simulations in teaching and learning

According to Rooney and Nyström (2018), within the existing academic literature, the term 'simulation' is commonly employed to indicate the representation of a process or situation through imitative means. Falloon (2019) refers to ICT simulations as computerised representations of real or imagined scenarios or phenomena that provide an engaging and dynamic learning experience through interactive visualisation. The concept of computer simulations has also been extended to web-based or remote laboratories, enabling real-world experiments to be conducted remotely and allowing for simultaneous visualisation of both the real and theoretical behaviours of a phenomenon, thus highlighting the impact of choices made (Tho & Yeung, 2016).

This section of the review provides an in-depth discussion of the role enacted by ICT simulations in the pedagogical processes. This review will focus on teachers' pedagogical support of students through ICT simulation, learners' perceptions about integrating ICT to support teaching and ICT and students' performance.

2.5.1 Pedagogical Support through ICT Simulations

Abbas et al. (2013) believe that technology has transformed pedagogical methods. Technology and constructivism share a mutual relationship, where the implementation of one fosters the effectiveness of the other (Abbas et al., 2013). Vygotsky's theory of constructivism states that learning takes place by the zone of proximal development (ZPD) in contexts where learners are actively creating their knowledge with assistance from a knowledgeable adult, while technology refers to the purposeful design of tools and environments that foster active learner engagement (Borthick et al., 2003).

Since the basic tenet of constructivism is that knowledge must be constructed by the learner, knowledge cannot be supplied by the teacher (Abbas et al., 2013; Chaudhary, 2018). Recent initiatives to integrate technology into the classroom environment have been guided by constructivist principles. The utilisation of computers, digital devices, and digital tools empowers students to assume a more active and central role in the learning process (Haleem et al., 2022). Thus, in a technologically driven lesson, the teacher becomes a guide in the learning process and can cultivate students to think and reason critically (Chaudhary, 2018).

The growing prevalence of technology integration in educational settings has fuelled the widespread adoption of computer simulations among educators worldwide as a tool for fostering conceptual understanding of scientific concepts (Almasri, 2022). While this is widely accepted, Matute-Vallejo and Melero-Polo (2019) asserted that over the past several decades, educational methodologies have undergone a transformative evolution to align with the rapidly evolving technological landscape, effectively leveraging the advantages offered by emerging technologies . This affordance requires teachers to possess both pedagogical knowledge (how to teach) and technological knowledge (how to manipulate hardware and software), along with content knowledge, to support effective learning experiences for their students (Dennen et al., 2018). Within this context, ICT simulations act as a powerful agent that supports teachers' knowledge to teach and how they mediate content.

One of the advantages of teaching through ICT simulations pointed out by Aoude (2015) is that ICT simulations offer unique advantages over real-life experiments in that they allow educators to manipulate the pace of physical phenomena, enabling them to accelerate or decelerate the process at will. This capability, which is unattainable in real-world settings, empowers teachers to control the tempo of demonstrations and facilitate student comprehension. Additionally, computer simulations provide the flexibility to repeat demonstrations as frequently as necessary, ensuring that students have ample opportunities to grasp complex concepts. Furthermore, the ability to effortlessly modify various parameters within simulations allows students to observe the direct impact of these changes on the phenomenon being studied. These pedagogical benefits of computer simulations foster an exploratory learning environment where students are encouraged to pose inquiries, formulate hypotheses, gather observations, and interpret outcomes, ultimately fostering critical thinking and problem-solving skills (Abbas et al., 2013; Almasri, 2022; Aoude, 2015; Chaudhary, 2018).This shows that the utilisation of ICT simulations effectively engages students in the acquisition of diverse forms of knowledge. The following subsection provides insight into the learners' perceptions and views on ICT integration in teaching.

2.5.2 Students' perceptions or views towards ICT in teaching

The term student engagement is referred to as "*how involved or interested students appear to be in their learning*" (Axelson & Flick, 2010, p. 1). As defined by Chaudhary (2018), student engagement represents the cognitive investment learners demonstrate through active participation and emotional attachment to their learning experiences. Incorporating ICT into learning provides opportunities to turn traditional and passive teaching methods into interactive and fun learning (Aoude, 2015; Vlachopoulos & Makri, 2017). Arguably, there is little known about the student's views about the use of ICT in teaching abstract concepts. It is, therefore, necessary to assess student engagement and perceptual involvement learners feel in their experiences with simulation-based learning activities while learning about atomic theory and structure.

It has been proven that visual learning plays a very important role in developing critical thinking and visual literacy which subsequently develops a better understanding of abstract concepts (Bhat, 2015). As Vorona-Slivinskaya et al. (2020) maintain, visual representations can be used to encourage learning and support different learning styles. ICT simulations have the power to provide visuals to learners. As posited by Almasri (2022), the integration of technology into the learning process has significantly enhanced student engagement and enjoyment of the learning experience. Students encountering difficulties in grasping a particular subject can readily access online tutorial videos. These videos, along with live-streaming content, offer alternative perspectives and facilitate a deeper understanding of concepts and subjects. The utilisation of such multimedia resources fosters an engaging and interactive learning environment (Raja, 2018; Vavra et al., 2011).

The implementation of interactive learning methodologies fosters student contentment with the learning environment, establishing it as a critical construct that directly contributes to positive student outcomes. Student satisfaction refers to a state of contentment and fulfilment derived from an individual's successful fulfilment of their role as a learner, fostering active participation and engagement within the educational setting (Pelletier et al., 2016). The significance of both student engagement and satisfaction implies that a learning activity (e.g. ICT simulations) may not be effective in achieving the desired results unless the students are engaged with the process and satisfied with the learning environment as well (Pelletier et al., 2016). In the context of this study, schools in South African rural areas or previously disadvantaged communities suffer from shortages of modern teaching and learning materials

(Mwapwele et al., 2019). Therefore, students in these schools tend to be more optimistic and develop positive attitudes about ICT integration in learning whenever they are allowed to learn with technology.

2.5.3 ICT impact on students' attitude and performance in science

With all the positive attributes of ICT integration alluded to above, there is no doubt that it has a positive influence on the performance of the learners. Available research data indicates a positive correlation between students' favourable perceptions of ICT and their achievement in mathematics and science (Courtney et al., 2022). A plethora of research studies have corroborated the idea that students' academic success in mathematics and science is positively correlated with their self-directed utilisation of ICT (Hu et al., 2018; Juhaňák et al., 2018; Kunina-Habenicht & Goldhammer, 2020; Meng et al., 2019).

According to Courtney et al. (2022), interest in ICT use, perceived self-confidence in ICT use, and perceived self-competence in ICT use are strongly associated with positive outcomes in the academic performance of learners in science. An Australian study done by Silin and Kwok (2017) to investigate students' attitudes towards using ICT in a social constructivist environment revealed that effective use of ICT is significantly and positively connected with attitude towards using ICT. Their study found that engagement, communication, information gathering, collaboration and efficiency are what students enjoyed the most about using ICT. In a similar study, Rhema and Miliszewska (2014) in Libya demonstrated a significant correlation between students' positive attitudes towards ICT and its benefits. UNESCO (2002) maintained that research has suggested that ICT can add value to the learning process. ICT use in educational settings with academic purposes is useful in improving students' performance in science (Erdogdu & Erdogdu, 2015; Luu & Freeman, 2011; Skryabin et al., 2015). One of the objectives of this study is to help improve the academic performance of the learners by improving their understanding of abstract concepts of atomic theory and structure.

The primary objective of this investigation is to delve into the potential of ICT integration in enhancing the JSLs' comprehension of abstract concepts. The subsequent section delves into the theoretical underpinnings of this study, with a particular emphasis on TPACK and activity theory.

2.6 Theoretical Framework

Theoretical frameworks in educational research provide a lens for understanding the types of data to collect, the questions to ask, and the factors to investigate (Svinicki, 2010). In the context of this study, the Technological Pedagogical and Content Knowledge (TPACK) model and Activity Theory (AT) shaped the purpose and the research design for this study. The two theories provided a theoretical framework that also facilitated the interpretation of the collected data and regulatory decisions about what to do at each stage of the research process.

This subsection aims to provide an overview of the theoretical underpinnings of this study, namely, the Technological Pedagogical and Content Knowledge (TPACK) model. TPACK is a framework that profiles the teacher competencies in technology integration for effective teaching and learning as Koehler and Mishra (2009) posited. On the other hand, the Activity Theory (AT) is a framework that describes human interaction with the environment and tools that affect conscious learning (Jonassen & Rohrer-Murphy, 1999). To begin with, the genesis of TPACK is outlined in the next sections.

2.6.1. Technological Pedagogical and Content Knowledge

TPACK has its roots in the work of Lee Shulman and associates in the late 80s about Pedagogical Content Knowledge (PCK). Shulman (1987) defined PCK as the integration or amalgamation of pedagogy and content, which covers the ‘what’ and ‘how’ of teaching. In continuation to Shulman’s work, Loughran et al. (2012) argued that PCK is not merely about knowing the subject matter but rather about understanding the multifaceted interplay of factors that contribute to successful student learning. In a nutshell, what a teacher knows influences how they teach and what students learn.

Two decades after the birth of PCK, Mishra and Koehler (2006) reformed and expanded the concept of PCK to TPACK. They included the dimension of technology incorporation in the pedagogical process and described TPACK as a framework for teacher knowledge of technology integration for effective teaching. The TPACK framework for teacher knowledge is described in detail, as a complex interaction among three core bodies of knowledge known as Content Knowledge (CK), Pedagogical Knowledge (PK), and Technological Knowledge (TK).

Content Knowledge (CK) refers to the body of knowledge and information that teachers teach and that learners are expected to learn in a given subject or content area (Rosenberg & Koehler, 2015). Pedagogical Knowledge (PK) is described as knowledge about teaching and learning that is not topic-specific, such as knowledge of learning theory, classroom management, and student motivation (Auerbach, 2018). Lastly, Technological Knowledge (TK) is expressed as the aspect of competency that is concerned with teachers' knowledge of technology and the ability to utilise technologies, technological tools, and associated resources to improve teaching practice (Koehler et al., 2013). TPACK is built on the notion of the integration between the three discussed core knowledge bases. The diagram in Figure 2.1 illustrates the intersection among the triangulated areas of the TPACK framework.

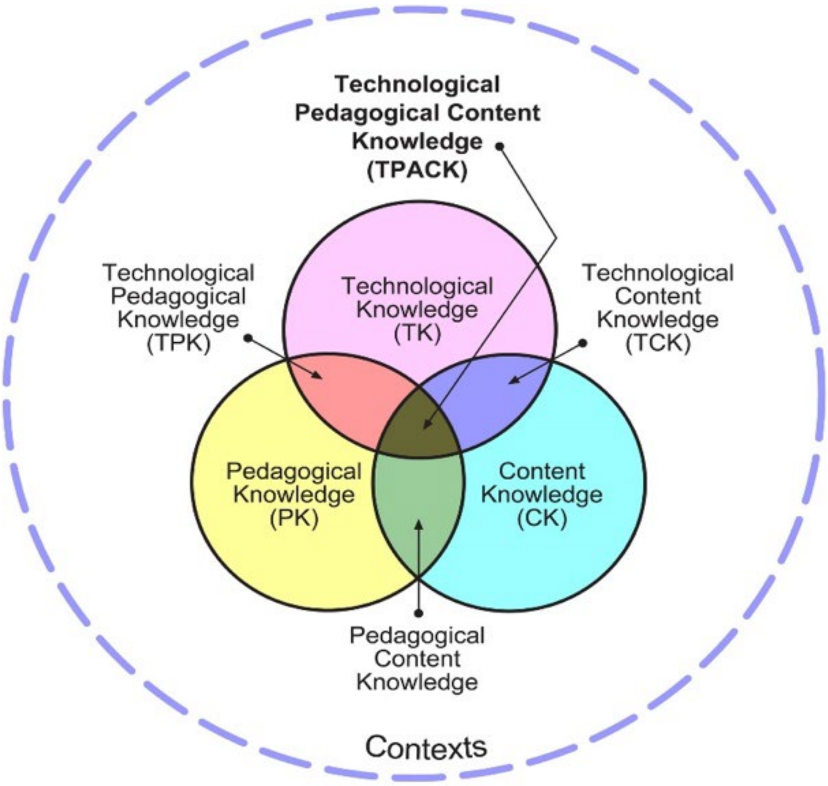


Figure 2.1: The TPACK framework and its knowledge components.

From Figure 2.1, there is an intersection between the core components of the TPACK framework. These intersections lead to four other knowledge bases within the framework. The first three are Pedagogical Content Knowledge (PCK), Technological Content Knowledge (TCK), and Technological Pedagogical Knowledge (TPK).

The intersection between CK and PK results in PCK. Fernandez (2014) argued that Pedagogical Content Knowledge (PCK) is a concept that represents the teachers' professional knowledge. It is defined as a combination of CK and PK in special ways that result in the transformation of disciplinary content into forms that are suitable for teaching (Chan & Hume, 2019). Following the aforementioned, Loughran et al. (2012) maintained that PCK is the knowledge that teachers develop over time, and through experience, about how to teach particular content in particular ways to lead to enhanced learners' understanding.

TCK is a result of the intersection between TK and CK. TCK refers to the teacher's understanding of how integrating technology and content can influence the learners' understanding of the subject matter (Koehler & Mishra, 2009). TCK seeks to utilise different technologies and considers which specific tools might be best suited for specific subject matters or topics (Nguyen et al., 2022).

Among these intersections is TPK which is the combination between TK and PK. TPK is the knowledge of how technology influences pedagogy (Koehler & Mishra, 2009). For example, in this study, the researcher will integrate ICT simulations into the lessons to develop a better understanding of JSLs' knowledge of atomic theory. TK will meet PK to create a more effective learning environment.

What is of importance in this study is the interaction of all three core knowledge bodies which results in TPACK. As Mishra and Koehler (2006) advocated, TPACK is the basis of effective integration with technology, requiring an understanding of all three knowledge dimensions, TK, PK, and CK. TPACK is a framework that emphasizes the knowledge required by teachers to integrate technology into their teaching in any content area (Schmidt et al., 2009). Serhat (2018) posited that within the TPACK framework, specific technological tools like computer hardware, software, and applications are best used to guide learners towards a better understanding and more robust understanding of the subject matter. Thus, the main aim of this study was to develop an understanding of junior secondary learners' knowledge about atomic theory using ICT simulations. In line with the TPACK theory, this also was underpinned by the Activity Theory. In the next paragraphs, the AT is unpacked in detail.

2.6.2. Activity Theory

Activity Theory (AT) was initially developed by Leont'ev in the 20th century in the former Soviet Union. According to Leont'ev (1974), an activity is initiated by a motive such as a need or a drive. Over the past 20 years, Leont'ev conception of activity has been further developed by Engeström (1999) with the definition of AT as a theoretical framework that describes how people act to achieve a goal.

Activity Theory is also rooted in Vygotsky's explanation that historical-cultural psychology proposes for brain development. According to this theory, mental functions are developed from the performance of external functions, for example, engaging with tools and artefacts to perform activities or achieve set goals. Figure 2.2 depicts the classical activity system triangle that is expanded to include the object, subject, mediating artefacts (signs and tools), rules, community, and division of labour (Leont'ev & Cole, 1981).

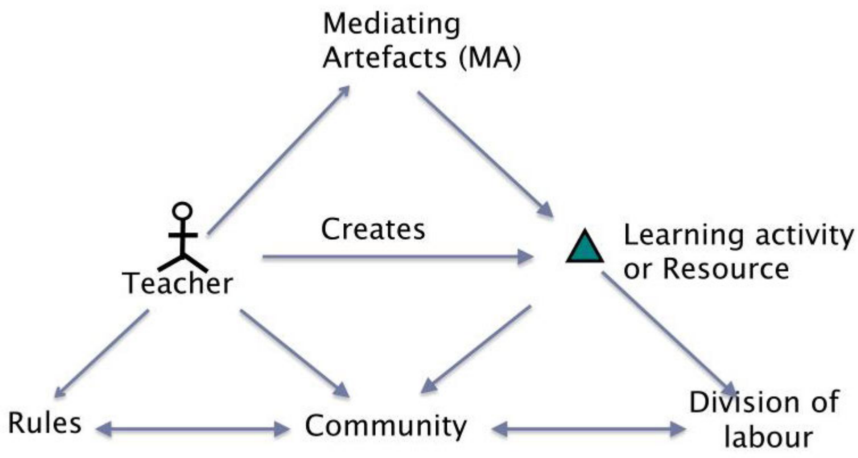


Figure 2.2: Activity Theory System Diagram

Regarding this study, the components of the activity theory in Figure 2.2, the subject in an educational activity system is the person or group of people who carry out the activity, it may be a teacher or a group of learners. The object is the goal or purpose of the activity. The mediating artefacts are tools that are utilised to complete the activity, these include textbooks, audio-visual aids, materials and instructional strategies, to mention a few. The rules include educational laws and the national curriculum, and school and classroom rules, to mention a few. The community refers to the social and cultural context in which an activity takes place. For example in a science classroom, the community includes the teacher, other students, the curriculum, textbooks, and other resources (Engeström & Toiviainen, 2010). Finally, labour is distributed among teachers, school subjects, media artefacts, and modes of work (Karasavvidis, 2009).

Activity Theory in Education

Activity theory acknowledges that everything in the classroom has a cultural and social meaning (Foot, 2014). The way learners interact with each other and with the teacher is mediated and influenced by objects such as classroom artefacts, and technology (Nussbaumer, 2012). Learning occurs within these contexts, and usually, through specific activities (Hew & Brush, 2006).

Activity Theory has its implication of the integration of technology as a tool that mediates social action. These tools, or artefacts, include instruments, signs, language, machines, and computers. The relationship between subject and community is mediated by rules and the relationship between object and community is mediated by the division of labour (Terpstra, 2015). In this study, the tools are ICT simulations. Since this study is underpinned by the theory behind TPACK, in the next paragraphs, the researcher outlines how the AT is within the TPACK framework.

2.6.3 Activity Theory within the TPACK framework (TPACKTIVITY)

Terpstra's (2015) TPACKTIVITY study illustrated the application of Activity Theory (AT) to identify the objectives, mediating tools, rules, and community within activity settings that can either foster or hinder TPACK development. According to Terpstra (2015), the integration of the TPACK teacher knowledge framework with Activity Theory (AT) to provide explanations for transformations in knowledge and actions yields a novel conceptual framework termed TPACKTIVITY.

While the TPACK framework focuses on the specific knowledge domains teachers employ for technology-integrated instruction, Activity Theory (AT) provides a framework for comprehending how contextual factors shape and influence teacher and learner knowledge. The TPACKTIVITY framework integrates the knowledge and skills teachers possess with pedagogical strategies to effectively teach with technology, fostering a comprehensive understanding of the learning process. The TPACKTIVITY framework conceptualises teacher knowledge as an active and interconnected construct, encompassing pedagogy, content, and technology. This framework sheds light on how teacher knowledge is developed within specific settings, mediated by tools that facilitate the transfer of knowledge across diverse activity settings.

This study aims to combine the two theoretical frameworks to identify objectives (learners' understanding of atomic theory) and integrate mediating tools (computers and ICT simulations) to transform the pedagogy and teaching of content as per TPACK framework regulations. The next paragraph provides insight into how TPACK and Activity Theory can be used to develop the learners' understanding of atomic theory using ICT simulations.

2.6.4 TPACKTIVITY in using ICT to develop JSL's Understanding of Atomic Theory

In this study, TPACKTIVITY will guide the teaching or the presentation of the atomic theory which is known as pedagogical content knowledge. Here, the most powerful analogies examples, explanations, and demonstrations of the atomic theory will be presented in comprehensible illustrations (ICT simulations). TPACK will provide an understanding of what makes the learning of atomic theory easy or difficult, alongside the pre-knowledge that learners have brought with them to the learning environment (Shulman, 1986).

To deepen the understanding of learners' knowledge about atomic theory, a proper understanding of information technology and tools is essential and required. This is necessary to afford the learners the ability to utilise technology to accomplish a variety of different tasks and to develop different ways of accomplishing those tasks. Activity Theory is recognised for its capability to pinpoint the underlying causes of failure or subpar performance within existing circumstances by illuminating contradictions that arise either between distinct activities, between an earlier iteration of an activity and its subsequent evolution, or within the activity itself (Hashim & Jones, 2007). Together with the productive application of ICT advances and flexible use of technology incorporated in TPACK, performing tasks under the TPACKTIVITY framework will be more fruitful.

For instance, research question 1 for this study seeks to identify the JSLs' prior understandings of the atomic theory, and activities conducted will act as a lens in data analysis for this action research. It will assist in identifying reasons why learners struggle with understanding the abstract concepts of atomic theory, and how engaging in activities like PhET simulations will improve their understanding. This information will be gathered from data generated through tests, interviews, and classroom observations. The TPACKTIVITY will provide a framework for accomplishing these activities, however, the literature is unclear as to how TPACKTIVITY can be used to effectively design instruction since it is a fairly new framework, thus, this study aims to add to knowledge in this area.

2.7 Chapter Summary

This chapter outlined the relevance of science education research in developing countries, particularly the importance of technological advancement in science education to overcome issues faced by developing, third-world nations. This was then linked to research on students' prior knowledge of science, specifically looking at misconceptions in science and the types of misconceptions that are found in science classrooms. The causes and effects of these misconceptions were also discussed with strategies that may be employed to address and circumvent these misconceptions. An extensive overview of challenges in teaching and learning the atomic theory was provided and linked to the opportunities and affordances of ICT integration to overcome these challenges.

Furthermore, the chapter discussed the role of ICT simulations in teaching and learning and attempted to link this to efforts that have been made to confront the challenges associated with teaching abstract science concepts in Chemistry. The advantages of ICT simulations for pedagogical support and positive influences on students' performance were discussed to justify their use in this study and how they can help develop the JSLs' understanding of the atomic theory.

The last part of the chapter discussed the theoretical frameworks that have been used to inform this study, namely, TPACK and Activity theory, jointly called TPACKTIVITY. In line with the debates raised in this chapter and the theoretical underpinnings highlighted above, the next chapter outlines in detail the methodology and research design that were followed to conduct this research.

CHAPTER 3

3. RESEARCH DESIGN AND METHODOLOGY

3.1 Introduction

The main purpose of this study was to develop JSLs' understanding of atomic theory using ICT simulations. Hence, this chapter focused on unpacking the research design and methodology that was applied to realise the main purpose. The chapter starts by first looking at the research paradigm under which this study was conceptualised. It proceeds to include a full description that discusses the methodology which speaks to the nature of the research study in line with the selected research paradigm. Furthermore, the chapter gives a detailed description of the methods and procedures that were used to generate and analyse data during the study. This includes a description of the instruments used which include a conceptual test, semi-structured interviews, and video-recorded lessons. Finally, the chapter concluded by looking at the ethical dilemmas and how these were addressed to produce credible and trustworthy data in line with the requirements of this study.

3.2 Research Paradigm – Interpretivism (Constructivism)

As indicated in Chapter 1, this study is conceptualised within the interpretive paradigm. This paradigm is also seen by other scholars as constructivist in its outlook as pointed out by Wahyuni (2012). For interpretivism, the purpose of social research and thus of education research is to understand the meaning which informs human behaviour within a particular context (Bertram & Christiansen, 2014). On the other hand, Cohen et al. (2007) maintain that the interpretive research approach has the intention of understanding the world of human interaction and that reality is socially constructed. For the researcher, the interpretive or constructivist approach is based on a natural approach to data generation such as interviews, observations, document reviews, and visual data analysis (Mackenzie & Knipe, 2006).

The variations of the interpretive approach in this study drawing from the attributes of hermeneutics and symbolic interactionism were implemented. Hermeneutics refers to the philosophy of interpretation of texts whilst symbolic interactionism provides how reality is constructed (Mackenzie & Knipe, 2006). These variations assisted in ensuring that the researcher applied hermeneutics in data generation and that learners constructed their understanding of atomic theory and structure. According to Creswell and Creswell (2018), the constructivist researcher is most likely to rely on qualitative data generation methods and analysis. Hence the next section outlines the methodology adopted in this study in line with the requirements of a constructive paradigm.

3.3 Methodology

As alluded to in Chapter 1, this study followed the qualitative research approach. According to Creswell and Creswell (2018), qualitative research is a process of steps used to collect and analyze information to increase our understanding of a topic or issue using non-numerical data. In line with the latter assertion, Cohen et al. (2018) pointed out that qualitative research data generation strategies that are frequently used include one-on-one interviews; focus group interviews; structured or unstructured questionnaires and observations, to mention a few. Some of these data generation strategies were employed in this research study as well.

Predominantly, a qualitative research method does not rely on a single data source (Cohen et al., 2018). As a result of the above, in this study, text interpretations, interviews, and observations were used to explore how the JSLs' understanding could be developed using ICT simulations and to investigate their views on ICT incorporation in developing their understanding. Several approaches are linked to qualitative research. For example, Bertram and Christiansen (2014) mention case studies, ethnography, phenomenology, and action research amongst others. Given the main purpose of this study and the need to respond to the immediate problem, the most suitable research method adopted for developing learners' understanding of atomic theory using ICT simulations was action research. Hence, the next section outlines the research design that was followed.

3.4 Research Design

This section provides a detailed description of action research which is the research design that informed data generation for this study. The following description is the discussion of data generation strategies and data generation instruments utilised. The last part unpacks the process that was followed towards data analysis for the three research questions that are articulated in the preamble of this study.

3.4.1 Method- Action Research

As mentioned above, this study adopted an action research method. Action research is described by Bertram and Christiansen (2014) as the style of research in which the researcher studies their practice. Predominantly, this is done to increase self-awareness and change current practices for the better. Also, action research in education has been seen as an "*important way for teachers to engage in professional learning*" (Bertram & Christiansen, 2014, p. 45).

The action research method starts with a question or an observation about a current problem (Clark et al., 2020). Additionally, Cohen et al. (2018) asserted that after identifying the problem area and narrowing it down to make it more manageable for research, the development process continues as the action plan to investigate the question. This involves gathering data and evidence to support the solution to the problem. This action plan is carried over a cycle of stages known as the action research cycle. Figure 3.1 below represents the cycle of the action research approach taken from the work of Zuber-Skerritt (2001).

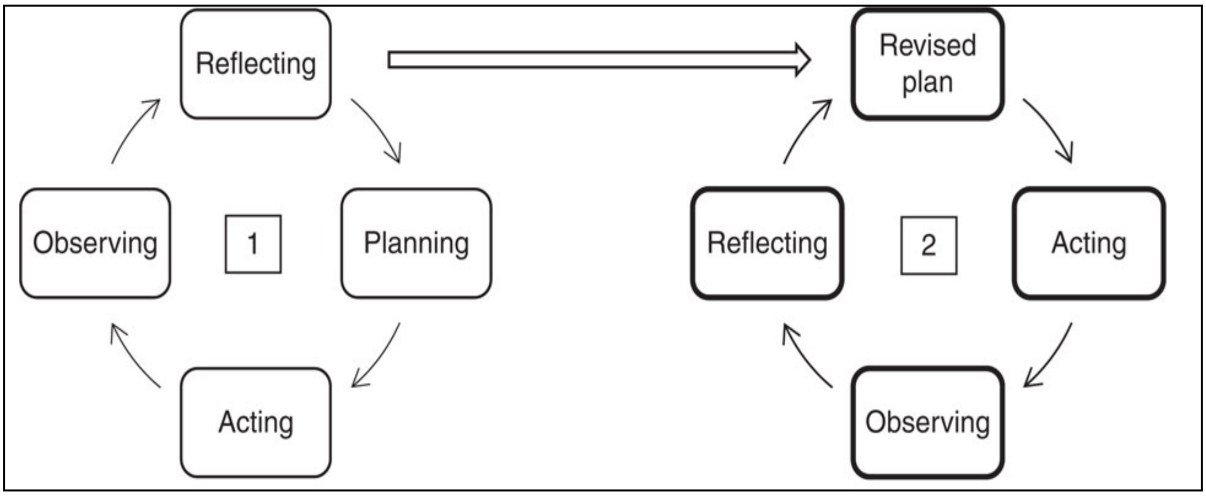


Figure 3.1: Action Research Cycle.

As shown in the diagram, four discreet phases are key in the action research cycle. These are (i) Planning, (ii) Acting, (iii) Observing, and (iv) Reflecting. 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. For this study, these action research cycles are unpacked in the paragraphs that follow, beginning with cycle I.

Action Research: Cycle I

1. **Planning**

The first phase was planning, which involved identifying and analysing the problem. In this case, the problem was the lack of JSLs' conceptual understanding of atomic theory concepts. This was achieved by administering a diagnostic conceptual test (see Appendix A.1) with the participants of this study to gather their prior understanding or knowledge of atomic theory concepts before the ICT intervention. This test was marked with a corresponding memorandum (Appendix B.1).

The second part of this phase included designing and preparing an intervention that was geared to use ICT simulation (voice- annotated, PhET and ChemThink) to develop their conceptual understanding of the knowledge of the atomic theory. This intervention is incorporated in the day-to-day teaching of grade 10 content of Physical science in line with the requirements of the annual teaching plan (ATP).

For the first cycle, five lessons were conducted as demonstrated in Table 3.1. The first lesson was based on the history and development of atomic theory and its structure. The second lesson was based on Rutherford's atomic model and experiment. The third lesson focused on the structure of the atom and sub-atomic atomic particles. The fourth lesson was based on the representation of the atom using notation and the fifth and last topic was focused on isotopes.

2. **Acting**

The second phase of the cycle was acting on the problem, which generally includes questioning and, or collecting data related to the problem. For this study, the ICT simulations in the form of voice annotated simulations from YouTube, ChemThink and PhET simulations were utilised as means to confront JSLs' prior knowledge about the atomic theory. Table 3.1 shows the structure of the ICT simulation-based intervention.

Table 3.1: The ICT simulation-based intervention lessons

Lesson	Content	Duration	Simulation used
1	History and development of the atomic theory and its structure	60 min	Voice annotated simulation
2	Rutherford's experiment	60 min	**PhET Simulations** Rutherford's Scattering
3	Structure of the atom and sub-atomic particles	60 min	**PhET Simulations** Building an atom **ChemThink** Atomic structure
4	Representation of the atom	60 min	**PhET & ChemThink**

	using notation $^{A}_{Z}E$		Atoms & Elements
5	Isotopes and Atomic Mass	60 min	**PhET Simulations** Isotopes and Atomic Mass

3. **Observing**

After the implementation of the ICT simulations-based intervention, another set of data was collected in the form of a post-intervention test. This test is similar to the one that was used in the planning phase as a diagnostic test. In addition to this data set generated in the observation phase, lesson observation taken as video records of the lesson was taken. This data set was important to provide insights into how the JSLs were engaging with the ICT simulations. In addition, this also provided insights into the role of the teacher in key teaching episodes towards developing JSLs' understanding of the atomic theory concepts.

4. **Reflecting**

The fourth and last step of the action research cycle was reflecting, which involved evaluating the effectiveness of the ICT-simulation-based intervention used in developing JSLs' understanding of the atomic theory concepts. In this stage, data were analysed, and new ideas were implemented and revisited. Given the nature of action research, the cycle was repeated post the reflection stage for improvements.

Action Research: Cycle II

The second cycle included improvements from cycle 1. The same steps were followed as shown above. Because of continuous formative assessments between cycle 1 and this cycle, the activities in the revised plan were informed by the lack of understanding of the specified actual content in the concept test. It was formatively observed that the JSLs experienced a challenge in understanding Rutherford's experiment, particularly about the interpretation of the meaning of the movement of the alpha particles. This was achieved by the evaluation of the JSL's performance in question three of the post-test and other tasks that were used as classroom activities.

Thus, Rutherford's experiment formed part of the revised intervention. The ICT simulations were reconducted while the researcher provided a thorough explanation of Rutherford's experiment simulation using content knowledge as well as the aspects of PCK. The post-test was then re-administered a the end of the second cycle, but the focus was now on the JSLs' performance in question three of the post-intervention to establish if there was any improvement.

3.5 The Participants and the Research Site

Selecting participants 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. In this study, the researcher adopted purposive sampling. Purposive sampling is a sampling procedure that relies on the judgement of the researcher when it comes to units (people, cases, and events.) that are to be studied (Sharma, 2017, p. 751).

As mentioned earlier, the researcher's purpose was to develop the JSLs' understanding of atomic theory and its structure using ICT simulations. Purposive sampling allowed the researcher to choose the whole population with similar experiences, backgrounds, knowledge, and beliefs (Rai & Thapa, 2015). Therefore, in this study, all learners in grade 10 Physical science classes were taken as a sample since the same annual teaching plan and syllabus were in effect. This was a cohort of 30 learners. There were 18 girls and 12 boys who were from a township school in Umlazi district in KwaZulu Natal province. All these participating learners were Second Language Speakers of English who were predominantly Zulu speakers.

3.6 Data Generation

According to Clark et al. (2020), the goal of qualitative data generation in action research is to build a complex and nuanced description of social or human problems from multiple perspectives. Table 3.2 provides a detailed outline of process per research question that was followed for data generation, Additionally, Table 3.2 summarises the specific purpose and the role of each method or instrument that was used per research question.

Table 3.2: Summary of Data Generation Process.

Research Question	**Instrument**	**Data generation Method**	**Purpose and Role**
What are the JSLs' prior understandings of the atomic theory?	A diagnostic test designed to measure the prior understanding of the atomic theory	Valid and reliable diagnostic conceptual test was administered to JSLs.	• To diagnose the JSLs' understanding of the atomic theory before the ICT intervention

	concepts (Appendix A.1)		• To answer RQ1
How can the JSLs' understanding be developed through integrating ICT simulations?	• Classroom observation sheet (Appendix C) • Lesson Plans (Appendix D)	Video recording during the lesson	• To allow the researcher to observe ICT teaching and learning episodes
	A test designed to measure the understanding of the atomic theory concepts (Appendix A.1)	Valid and reliable post-test was administered to JSLs	• To determine the effectiveness of using ICT simulations to address JSLs' prior understanding of atomic theory. • To answer RQ2
What are the JSLs' views on ICT simulations integration in teaching atomic theory and its structure?	Interview schedule (Appendix E)	One-on-one semi-structured interviews were conducted post-intervention	• To engage JSLs about their experiences of using ICT to learn
	Focused group Interview schedule (Appendix F)	Semi-structured group interviews were conducted in class post-intervention	• To determine the JSLs' experiences with ICT simulation integration in teaching and learning the atomic theory concepts using collaborative learning • To answer RQ3.

In the sections below, each data generation instrument is explained.

3.6.1 Diagnostic conceptual test

The diagnostic conceptual test (see Appendix A.1) was administered to answer the first research question about identifying the learners' prior understanding of atomic theory concepts. The diagnostic test comprised multiple-choice questions and structured questions administered to JSLs. The researcher invigilated the participants to ensure an uninterrupted writing session. The diagnostic test aimed to reveal the understanding of atomic theory concepts 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 is created from the existing knowledge. The researcher marked the learners' test scripts using a memorandum (see Appendix B.1) to identify their prior understanding. The prior understandings probed were used to prepare for the classroom lessons.

3.6.2 Interview schedules

Semi-structured interview schedules were used as instruments for this study. Six learners were selected randomly from each class to answer semi-structured one-on-one interview questions (see Appendix F) after the intervention phase, which was about integrating ICT simulations in teaching and learning, and as the intervention strategy in addressing JSLs' prior understanding. The participants were interviewed for 15 minutes. The second schedule of interviews was conducted as focused group interviews (see Appendix G) after the intervention phase to determine JSLs' understanding of using ICT simulations in atomic theory concepts using collaborative learning.

3.6.3 Lesson plans

Lesson plans (see Appendix C) were also used as data generation instruments. To answer the second research question, lesson plans were prepared. The researcher ensured lesson plans included the relevant content, pedagogy, and technology. The classroom lessons were conducted in a social setting using social constructivism theory and applied the TPACKTIVITY theory for incorporation of content, pedagogy, and technology knowledge infused with activity theory. Learners were asked to answer baseline questions in every lesson as a group. The ICT simulations from different websites were used during the lessons to address the JSLs misconceptions.

3.6.4 Observation schedule

During the classroom lessons, the classroom observation data was generated through video recording. The classroom observation sheet schedule (see Appendix D) was used to gather more data to answer research question 2. Classroom lessons were conducted during the normal teaching hours aligned with the CAPS notional hours. This observation focused on using ICT simulations to develop the JSLs' understanding of the atomic theory concepts.

3.6.5 Post-test

A diagnostic conceptual test (see Appendix A.1) that was used before intervention was used as a post-test. A post-test is a test given after a lesson or period of instruction to determine what learners have learnt. The purpose of giving the same test was to find what change was brought about by the intervention towards understanding the concepts. The post-test was administered to JSLs, and then the researcher marked the learners' test scripts to measure their achievement and the effectiveness of using ICT simulations.

3.7 Pilot Study: Validating the Diagnostic Conceptual Test

As indicated earlier, this study intended to develop the junior learner's understanding of atomic theory using ICT simulation. To be able to achieve this, the researcher needed to gather valid and reliable data that reveals these prior understandings of JSLs. As a result, this necessitated the need to validate this test. To do so, the diagnostic test was given to a pilot sample of 30 grade 10 Physical science learners from the same school but different classes to enhance both content and face validity. These were learners who were not the target population in this study.

The test comprised questions that tested the basic understanding of atoms from the previous grades. The questions for the concept test were sourced from tests and examination question papers that were set by the South African Department of Basic Education, therefore, the questions were deemed valid. The diagnostic test for the pilot study had three questions. Question one included seven multiple-choice questions. Questions two and three were structured and open-ended questions, (see Appendix A.2) the JSLs were expected to demonstrate their prior understanding of the following aspects: understanding and identifying the sub-atomic particles, differentiating between structures of different atoms, and understanding the development or work done by scientists to develop the atomic theory as we know it. The reflection of the pilot study suggested that there were a few changes that needed to be made to this instrument. For instance, question 2 in Appendix A.2 tested the knowledge of the Aufbau diagram, when revisions were done to the instruments, the question was replaced by atomic notation, knowledge of isotopes and their chemical properties (see Appendix A.1) as per CAPS requirements. This was done to test as many atomic theory concepts as possible compared to a focus on one concept. Also, the Aufbau diagram was considered to be difficult for the JSLs since the atomic theory was still in the introductory phase in terms of the ATP.

Consequently, the diagnostic conceptual test was adapted for data generating valid and reliable data in this study (Appendix A.2).

3.8 Data analysis

The process of data analysis in this study happened in three important phases. The first set of data were analysed before the ICT intervention, and it was geared towards providing answers to the first research question about JSLs' prior understanding of the atomic theory. The second phase entailed the analysis of the ICT simulations and how they were used to develop the JSLs' understanding of the atomic theory. This provided responses to the second research question. The last phase of data analysis pertained to JSLs' view on the incorporation of ICT simulation in developing their understanding of the atomic theory. This was inclined towards answering the third research question. These processes are briefly unpacked below for each question.

3.8.1 Analysing for Prior Understandings

After administering the diagnostic concept test, the JSLs' responses were marked using a corresponding memorandum (see Appendix B.1). Each answer sheet was assessed and evaluated for responses. The purpose of the assessment analysis was not to check for correct or incorrect answers but to acquire insight into the JSLs' prior understanding of the atomic theory concepts and check for patterns in their responses for thematic analysis. A set of prior understandings about the atomic theory was generated. From the generated prior understandings, codes were used throughout the analysis to locate these prior understandings in three themes derived from how the content is structured in the policy document (CAPS)

3.8.2 Developing the JSL's Understanding through ICT Simulation

During the ICT simulation intervention, video recordings were taken and transcribed to formulate a tentative understanding of classroom activities that occurred during this period. The video analysis approach for the recordings was content analysis where the focus was on identifying and describing how the JSLs' understandings were developed by analysing the contents of the video recordings through the meaningful use of ICT.

Data generated through video recording was analysed using a TPACK rubric adapted from Hwee and Koh (2013) (see Appendix E). The TPACK rubric consists of five dimensions namely *(i) Active Dimension* where the lesson activities engage students in active participation and utilization of ICT tools *(ii) Constructive Dimension* where the lesson activities promote students' construction of personal meaning and understanding through ICT-based activities, *(iii)Authentic Dimension* where the lesson activities are connected to the real-world phenomena and provide students to utilize their knowledge and skills in real contexts, *(iv) Intentional Dimension* where the lesson activities are carefully designed with clear learning objectives and use ICT tools in a meaningful and intentional way to support those objectives, and *(v) Cooperative Dimension* where the lesson activities encourage students to collaborate and share knowledge through ICT-mediated interactions (Hwee & Koh, 2013; Koehler et al., 2013)

Lessons conducted during the intervention were analysed using these dimensions on a Likert scale rating of 1-4. Each dimension was rated according to the observations made from the recordings. An example of the active dimension is illustrated below, and all dimensions are fully unpacked in Chapter 4.

Dimension	1	2	3	4
Active	There is sporadic use 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 using ICT to work with subject matter.

Figure 3.2: TPACK rubric Active dimension.

3.8.3 JSLs' Views on ICT Integration

The last phase of data analysis for this study revolved around the analysis of data generated post-ICT intervention to get the JSLs' views, opinions, and experiences about the use of ICT in teaching and learning. This includes data generated from interview schedules. The analysis method known as qualitative thematic analysis was used to analyse data from one-on-one interviews and focused group interviews. The participants' responses from semi-structured interviews were transcribed, organised, coded, and themed into categories. Emerging themes from interview transcripts are detailed in Chapter 4.

3.9 Research Rigour

In qualitative research, rigour denotes the methodological approach that fosters credibility and trustworthiness in the research findings. It enables researchers to establish consistency and replicability in their research methods over time (Cresswell & Cresswell, 2018). The unique components of qualitative research concerning qualitative rigour include credibility, transferability, dependability, and confirmability. These are described below and unpacked in detail how they were ensured in this study.

3.9.1 Credibility

Establishing credibility entails guaranteeing a close alignment between the raw data generated and the researcher's subsequent interpretations of that data (Gonzalez, 2020; Munn et al., 2014). In this study, credibility was maintained through prolonged engagement with data, and persistent observation of JSLs' responses in the classroom and activities. Data generated from the diagnostic test were corroborated with focus group interviews**.**

3.9.2 Transferability

Transferability assesses the degree to which the findings of a research study can be generalised and applied to other contexts, situations, and environments (Cope, 2014; Houghton et al., 2013). The concept of rigour in qualitative research encompasses the methodological strategies employed to foster trust and confidence in the research findings. It enables the researcher to ensure consistency in their research methods across different contexts and timeframes (Cresswell & Cresswell, 2018). The unique components of qualitative research concerning qualitative rigour include credibility, transferability, dependability, and confirmability.

3.9.4 Dependability

Dependability serves to assess and establish the consistency and trustworthiness of a research study's findings (Cohen et al., 2018; Creswell & Creswell, 2018). To establish dependability, researchers meticulously document the procedures employed for data collection, analysis, and interpretation. Additionally, they provide comprehensive contextual details about each instrument utilised in the study. This thorough documentation facilitates replication of the study by other researchers, enabling the production of consistent results, for example, diagnostic conceptual tests, ICT simulations, and post-tests used in this study must ensure dependability.

3.9.4 Confirmability

Confirmability refers to whether the findings based on theoretical frameworks are accurately derived from the data (Houghton et al., 2013). Therefore, the teacher as the researcher used the TPACKTIVITY framework to analyse and interpret the findings derived from incorporating ICT simulations in lessons and the Activity theory to evaluate the impact of the learners' participation in developing their knowledge of atomic theory. Credible research should yield findings that accurately represent and impartially convey the information gathered from participants. The data should speak for itself. To enhance the credibility of research findings, researchers can employ various techniques, including promptly documenting their personal reflections, potential biases, and emerging insights following an interview. Furthermore, researchers should adopt a facilitative approach to interviews, allowing participants to guide the conversation while seeking clarification when necessary (Cresswell & Cresswell, 2018). ICT simulations can be used in schools of different socio-economic contexts to evaluate whether the results apply to other situations.

3.10 Ethical Considerations

According to Cohen et al. (2018), researchers have an ethical duty to demonstrate quality. As Hammersely and Traianou (2012) argue, the ethical conduct of research extends beyond treating participants with respect and encompasses the fundamental responsibility to investigate meaningful questions and cultivate, generate, evaluate, and defend accurate factual knowledge.

There are several ethical considerations for this research project, namely, the ethical clearance (see Appendix H) by the university (UKZN), permission letters to the parents of the learners who participated in the research (see Appendix I), voluntary participation, and the right to withdraw from the project as well as protection of anonymity and confidentiality. The letters requesting permission to conduct the research study (see Appendix J) were also sent to the Department of Education and the school principal (see Appendix K). The Department of Education granted the researcher permission to conduct the study in one school. The school's principal also offered permission to conduct the research study. An informed consent form was secured from each participant (see Appendix L). Participation in this research study was voluntary. They were allowed to 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 the action research cycle, when the meeting was conducted, the purpose of the study was explained to the participants. During the ICT-intervention period, a reflective journal (see Appendix M) was used and kept to inform the planning and execution of lessons.

3.11 Chapter Summary

This chapter narrated the research design and methodology adopted in the study. Furthermore, it highlighted the data generation methods utilising different instruments. The chapter detailed a qualitative research methodology, and data analysis approach and further discussed rigour that ensured credibility and trustworthiness of the study. Finally, the chapter meticulously examined ethical dilemmas encountered during the research process and outlined the strategies employed to mitigate these challenges, thereby ensuring the reliability and validity of the collected data. The subsequent chapter delves into a thorough analysis of the data, presenting the key findings of the research. The researcher discusses the analysis of the data generated from the diagnostic conceptual test, post-test, interviews, observations, and discussions. The findings are discussed in detail according to each research question.

CHAPTER 4

4. RESULTS AND FINDINGS

4.1 Introduction

The main purpose of this study was to develop the JSLs' understanding of atomic theory concepts using ICT simulations, particularly the PhET simulations and ChemThink. This chapter reports on the qualitative results and findings of the data generated in the study. The first data set was generated using a validated diagnostic conceptual test (see Appendix A.1) before the ICT-based intervention. The analysis of this data was key in responding to the first research question about JSLs' prior understanding of atomic theory. The second dataset was generated with the same test post the ICT-based intervention. The post-intervention dataset provided insight into the intervention and developed the JSLs' understanding of the topic. The third dataset was generated through videotaped lessons based on ICT integration. This dataset was crucial in responding to the second research question about how the researcher could develop an understanding following the teaching cycles in action research. The last dataset comprised of one-on-one and focus group interviews. This set of data in the form of interview transcripts was important in responding to the third research question about the JSLs' views on integrating ICT in teaching atomic theory.

As indicated in Chapter 3, the diagnostic conceptual test was marked with a corresponding memorandum (see Appendix B.1) to evaluate if there was an impact on JSLs' understanding of the concepts. In this study, the components of TPACK, as explicated in Chapter 2, were used to map the quality of teaching with ICT simulations in key teaching episodes. Data from the interviews were analysed thematically to evaluate the views of JSLs on ICT integration. Given the above, the presentation of results is separated into three main sections in this chapter. These are (i) JSLs' Prior Understanding of the Atomic Theory and its' structure, (ii) The Development of JSLs' understanding of the Atomic Theory through ICT simulations, and (iii) JSLs' Views of ICT Integration in Teaching Atomic Theory. The synopsis of this chapter culminates with the findings aligned with each research question.

4.2 JSLs' Prior Understanding of the Atomic Theory and its Structure

After administering the diagnostic conceptual test, a performance analysis of the questions was conducted. The results of the marking process are shown in Table 4.2. Each MCQ's distribution of the responses is shown for each choice. This set of data was not meant for quantitative measures. However, it was important to provide a descriptive analysis and to gain insight into the JSLs understanding of the concepts examined.

Table 4.1: Diagnostic test MCQ results

Sample: N=30	MCQ	1.1	1.2	1.3	1.4	1.5	1.6	1.7
	Correct Answers	A	A	B	C	B	D	D
	Participants responses							
	A	6	1	3	14	12	0	2
	B	8	22	14	3	6	18	20
	C	4	2	6	8	4	8	2
	D	12	5	7	5	8	4	6
% Pass		**20**	**3**	**46**	**26**	**20**	**13**	**20**

Table 4.1 displays the JSLs' performance in Section 1 of the diagnostic conceptual test. From the distribution above, the overall question was poorly answered since none of the questions acquired 50% of correct responses. Therefore, each question was analysed for potential misconceptions or conceptual errors. However, it must be noted that the numbers displayed are not used as a technique to provide a descriptive statistical analysis. They are used to diagnose what is the extent to which a particular conception is understood. With reference to Table 4.1, in question 1.1, only 6 out of 30 respondents understood that the protons and neutrons have approximately the same mass. A substantial number of 8 respondents chose B which says that these subatomic particles do not have the same mass. Then, the majority of

the 12 respondents deduced that none of the given options were true. This indicates the conflicted reasoning regarding the mass of subatomic particles.

In question 1.2, the participants were asked about Neil Bohr's model and only 1 participant gave a correct response. Then, 22 out of 30 participants understood that Bohr's model suggested that the electrons are scattered throughout the atom. This choice indicates that learners confuse the JJ Thomson model with Bohr's model. About 5 respondents chose option C. This implies that some learners have a conceptual error that Bohr's model suggests that electrons move according to their energy level. The observation made by Salazar et al. (2019) that errors in learning atomic concepts is a typical example of confusion about microscopic representation models which lead to misconceptions.

Even though 14 respondents were able to answer question 1.3 correctly, 13 out of 30 respondents had an understanding that the central region of an atom is called the centre or the core. They do not understand that it has a specific name, the atomic nucleus. Both questions 1.4 and 1.5 tested the atomic mass concept, and the respondents demonstrated a limited understanding of atomic mass, its relation to mass number, and the factors that affect atomic mass. In question 1.6, 18 respondents had a prior understanding that changing the number of electrons changes the mass of the atom. This indicated the existing misconception between atomic mass and atomic number. Lastly, in question 1.7, 20 respondents had a prior understanding that the electrons are positioned at the centre of the atom with the neutrons. Again, this indicated the misconception that the JSLs have the subatomic particles and their positions in atoms.

The following descriptive analysis is based on the structured questions in Sections 2 and 3 of the diagnostic conceptual test (see Appendix A.1). The concept that was tested in question 2.1 was the understanding of the atomic number. All participants attempted the question, but only 1 out of 30 participants was able to identify the element and write the correct number of protons and electrons. Then, 29 participants concluded that Fe has 56 protons. Thus, 97% of the participants could not understand the numbers that represent the number of neutrons or make a relation between the number of protons and electrons. This observation shows a lack of understanding of the atomic number and the number of protons. Question 2.2 tested the understanding of electron arrangement, also called the electron configuration. In this question, 0 out of 30 participants were able to give the correct electron configuration. This was one of the most unattempted questions. This potentially indicates that learners lack understanding of the electron arrangement and what it means for the structure of the atom.

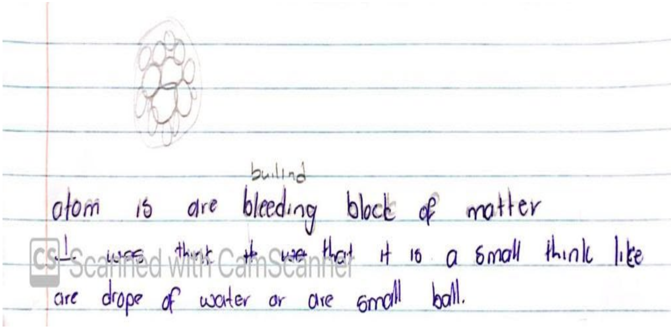
In question 2.3, the understanding of the concept of isotopes was tested and respondents provided various responses to this question. For example, participant *JSL 1* responded that the reason why the atomic numbers are the same and mass numbers are different is that they are different in size while respondent *JSL 8* responded that it is because they are in different groups. Generally, the participants' responses indicate that learners poorly understand the concept of isotopes and what it means for atoms to have the same atomic number and different mass numbers.

The diagnostic conceptual test also tested the JSLs' understanding of the chemical properties of atoms in question 2.4 and no participant in the sample answered this question correctly. About 28 participants concluded that atom A is unreactive because it has a "smaller size" or "it has a small number of atoms. This demonstrates that JSLs potentially have a poor understanding of how the structure or electrons of the atom determine its reactivity.

The last section of the diagnostic conceptual test was based on Rutherford's experiment and model. For this question, all 30 respondents had difficulty making sense of the purpose of the experiment, the intention of the experiment, and the conclusions made from the experiment. This potentially demonstrates the poor knowledge about the history of developments of different atomic structures and the role that those developments played in understanding the basic atomic structure.

To attain more credibility and increase the trustworthiness of the data generated by the pre-test instrument, additional activities were conducted pre-intervention to acquire the JSLs' prior understanding of the atomic theory and its structure. One of the activities included verbal instruction to draw the structure of the atom and write their understanding of an atom. This activity served as a quick informal way to acquire the JSLs' knowledge and thought processes. Some of the JSLs' responses are displayed in Figure 4.1 below.

JSL 3's response ***JSL 25's response***



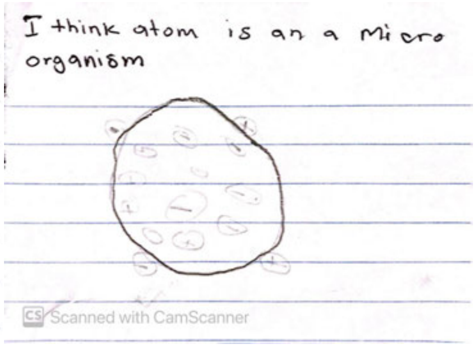


Figure 4.1 A **Figure 4.1 B**

Figure 4.1 A & B:Visual representations of the participants' prior understanding of the atom

The analysis of these responses further provided two additional prior understandings that the JSLs have about the atoms, a) atoms are or could be alive, and they are the smallest living organisms like cells as shown in *JSL 25's* response. Secondly, their movement as well as that of their electrons indicate that they are living organisms.

As indicated earlier the first research question was about the JSLs' prior understanding of atomic theory and its structure. The next section outlines the list of the prior understandings and potential conceptual errors gathered from the analysis of the pre-test.

Prior understanding of the JSLs and potential misconceptions

i) JSLs have a conflicted understanding of the mass of the subatomic particles (electrons, protons, and neutrons).

ii) JSLs assume that the electrons are scattered throughout the atoms according to Bohr's atomic theory. They confuse this tenet from JJ Thomson's model and that of Bohr's model.

iii) JSLs regard electrons as positively charged particles, instead of protons.

iv) Generally, the JSLs call the nucleus of the atom as a "centre or core" which emanates from the knowledge of earth science models in the senior phase.

v) The atomic mass is always a whole number instead of a mass number being the rounded atomic mass.

vi) The protons can move or be found around the nucleus where the electrons also orbit.

vii) The JSLs cannot differentiate between the atomic number and the atomic mass and what both these numbers represent.

viii) JSLs confuse the meaning of A and Z in the notation ${}^{A}_{Z}E$. A is the number of protons and Z is the number of electrons.

ix) JSLs lack an understanding of the concepts of isotopes and what it means for atoms with the same atomic number but different masses.

x) All atoms of elements are the same, they have the same chemical properties or behave the same, regardless of their electron arrangement.

xi) According to Rutherford's experiment, the alpha particles are atoms of elements.

xii) The JSLs cannot explain why the alpha particles deflect while others pass through in the gold foil experiment.

xiii) Atoms are microscopic and basic units of matter; they are micro-organisms and are like cells.

xiv) An atom is the same as a molecule since they are all microscopic.

The above list of prior understandings and misconceptions was grouped into themes in Table 4.2 since there were prevailing similarities of misconceptions across the concepts of the atomic theory and its structure.

Table 4.2: Thematic grouping of JSLs' prior understandings

Themes	Sub-themes and aspects	Prior understandings
Knowledge of subatomic particle	• Mass of protons, electrons, and neutrons • Charges of subatomic particles • Atomic number, notation, and isotopes	(i), (iii), (v), (vi), (vii), (ix)
Knowledge of assumptions regarding atomic model	• JJ Thompson and Bohr's model • Rutherford's model • Planetary comparison	(ii), (iv), (xi), (xii)
Knowledge of the microscopic nature of the atom	• Comparison to cells • Comparison to molecules • Chemical properties	(x), (xii), (xiv)

The above thematic grouping was necessary for discussions in Chapter 5. As alluded to in Chapter 3, this part of the research formed the planning phase of this action research. The next phase that will be reported is the acting phase where the researcher implemented the

ICT-simulation integrated teaching as a means of intervention or developing the JSLs' understanding of the atomic theory and its structure.

4.3 Developing JSL Understanding of the Atomic Theory and its Structure through ICT Simulations

To address the second research question about developing the JSLs' understanding of the atomic theory and its structure through ICT simulations, the researcher conducted lessons incorporating ICT simulations as a means of intervention to develop the JSLs understanding of the atomic theory. The lessons were conducted using the two action-research cycles described in Chapter 3. For cycle 1, five lessons were recorded and analysed as a unit. The first lesson was based on the *history and development of the atomic theory*, the second lesson was based on *Rutherford's scattering experiment*, the third lesson was about the *structure of the atom and sub-atomic particles*, the fourth lesson was based on the *representation of the atom using notation* $^{A}_{Z}E$ and the fifth lesson was based on *isotopes and atomic mass*.

For cycle 2, only two lessons were conducted due to time constraints. This decision also was informed by the performance of some of the questions in the formative analysis of the JSLs immediately after cycle 1 of the ICT intervention. The two repeated lessons were about the *Rutherford scattering experiment* and the second lesson was about the *structure of the atom and sub-atomic particles.*

All the lessons in each cycle were video recorded, transcribed, and analysed by the researcher using a TPACK rubric taken from Hwee and Koh (2013). To gain insights into the development of JSLs' understanding through ICT, this study borrowed from the work of Hwee and Koh (2013) about the use of ICT for meaningful learning. The analysis then focused on the five dimensions that articulate how ICT was used meaningfully in a lesson. These are *(i) Active Dimension (ii) Constructive Dimension, (iii)Authentic Dimension, (iv) Intentional Dimension, and (v) Cooperative Dimension.* In addition to these video analyses, for each cycle, a representative TPACK map showing how the ICT simulation in segmented teaching episode was constructed to describe the quality of the teachers' incorporation of ICT simulation in developing the JSLs' understandings. In the next section, the first cycle is unpacked.

4.3.1 Incorporation of ICT for Meaningful Learning: Cycle 1

The rubric in Appendix C provided the extent to which each dimension was engaged using ICT simulation in each cycle. In this section, these dimensions are unpacked for the five lessons analysed in the first cycle, starting with the active dimension.

(i) Active Dimension

The active dimension refers to the duration in which students were actively engaged with the ICT tools to acquire information or knowledge about the content being taught in the lesson. the longer the duration spent by learners engaging with ICT tools to learn the subject matter, the more it was considered active (Hwee & Koh, 2013). Figure 1 below shows an extract from the TPACK rubric that describes the extent to which this dimension was observed in the recorded lessons.

Dimension	1	2	3	4
Active	There is sporadic use 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 using ICT to work with subject matter.

Figure 4.2: Active Dimension in a TPACK rubric

Using the rubric, the transcribed video lessons were evaluated. Table 4 summarises the observed extent to which the active dimension to develop JSLs' understanding of the atomic theory and its structure was engaged measured at a Likert scale of 1 – 4.

Table 4.3: Meaningful use of ICT in cycle 1 (Active dimension)

Active Dimension	1	2	3	4
Lesson 1	✓			
Lesson 2			✓	
Lesson 3		✓		
Lesson 4		✓		
Lesson 5		✓		

In the first lesson, there was less engagement with the ICT simulation. In lessons 3 to 4, the simulations were engaged half the time, and in lesson 2, there was a substantial engagement with the simulation. These values were average and produced a score of 2, indicating that the JSLs were using ICT to work with the subject matter half the time in the first cycle. Figure 2 shows the JSL actively engaging with the ICT tools during cycle 1 lessons.

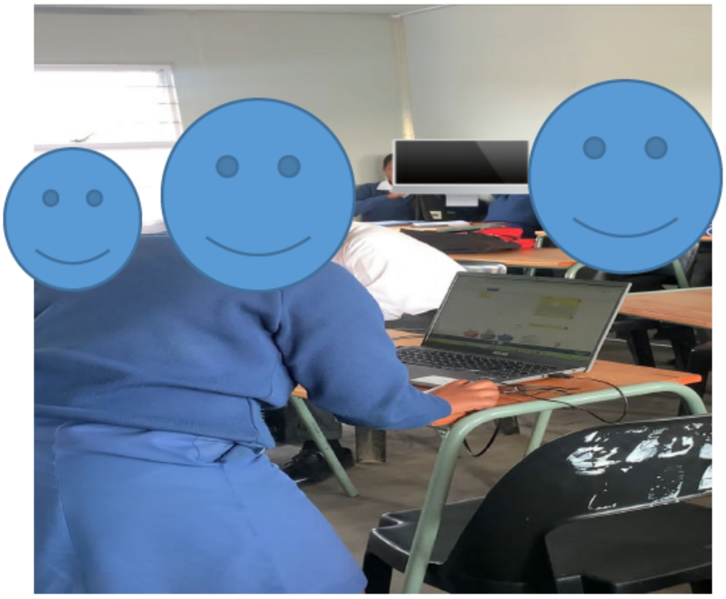


Figure 4.3: JSL actively working with ICT simulation in cycle 1.

In the next section, the constructive dimension is unpacked.

(ii) Constructive Dimension

According to Hwee and Koh (2013), the constructive dimension is a measure of how the use of ICT tools in lesson activities engages students in different interpretations of the content of the subject matter rather than perpetuating convergent thinking. Hwee and Koh (2013) stated that higher levels of constructive dimension are indicated by the ability of learners to use ICT tools to construct and reflect on their knowledge about the subject matter and be able to express it in verbal and written forms. The following extract in Figure 3 shows a rubric section that was used to analyse the extent of engaging the constructive dimension.

Dimension	1	2	3	4
Constructive	ICT tools are used 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 learners to synthesize information to construct verbal and written, expressions of the subject matter

Figure 4.4: Constructive dimension in a TPACK rubric.

Below is a summary of the constructive dimension observed in the recorded lessons.

Table 4.4: Meaningful use of ICT in cycle 1 (Constructive dimension)

Constructive Dimension	1	2	3	4

Lesson 1	✓			
Lesson 2		✓		
Lesson 3	✓			
Lesson 4	✓			
Lesson 5		✓		

The results displayed in Table 5 indicate that the average constructive level for the lessons was 1. This means that most lessons in Cycle 1 incorporate ICT simulations for transmitting and reproducing subject matter without meaning. For example, in lesson 4, the JSLs were taught how to represent the atom using the notation ${}^{A}_{Z}E$. The activities in this lesson allowed for the transmission of knowledge rather than using the ICT tools to support different angles and interpretations of the content that was taught. Figure 4.5 shows that the teacher used the traditional content aspect only without technology applications as per the TPACK model for the transmission and reproduction of knowledge.

Figure 4.5: Lesson 4 in Cycle 1.

(iii)Authentic Dimension

Hwee and Koh (2013) describe the authentic dimension as how the ICT tools in the lesson activity help students connect with the real-world phenomenon related to the subject matter being taught. The more the activities supported the students to make connections between their own experiences and the real-world phenomenon associated with the subject matter, the more it was considered authentic.

Dimension	1	2	3	4

Authentic	No representations of real-world phenomena or problems related to the subject matter are presented with ICT tools.	ICT tools are 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 to propose solutions.

Figure 4.6: Constructive dimension in a TPACK rubric.

The data in Table 4.5 below displays the authentic dimension scores for the recorded lessons.

Table 4.5 : Meaningful use of ICT in cycle 1 (Authentic dimension)

Authentic Dimension	**1**	**2**	**3**	**4**
Lesson 1	✓			
Lesson 2			✓	
Lesson 3		✓		
Lesson 4		✓		
Lesson 5		✓		

The analysis of the recorded lessons against the TPACK rubric demonstrated that most lessons were more authentic, with an average score of 2 since ICT simulations are designed to imitate or reproduce real-world phenomena. For example, lesson 1 was accorded a score of 1 since it was a voice-annotated simulation with a mere narration about the history and development of the atom, and lesson 2 was accorded a score of 3 because the ICT tools were used to emulate the real- world experiment. This way, the JSLs made clear connections between their experiences and the real-world phenomenon demonstrated by the ICT simulations. Figures 4.7 and 4.8 show one of the simulations conducted in lesson 2 (Rutherford's Scattering) that reproduced the real-world experiment and help the JSLs investigate and draw their conclusions about the real-world phenomenon. Rutherford's Scattering reproduced the real-world experiment and helped the JSLs investigate and draw their conclusions about the real-world phenomenon.

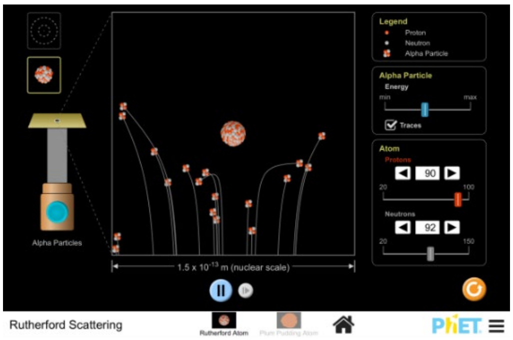


Figure 4.7: The Rutherford Scattering simulation.
From http://phet.colorado.edu/

Figure 4.8: Lesson 2 in cycle 1

The next section will discuss the intentional dimension of lessons in cycle 1.

(iv) Intentional Dimension

The intentional dimension refers to the extent to which ICT tools were used in the lesson to engage students with activities that will help them self-diagnose and fix their learning gaps concerning the content being learnt (Hwee & Koh, 2013). For a lesson to be considered intentional, it must provide opportunities for students to engage in continual self-diagnosis and remediation of learning gaps.

Dimension	1	2	3	4
Intentional	Learners do not use ICT tools to support them in diagnosing, strategizing about, or improving their learning gaps in 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.

Figure 4.9: Intentional dimension in a TPACK rubric

Table 4.6 displays the analysis of intentional dimension for the five recorded lessons measured against the TPACK rubric.

Table 4.6: Meaningful use of ICT in cycle 1 (Intentional dimension)

Intentional Dimension	1	2	3	4
Lesson 1	✓			
Lesson 2	✓			
Lesson 3		✓		
Lesson 4	✓			
Lesson 5		✓		

The observation of recorded lessons indicated that the JSLs had challenges using ICT tools to support them in self-diagnosing their learning gaps. During the lessons, the JSLs were mainly dependent on the teacher for instructions and simulation manoeuvres. In most cases, they were unable to self-diagnose or fix their learning gaps until the teacher assisted and asked prompting questions. Hence the average score is 1, indicating that there must be reinforcement of intentional dimension in cycle 2.

The final dimension in the TPACK rubric is the cooperative dimension and the next section will discuss the cooperative dimension for cycle 1 lessons.

(v) Cooperative Dimension

According to Hwee and Koh (2013), the cooperative dimension is the extent to which the ICT tools are used for group work activities. This dimension comprises opportunities for learners to build knowledge while talking and discussing the subject matter in a group set up either around or through the computer. The more the learners interact with each other, the more the lesson is considered cooperative.

Dimension	1	2	3	4
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.

Figure 4.10: Cooperative dimension in a TPACK rubric

The cooperative dimension analysis for the five lessons is displayed in Table 4.7 below.

Table 4.7: Meaningful use of ICT in cycle 1 (Cooperative dimension)

Cooperative Dimension	1	2	3	4
Lesson 1	✓			
Lesson 2		✓		
Lesson 3	✓			
Lesson 4	✓			
Lesson 5	✓			

Most lessons in cycle 1 were not cooperative or allowed the JSLs to work in groups, for example, in lesson 1, JSLs were passively learning about the development of atomic theory, but, in lesson 2, they were allowed to do simulations in a group setting and have discussions since they were using their mobile devices as well. This is displayed in Figure 8 below. The average cooperative score is 1. This implies that cycle 2 lessons would need to be designed to be more cooperative, allowing JSLs to interact and have discussions about the ICT tools used for the subject matter.

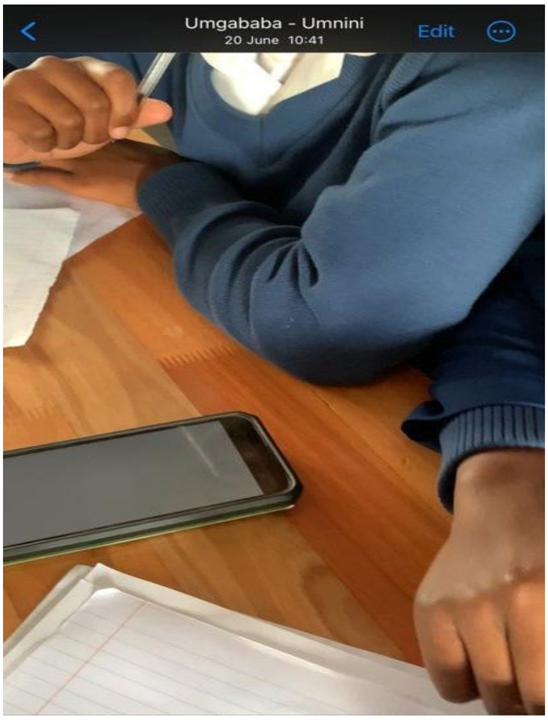


Figure 4.11: JSLs working cooperatively using mobile devices in lesson 2 Cycle 1

The reflection of lessons in cycle 1 from the entry journal (see Appendix E) of the researcher indicated that an improvement and change of lesson approach was required to ensure that the TPACK dimensions are incorporated efficiently in cycle 2. The next section will demonstrate a TPACK map analysis example for lesson 2 in cycle 1.

TPACK MAP (Cycle 1)

In addition to recorded and transcribed lessons, a TPACK map was developed to analyse the integration of the technological, pedagogical, and content aspects of the lessons. Through this map, the researcher was able to utilise content knowledge and enhance the learning outcomes. The TPACK map below is based on the analysis of lesson 2 (The Rutherford Scattering).

TPACK MAP (Cycle 1)

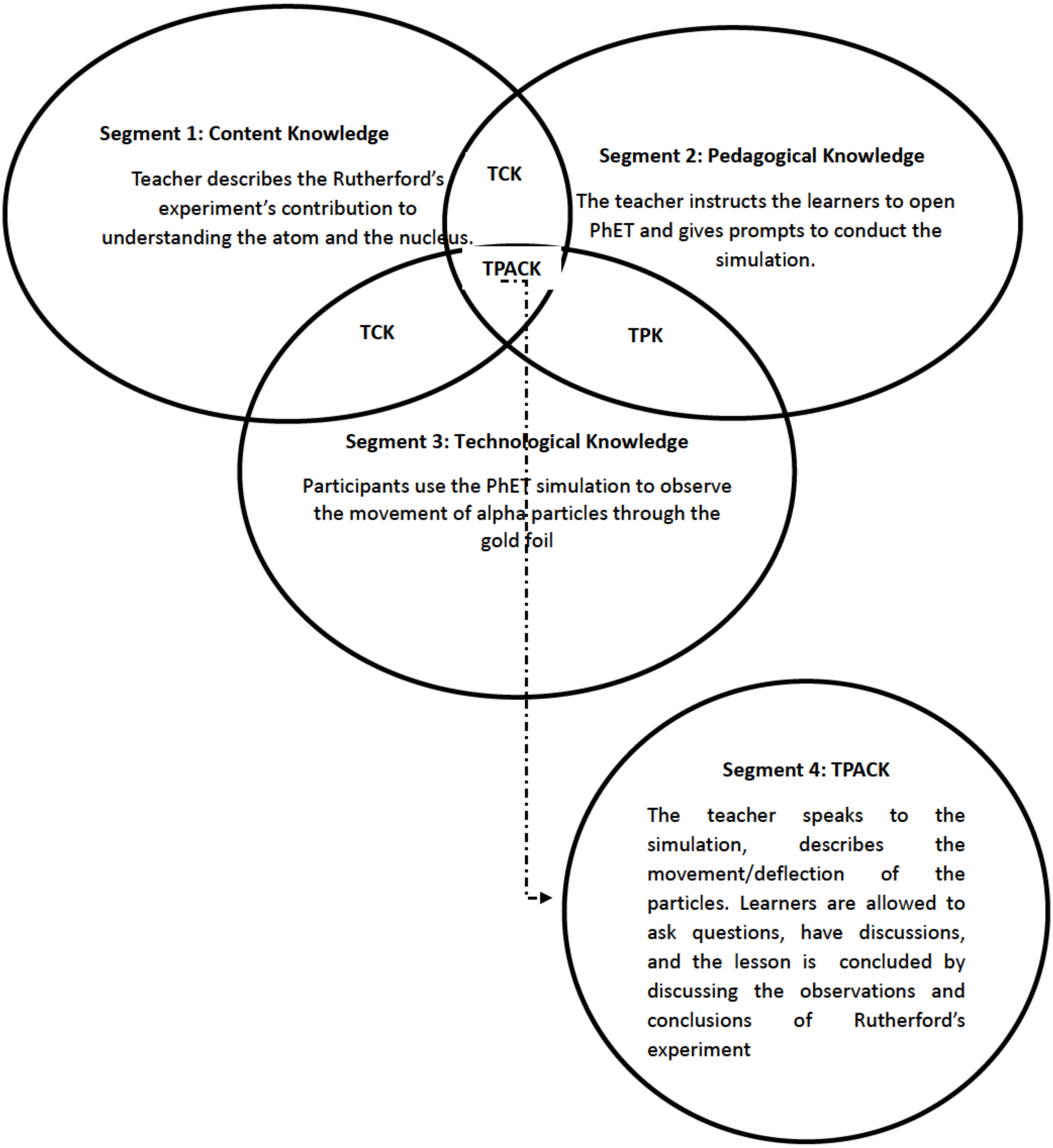


Figure 4.12: TPACK MAP (Cycle 1)

The TPACK map demonstrates how the technology integration was achieved in lesson 2 of cycle 1. The lesson was divided into segments that highlight the different areas of knowledge. The first segment focused on content knowledge (CK), what the teacher was teaching and what the teacher's knowledge of the subject. The second segment was focused on pedagogical knowledge (PK), and what instructional strategies the teacher used to meet the needs and requirements of the lesson. The third segment was technological knowledge (TK) which shows what digital tools available were used and if the teacher knew well enough to use and, in this case, PhET simulations were used. The last segment shows the integration of the three areas of knowledge (TPACK).

4.3.2 Incorporation of ICT for Meaningful Learning: Cycle 2

As alluded to in Chapter 3, the action research plan consisted of two cycles. The previous section presented the results emerging from the analysis done in cycle 1. After careful observation and reflection (documented in the researcher's journal) on the five lessons in cycle 1, two lessons were repeated. This was based on the average scores obtained in the analysis of the dimensions of ICT for meaningful learning, achievement of lesson objectives in integrating ICT simulation, and the performance of JSLs in between the AR cycles. The repeated lessons were lesson 2 based on Rutherford's scattering experiment and lesson 3 founded on the structure of the atom and its sub-atomic particles.

These lessons were also analysed using the same rubric. Table 4.8 below shows the summary of the average scores of the two repeated lessons.

Table 4.8: Summary of average scores of TPACK dimensions for lessons in cycle 2

Lesson	**Dimensions**				
	Active	**Constructive**	**Authentic**	**Intentional**	**Cooperative**
1	4	3	3	2	3
2	3	3	4	3	2
Average	**4**	**3**	**4**	**3**	**3**

The average scores in Table 9 show improvements in the repeated lessons with the TPACK dimensions of higher quality than in cycle 1 lessons. For example, in the Rutherford Scattering lesson, the active dimension had an average score of 4 since the JSLs were actively engaging with the ICT simulation for the whole lesson duration. Since this was a repeated lesson, the JSLs worked independently to complete activities.

Secondly, the second cycle also exhibited an improvement in the constructive dimension as the JSLs implemented divergent thinking to interpret the scattering experiment. For example, they were able to ask questions like:

> JSL 5: "*What did the alpha particles tell us about the presence of the nucleus in atoms*".

This question indicated the enhancement of divergent thinking of the JSLs to generate many different ideas and possibilities in an open-ended, spontaneous, and free-flowing learning environment.

The authentic dimension in cycle 2 also showed improvement since the researcher made relations between the technological tools used and the real-life simulations intended for developing the JSLs' understanding of the atomic structure. In cycle 2, the teacher incorporated other activities such as building atomic structure models using glue balls, cardboard, and strings, as depicted in Figure 4.12.

Figure 4.13: JSLs performing class activities in cycle 2

Other forms of ICT tools like YouTube animations (Figure 4.13) were used to increase the authenticity by showing similar content as that of PhET simulations.

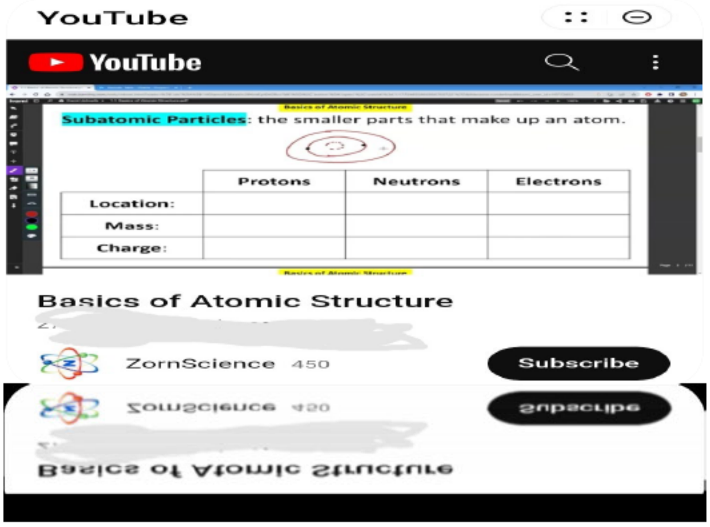


Figure 4.14: YouTube animations on basic atomic structure. Snapshot from https://www.youtu.be/zzK szNZWGO?si=tkeqPiiV9b4T140x

Regarding the intentional dimension, in cycles 1 and 2, it could be inferred from the analysis that the JSLs were more intentional in cycle 2. They were determined to seek knowledge and fix their learning gaps. They were asking deliberate questions and constantly engaging with the ICT tools to self-diagnose the gaps and fix them. For instance, after these lessons, the JSLs translated between more than one representation of atoms. After the teacher's explanation, they understood that the atomic models are only analogies of atoms and not real pictures of them. The JSLs were asking questions such as:

JSL 10: *"Does this mean that there was a common reasoning behind each model, and how did the limitations of each model contribute to understanding the structure of the atom?"*

They did this with minor assistance from the teacher. The reflection stage of the action research plan revealed that there was little substantial cooperation in cycle 1 lessons. For cycle 2, the teacher designed groupwork worksheets and more activities that require discussion among the JSLs to improve the cooperative dimension.

To present an improvement of lessons in cycle 2, a TPACK map for cycle 2 was compiled to compare the quality of teaching after the reflection stage in the action plan. The TPACK map diagram is displayed next.

TPACK MAP (Cycle 2)

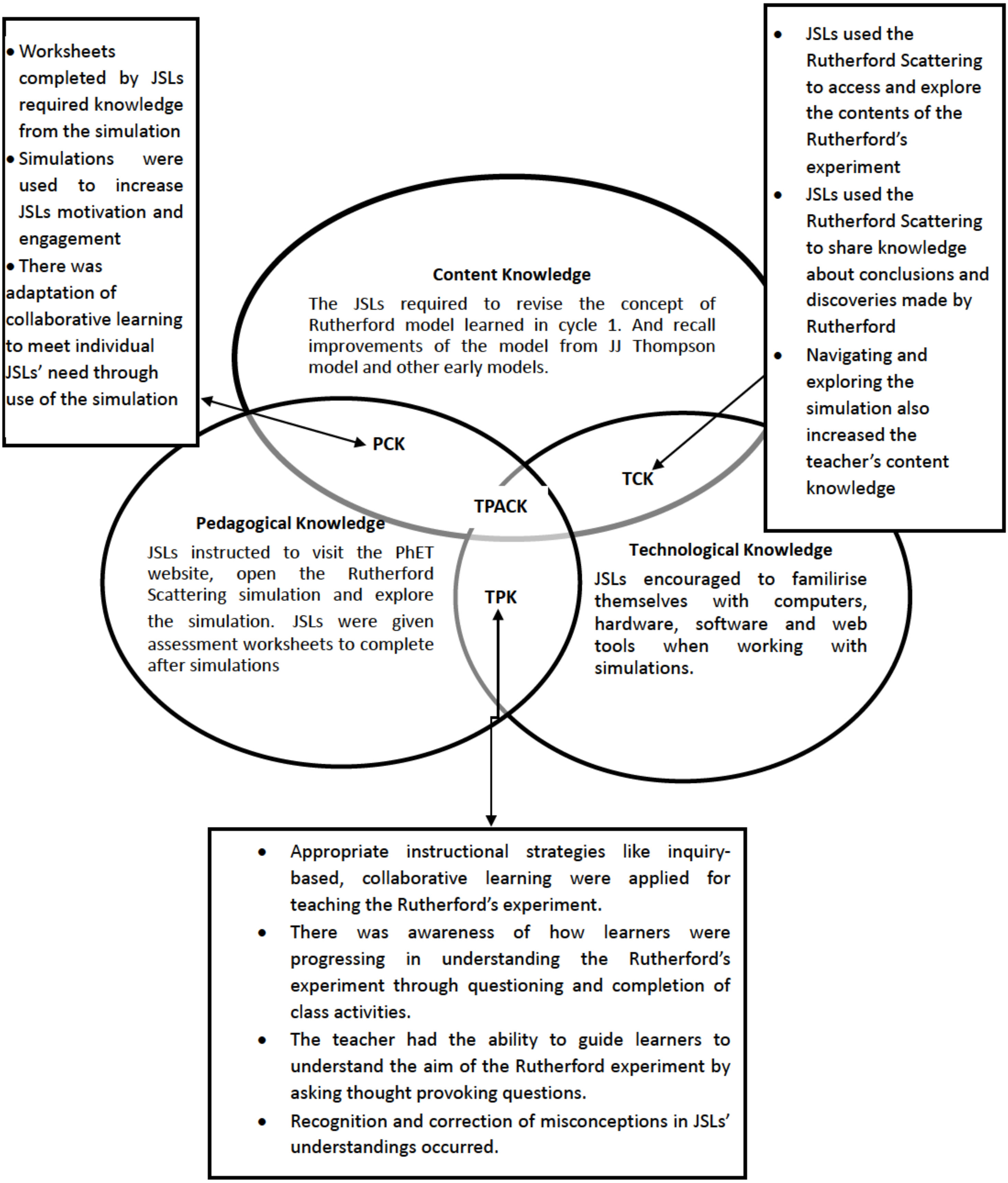


Figure 4.15: *TPACK MAP (CYCLE 2)*

4.3.3 JSLs' Overall Performance after the ICT intervention

This section aims to show the JSLs' overall performance after the intervention stage of the action research plan. Table 4.9 displays the overall results of the JSLs in the diagnostic conceptual test and post-test. The data shows the correct and incorrect responses by the sample of 30 JSLs in both the diagnostic conceptual test and post-test. The level of performance provides insight into the role played by implementing and integrating the ICT tools to develop the JSLs' understanding of the atomic theory concepts.

Table 4.9: JSLs' overall performance

Questions	Pre-test	Post-test
Section 1	***Correct responses***	***Correct responses***
1.1	6	30
1.2	1	19
1.3	14	30
1.4	8	27
1.5	6	29
1.6	4	18
1.7	6	30
Section 2	***Correct responses***	***Correct responses***
2.1.1	1	30
2.1.2	1	30
2.1.3	1	30
2.1.4	2	30
2.2	0	18
2.3	1	28
2.4	0	13
Section 3	***Correct responses***	***Correct responses***
3.1	0	25
3.2	0	25
3.3	0	25
3.4	0	25

Table 4.9 shows a substantial improvement in the performance of the JSLs' post-intervention. In section 1, only the two-tier questions 1.2 and 1.6 were challenging for some of the participants. In section 2, question 2.1 had a 100% improvement. The JSLs could give the correct number of protons, neutrons, and electrons when given an atom of the element. There was also above 50% improvement in 2.2 since the JSLs could identify the atoms and the

electron arrangement of the atom. The section that showed the greatest improvement is section 3, from 0 out of 30 correct responses in the pre-test to 25 out of 30 correct responses in the post-test. However, it was noticed that if the learner could not answer the first question correctly, they could not answer the rest of the questions.

This subsection addressed research question 2 which was focused on the development process of the JSLs' understanding of the atomic theory and its structure through ICT simulations. The analysis of recorded lessons in two cycles was done and completed against the TPACK rubric for meaningful teaching. A TPACK map for one lesson was included as an additional analysis of ICT incorporation in the lessons. Lastly, the overall performance of the JSLs for pre-test and post-test was produced and reported on. The next subsection will address research question 3 which was aimed at finding out about the JSLs' view of ICT simulations integration in teaching atomic theory and its structure.

4.4 JSLs' view on integrating ICT simulations integration into teaching atomic theory and its structure?

As described in Chapter 3, this study used a qualitative research method design. This section analyses interview responses generated using the interview protocol (see Appendices E and F). The JSLs were interviewed to share their experiences and views of using ICT simulations to develop an understanding of the atomic theory and its structure. About 15 JSLs were interviewed individually and then focus group interviews took place afterward. The interviews were transcribed, thereafter, excerpts were manually coded by the researcher to generate themes. The analysis wasn't driven by a rigid coding scheme, but rather by the patterns and themes that surfaced from the data itself.

Codes emerged from repeated words, revealing participants' interest in using simulations for abstract concepts, their experiences using simulations, and the effectiveness of group work when working with simulations. After coding all the data, the codes sharing the same meaning were clustered into sub-themes, which were eventually grouped into themes. These were also shared with the critical friend group created by the research supervisor for validity. Table 4.10 displays information from the transcript that was generated. For example, the codes, "Visual nature of simulations" and "Pictures are better than words" shared a similar meaning and could be placed in the category "Simulations and learner understanding", leading to the theme "Simulations support learner understanding". The two other codes based on JSLs' expressions and collaborative learning were independently categorised with no merging themes.

Table 4.10: Codes and Themes from Interviews

Code	Description of code	Example from excerpt	Category
Visual nature of simulations	Simulations present a visual image that a learner can see	*It helps us understand better when we see the visual images of the atom*	Simulations and learner understanding
Pictures are better than words	Simulations aid learning more than text-based activities	*Miss, I think it is better to see the images than pictures from the textbook*	
Learning with simulations is fun	Simulations foster fun learning and boost memory retention	*Miss, simulations make learning to be more fun and exciting and it is easy to remember what is taught*	Positive attitude and optimism
Group work is more effective when working with simulations	Collaborative learning promotes convergent and divergent thinking	*Yes, Miss because we can discuss and come up with solutions when we work together*	Simulations and collaborative learning

From the interviews, it could be gathered that the JSLs had different views working with the ICT simulations. A considerable number of participants made positive remarks, especially regarding the visual aspect of the simulations to improve their understanding. Some participants had this to say about the simulations:

> *JSL 6: Yes, I believe ICT simulations are better than the book; they give us more information than the books and we get to learn about something that we can see.*

> *JSL 20: Miss, I think modern technology helps us to understand more easily. It helped me to discover more information about atoms.*

During the interviews, the emotional impact of the simulations was identified. Participants were optimistic about the learning environment that was created and excited by the shift from the conventional way of learning. It was gathered that the JSLs were more willing to participate, they were motivated to learn and became responsive to the positive learning environment they were exposed to during the ICT simulation intervention. This is how some of the participants expressed their emotions about the simulations:

JSL 10: I wish that we could use these simulations to learn other subjects like Life Sciences and Mathematics.

JSL 5: Miss, I like this way of learning because it is fun and interesting.

Participants were also provided with an opportunity to comment on the teaching approach that they preferred, and the responses were inclined towards collaborative learning. The majority of the participants suggested that working in groups makes it easier to navigate the simulations and promotes enquiry-based learning. This is what some of the participants had to say about collaborative learning:

JSL 7: uhm, Miss, sometimes it is easier to ask your peer than to ask the teacher.

JSL 10: I like working in groups because we get to express our opinions and share our views with our peers.

The researcher found out that some learners preferred collaborative learning because they had challenges working with the computers and it was easier for them to ask for help from their peers.

JSL 5: Miss, some of us are not good with computers so if we work in groups, our peers are able to help us.

The analysis of interviews indicated that learners had a positive reaction to exploring the ICT simulations and the JSLs highlighted that they wished that they were taught "like this" in other subjects, as it would help them understand better and enhance their performance.

4.5 Chapter Summary

This chapter focused on the analysis of the entire results of this study. The first step was to evaluate and analyse the diagnostic conceptual test results. As discussed in this chapter, the pre-test results indicated that the JSLs have a considerable number of misconceptions about the atomic theory concepts. This was important to respond to the first research question. From the analysis, it was discovered that there are similarities between the results obtained from this study and the findings from related studies conducted by other researchers in the field. This will be unpacked in the next chapter on discussion of results. The second task was to analyse the development of the JSLs' understanding by measuring the quality of the meaningful integration of ICT through the TPACK rubric and the signature TPACK maps.

This was to compare the quality of lessons of the two cycles of the action research. This analysis provided insights into the role of the researcher in developing JSLs' understanding of the concepts. Lastly, the chapter discussed the interviews conducted post-intervention to get the views of the JSLs about the integration of ICT simulations to learn about the atomic theory concepts. This analysis was also important in responding to the last research question. The next chapter will discuss the findings in line with existing literature to explore confirmation of existing knowledge, rebuttals if any and knowledge extensions from the findings of this work.

CHAPTER 5

5. DISCUSSING THE FINDINGS

5.1 Introduction

This chapter discusses the results and findings analysed at a descriptive level in Chapter 4 and positions them with existing literature to confirm, refute and extend what other scholars in the field have found concerning the phenomenon. In this chapter, this discussion will therefore happen on two levels, firstly, at an evaluative level informed by the three literature constructs in response to the critical questions asked. These are *(i) the JSLs' prior understanding and misconceptions in the knowledge of the atom (ii) integrating ICT simulation in developing JSLs' understanding (ICT integration and quality of TPACK), and (iii) JSLs' views on the use of ICT simulations as a resource for pedagogical support*. Secondly, the next level of discussion will be theoretical, thus looking into the recurring concepts and perspectives in the TPACK literature in the context of teaching school science with ICT affordances.

5.2. Discussions

5.2.1. JSLs' prior understandings and misconceptions in the knowledge of an atom

The diagnostic conceptual test investigated JSLs' prior understanding of the atomic theory concepts and its structure before the implementation of the intervention based on ICT simulations. This study found that there were 14 prior understandings as listed in Chapter 4. The research question was: *What are the JSLs' understandings of the atomic theory and its structure?* In Chapter 4, these prior understandings were grouped into three themes to unpack them. These themes describing the grouping of the prior understandings were: *(i) knowledge of the subatomic particles (ii) knowledge of assumptions regarding atomic models (iii) knowledge of the microscopic nature of the atom*

The diagnostic conceptual test revealed that JSLs in this study hold several misconceptions based on their knowledge of subatomic particles of the atom. This included a range of misunderstandings about the masses of protons, electrons, and neutrons, the difference between the atomic number and atomic mass, the concept of isotopes, subatomic particle arrangement, and misunderstandings about the charges of electrons and protons. In line with these observations, Kaya (2023) provided a Türkiye perspective in his study about the nature and origins of such prior understandings. According to him, the abstract and microscopic nature of atoms causes the difficulty of learners' understanding of these subatomic particles of atoms. Several studies such as Cokelez (2012); Fitriza and Gazali (2018); Kaya (2023); Taber (2015) have indicated that it is challenging for students to understand the subatomic particles and many students hold misconceptions about it.

Secondly, whilst on the knowledge of subatomic particles, the diagnostic conceptual test also indicated that the JSLs cannot differentiate between the atomic number and atomic mass. As a result, they cannot understand and make correct interpretations of the atomic notation ${}^{A}_{Z}E$. Such a finding is similar to what Tekin and Nakiboglu (2006) in a study of Turkish high school students' misconceptions of nuclear chemistry found. In their study, Tekin and Nakiboglu (2006) discovered that students could not comprehend the concept of isotope atoms they could not understand that one element can contain different types of naturally occurring atoms that have the same atomic number but different mass numbers. According to a French study by Cokelez and Dumon (2005), the source for students' misconception of isotopes is a failure to recognise the difference in the number of neutrons of two isotopes, that is, two isotopes of chlorine are ${}^{35}_{17}Cl$ and ${}^{37}_{17}Cl$ have 17 electrons and 17 protons each, however ${}^{35}_{17}Cl$ has 18 neutrons and ${}^{37}_{17}Cl$ has 20 neutrons.

Thirdly, this study also discovered that the JSLs had confusion regarding the charges of subatomic particles. They regarded electrons as positively charged particles instead of protons. Cambrilearn (2019) pointed out that this is attributed to the erroneous use of the word charge in Chemistry and on concepts of electricity and magnetism, especially in South African Physical science textbooks. Several studies that investigate the prior knowledge and understanding of the atom in different contexts have shown that this is a common misconception among students and novice teachers. For example, a study conducted by Fitriza and Gazali (2018) with high school students in Indonesia indicated that 30% of the students drew an atomic model that looked like a positively charged ball with negative charges in it, while Sari and Putri (2023) made similar observations in novice secondary school science teachers.

Fourthly, the findings in this study showed that some of the JSLs' misconceptions were based on assumptions about atomic models. These arise as a result of conceptual misunderstandings that the JSLs have since they were confused about the scientific knowledge they were taught in their junior years. For example, in Bohr's atomic theory, they assumed that the electrons are scattered throughout the atoms. This assumption is confused with JJ Thompson's postulation of the plum pudding model. A Switzerland study by Wiener (2020), found that the majority of teachers prefer to use historical atomic models to modern atomic models in the classroom because the teachers assume that their students' conceptions are centred on two historical atomic models, namely, the Bohr and the Rutherford model. This leads to limited knowledge and incorrect assumptions about other atomic models. This view was found similar to the observations made by Kaya (2023) in South Africa with grade 8 Natural Sciences learners, as the grade 8 curriculum introduces learners to the atom but does not expose them to different models of the atom and how the development of knowledge about atoms contributed to the evolution of these models over the years. Hence, this leads to erroneous assumptions about atomic models due to limitations and subsequently, flaws in knowledge (Kaya, 2023).

Some misconceptions were related to the use of analogies when teaching the atomic theory and its structure. In a Swedish study of using models and representations in learning and teaching about the atom, Netzell (2016) realised that some misconceptions are rooted in the analogical use of atomic models to describe information about the atom. For example, the diagnostic test results revealed the JSLs' comparison of the atom with the solar system. Two misconceptions revealed the JSLs' knowledge of earth science: they were calling the nucleus of the atom 'centre 'or 'core' and there was confusion regarding the position and movement of protons and electrons. It is these findings that revealed that there is a common comparison that is made by learners and that the atom is like a tiny solar system (Nakiboğlu & Taber, 2013; Taber & Adbo, 2013). According to these Swedish and Turkish studies, the comparison arises from the relationship between the nucleus and electrons that exhibit the characteristics of the planets orbiting the sun. Similarly, these findings can be attributed to the naïve misconceptions that are rooted in the knowledge of earth science and planetary models learnt in Geography in the senior phase.

Furthermore, most of the JSLs' misconceptions about the atom can be attributed to its microscopic nature. According to Taber (2018), these misconceptions occur as a result of an insufficient understanding of atomic particle-related ideas and an understanding of the atomic structure due to their microscopic nature. A description of the atom as a micro-organism was the most repeated before the ICT intervention. The JSLs were convinced that atoms are the same as micro-organisms. According to the JSLs, there is no noteworthy difference between the atom, molecule, and cells. In validation of these findings, in a Greek study conducted by Papageorgiou et al. (2016) to investigate secondary students' (8^{th} to 12^{th} grade) understanding of the atom and relevant misconceptions, students fail to differentiate between the characteristics of atoms, molecules, ions, and cells at the macro-level and those of their characteristics at the micro-level.

According to Papageorgiou et al. (2016), students cannot distinguish between the atom's identity and behaviour and other microscopic bodies such as molecules and cells. This is in conjunction with the inferences made by Tibell and Harms (2017) in a Biology study that students may struggle to assimilate the vast amounts of information they encounter in class, and thus fail to notice relevant connections between complex biology concepts and distinguish between them. Additionally, other studies revealed that these misconceptions can be attributed to the students' anthropomorphic thinking that atoms are alive because they can 'want' electrons, and 'require' the octet rule, to mention a few, which often cause confusion between the atom and the cell (Cokelez, 2012; Griffiths & Preston, 2012; Papageorgiou et al., 2016; Taber & Adbo, 2013). This is also related to both analogical thinking and the personification of atoms.

With the above-discussed JSLs prior conceptions found, the study worked on developing a proper understanding of the atomic theory and its structure by incorporating ICT simulations in the lessons. The next section discusses the results of integrating ICT simulations in developing the JSLs' knowledge about the atomic theory and its structure.

5.2.2 Integrating ICT simulations in developing students' understanding of atomic concepts.

As presented in Chapter 4, two cycles of the action research were implemented to answer research question 2 of this study, which was, *how can JSLs' understanding of the atomic theory be developed through integrating ICT simulations?* Based on the observations of the five lessons, it was evident in the first cycle that JSLs were transitioning from traditional instructional methods to a learner-focused (constructivist) approach. JSLs were allowed to actively work on developing their knowledge rather than passively receiving information. The findings by Dewi et al. (2021) when investigating the urgency of digital literacy for Generation Z students in Chemistry learning in Mandalika, Indonesia, showed that ICT can provide solutions to many of the issues associated with Chemistry education. For them, through ICT learning, many students were motivated to learn Chemistry concepts that are often difficult to grasp such as in organic chemistry and atomic structures.

In this study, an action research approach was implemented, and it occurred in two cycles. In these two cycles, various forms of ICT, including voice-annotated videos, animations, and simulations (PhET & ChemThink), were incorporated to increase the viability and efficiency of ICT integration in the lessons. Literature has advocated for this approach to ICT integration. For example, in London, Brosnan (2001) advocated the use of ICT to change basic pedagogy principles to offer exciting and new kinds of opportunities to foster good pedagogy practices while Eady and Lockyer (2013) acknowledge a significant role of ICT integration in Australian primary schools. This study has revealed that the incorporation of ICT simulations to learn abstract concepts like atoms allows a more enhanced visualisation phenomena of the content being learnt, hence, improving the learners' understanding.These results echo those of Netzell (2016) survey exploring the use of simulations, models, and representations for atom instruction among Swedish upper secondary school physics and chemistry teachers. The study found that Swedish teachers were very comfortable with and advocated using different visual representation forms in their teaching. Bratland et al. (2022) provided a Norwegian perspective on the use of technology for visualisation to promote digital competence, collaborative skills, and in-depth learning of abstract concepts, especially in science. Considering these findings, ICT's impact on science teaching and learning is undeniably significant. It offers immense potential to revolutionize science education.

The findings of this study revealed that ICT simulations, specifically, PhET simulations, provided an opportunity for learners to engage actively in activities that were difficult to do physically. This was also observed by Dunn and Ramnarain (2020) in their enquiry-based study with grade 8 Natural Science learners. They noted that in the South African context, ICT simulations like PhET simulations provided a good alternative to physical laboratories that do not exist in many South African schools. This is supported by a few studies in the literature on virtual laboratories, such as Balamuralithara and Woods (2009); Corter et al. (2004). Positive remarks about simulations and virtual laboratories have been observed in different fields of knowledge. For example, Corter et al. (2004) conducted a comparative study of remote versus hands-on labs in America. Their study revealed that over 90% of the respondents rated the effectiveness and impact of the remote labs to be comparable to or better than the hands-on labs. Subsequently, Balamuralithara and Woods (2009) noted that virtual laboratories or simulation environment laboratories had a significant impact on the engineering education system. In line with the findings above, Bodine et al. (2020) recommended students in Mathematics and Biology should have an opportunity to utilise agent-based modelling and simulations to perform experiments and collect and analyse data. In this study, the findings were indicative of the positive impact that the ICT simulations played in developing the JSLs' understanding of the atomic theory and its structure.

The section above has discussed the integration of ICT simulations to develop the JSLs' understanding of the atomic theory concepts in this study relating it to relevant literature. The next section will then focus on the quality of TPACK in the two cycles of this action research study. This includes the discussion of the TPACK dimensions and TPACK component integration described in Chapter 4 to map the quality of pedagogical support provided by the researcher to develop JSLs' understanding of the atomic theory and its structure.

5.2.3 The Quality of Technological Pedagogical Content Knowledge

To unpack the quality of TPACK during the intervention stage of the research cycle, the researcher used a TPACK rubric with the five dimensions of 21st-century learning and meaningful teaching. These dimensions were borrowed from the works of Hwee and Koh (2013). These were the: *(i) Active Dimension, (ii) Constructive Dimension, (iii) Authentic Dimension, (iv) Intentional Dimension, and (v) Cooperative Dimension.* The findings in this study show that in the early stages of the research, the active dimension scores for most lessons were low since the time that the JSLs spent working with ICT simulations and computers was not enough due to the lack of resources (computers and internet access), time constraints and challenges regarding operating the computers. McNulty (2023) acknowledges that integrating TPACK with curriculum standards in South African schools may be difficult due to the aforementioned challenges such as resources and internet connectivity. An Indonesian study by Sojanah et al. (2021) shares similar findings. When factors affecting teachers' TPACK were investigated, the results indicated that teachers' experience, training, facilities and infrastructure and self-efficacy, as well as motivation, were at a low level. Therefore, this incriminates to low levels of TPACK for the teachers.

During the intervention period, JSLs were provided an opportunity to construct their knowledge, reflect, and articulate their understandings of the phenomenon as per constructive dimension requirements (Hwee & Koh, 2013). JSLs were actively engaging with simulations to make sense of the atomic structure and related concepts. However, the rating for this dimension was relatively low due to JSLs' limited ability to manipulate ICT tools and the inability to construct divergent and convergent knowledge (a lack of critical thinking and in-depth understanding). These results are similar to the postulation made by Batiibwe and Bakkabulindi (2016) that Nigerian learners do not possess innovation, creativity, and critical thinking skills because of the absence of quality teaching to keep up with the 21st-century learning standards.

The one TPACK dimension that had a moderately good rating in both cycles is the authentic dimension. Almost all five lessons ensured that the activities conducted encouraged the JSLs to make connections between their own experiences (what they knew about the atom and its structure before the intervention), and the real-world phenomenon emulated by the simulations. This is due to the visual aspect of the ICT simulations as many studies stressed the importance of using ICT tools in teaching Chemistry to overcome classroom difficulties (Ojha, 2016; Raja, 2018). Raja (2018) maintained that the use of modern equipment technology and tools increases students' interactivity since visual images always have a strong appeal compared to words.

The learner-centred approach implemented in this study meant that the JSLs were facilitated towards continuous self-diagnosis and remediation of learning gaps about the atomic theory. This is the intentional dimension of the TPACK for meaningful learning as suggested by Hwee and Koh (2013). In this study, JSLs were constantly allowed to use simulations to diagnose themselves on what they knew and what they needed to understand. However, just like the active and constructive dimension, the intentional dimension rating was low in this study due to the inability of the learners to work independently. The researcher employed a strategy to mediate this challenge and that was incorporating the collaborative learning approach. This ensured that the cooperative dimension was included in the lessons. This way, JSLs could work with their peers to construct knowledge, discuss their learning gaps, and fix them. This is supported by results from a case study conducted in Italy by Di Blas and Paolini (2016) on the effects of TPACK and the academic achievement of university students. According to Di Blas and Paolini (2016), teaching with technology is a process where the knowledge is shared across the groups (teachers and students) and resources to reach the desired goals, and this in turn, fosters collaborative learning.

Another way of ensuring the quality of TPACK during the intervention process was done through the development of TPACK maps for the lessons. TPACK maps were necessary to track the interaction of different knowledge (technological, content, and pedagogical) in segments of the lessons. Shulman (1987) noted that the categories of content and pedagogical knowledge help the teacher to promote comprehension among students. Besides, Koehler and Mishra (2009); Koehler et al. (2013) later observed that when blended with technology knowledge, these categories of knowledge create a flexible learning environment for diverse groups of students and promote effective teaching. Lai (2011) observed that the TPACK model has allowed for an increase in both student engagement and collaboration, as well as flexibility in learning. Goradia (2018) provided an Australian perspective on the use of the TPACK framework in higher education. The findings revealed that the TPACK framework provides a useful tool to gauge the learning environment. The framework highlights a complex interaction between technology, pedagogy, and content knowledge thus allows educators to use innovative technologies that are in line with contemporary teaching practices.

This section has reflected on the quality of the TPACK in the process of developing the JSLs' understanding of the atomic theory and its structure. The next section will discuss the JSLs' views on the use of ICT simulations as a resource for the pedagogical process.

5.2.4 Student views on the use of ICT simulation as a resource for pedagogical support

Based on the analysis of the interviews conducted, the JSLs were receptive to the use of ICT simulation integration in their learning. They recognised the value of the ICT simulations in developing their understanding of the atomic theory and its structure. Three categories of the JSLs' views on working with ICT simulations for pedagogical support emerged. These were *ICT simulations for conceptual understanding, ICT for positive attitude and optimism* and *ICT simulations for collaborative learning*.

In the first category, JSLs believed that ICT simulations helped to improve their conceptual understanding of abstract atom concepts by including visual simulations compared to pictures in textbooks. It is generally acknowledged that the use of visual representations in science classrooms is necessary and beneficial to improve the cognitive understanding of the learners (Derman et al., 2019). Similar to this, the work of Cook (2006, p. 102) reported that "*learners have a limited working memory, and instructional representations should be designed with the goal of reducing unnecessary cognitive load* ".

In this study, the interviewed JSLs indicated that they would like to use simulations in other subjects as well and it makes conceptual understanding of abstract concepts easier thus improving their performance drastically. According to Dunn and Ramnarain (2020), South African students, especially Black learners from townships, are lagging far behind their peers in international science assessments like Trends in International Mathematics and Science Studies (TIMSS). They revealed that this is not just a temporary dip; it's a persistent pattern, raising concerns about systemic issues and unequal opportunities.

Even compared to other developing countries, South Africa's science performance is extremely bad, particularly among Black learners from disadvantaged communities. This reveals that– not only are they struggling overall, but they're falling behind even their developing counterparts. Hence the aforementioned reported views of the participants in this study are necessary for further consideration.

Positive attitude was observed among a group of participants, and this was revealed during the interviews. When questioned about what aspects of ICT simulations they liked, they responded that learning with simulations is fun, exciting, and interesting. These findings are in line with the observations made by Hambira et al. (2017) in a Namibian case study that investigated the emotional and cultural impacts of ICT on learners. In their study, Hambira et al. (2017) revealed that the use of ICT has emotional benefits and cultural impact. The study found that a large number of learners agreed that ICT allows them to enjoy being in class, motivates and boosts their confidence and provides hope for those learners from marginalised communities. Similar to these findings, scholars from different fields (Celik et al., 2012; Hammond et al., 2011; Kreutz & Rhodin, 2016) have advocated the use of ICT and shared the positive influence it has in motivating learners, empowering them and promoting self-regulating learning.

During the interviews, the JSLs also advocated the use of collaborative learning as shown in Chapter 4. A similar study was conducted in South Africa by Dunn and Ramnarain (2020) and it was found that learning through ICT simulations enabled learners to be active participants in investigations, making decisions about how they want to learn and engage in active thinking skills. ICT simulations provide an environment for learners that is suitable for enquiry and collaborative learning since it allows learners to question, discuss with each other, and explore through experimenting with the simulations (Gadzikwa, 2018). In addition, ICT simulations as a form of visual representations are essential for communicating ideas in the science classroom (Cook, 2006), thus adding value to collaboration among learners

Even with all the positive views from the participants, several participants indicated that they had a challenge using computers and doing simulations. In turn, this forested collaboration between the JSLs as they were constantly seeking support from peers and the teacher about the skills of manipulating the ICT hardware and software. This is because, in the context of this study, the JSLs were unfamiliar with computers, and this was a barrier for them. They needed support in developing their technological knowledge. This view is also similar to the observations made by Salehi and Salehi (2012) that pedagogical practices that integrate ICT may impose challenges for both educators and learners as there are a number of difficulties that can act as barriers. Furthermore, a Swedish study about students' and teachers' perceptions of ICT education conducted by Lindberg et al. (2016) found that it is difficult for some students to use ICT for learning purposes. Some students felt that ICT was not at all needed in their learning activities. For example, students reported that using ICT in Mathematics was time-consuming and demanded a lot of work to learn (Lindberg et al., 2016).

On the other hand, some studies also highlighted the potential distractions of ICT use in the classroom. For example, Maharaj-Sharma and Sharma (2017) argued that ICT loses its appeal when its use is arbitrary and ill-planned. Lindberg et al. (2016) discovered that learners are generally aware of the potential distractions that occur through the use of the Web and different apps on their smartphones. Students reported that they sometimes have a hard time concentrating because they do their things (social media and video games), resulting in them not understanding what is learnt. Similar observations were made during the intervention period in this study. Some JSLs would use internet access to open apps on their smartphones and stream the Web instead of completing tasks.

5.3. Chapter Summary

This chapter has discussed the findings of this study guided by the literature constructs in response to each research question at evaluative and theoretical levels. In response to the first research question, this study confirmed that JSLs hold several misconceptions (14 were revealed in this study) about the atomic theory and its structure. This was revealed by the use of the diagnostic conceptual test administered to all participants. The misconceptions were mainly based on the knowledge of the subatomic particles, knowledge of assumptions regarding atomic models and knowledge of the microscopic nature of the atom. These misconceptions provided a guide to a framework for this study. The findings for the second research question were discussed using two literature constructs: the integration of ICT simulations in developing JSLs' understanding of atomic concepts and evaluating the quality of the TPACK. This study used the adapted TPACK rubric which consists of five dimensions for meaningful learning to assess the effectiveness of ICT simulations during the intervention. The quality of the TPACK lessons was also assessed through the TPACK maps in cycles 1 and 2 of this action research. The discussion of the third research question focused on the JSLs' views on the integration of the ICT simulations supported by relevant literature. This confirmed the many benefits of ICT integration pointed out by learners during the interviews. Regardless of the challenges experienced during the interviews, the positive influences and attributes of ICT cannot be denied.

CHAPTER 6

6. CONCLUSIONS AND RECOMMENDATIONS

6.1. Introduction

This chapter provides the thesis of the study. It begins by providing answers to the three research questions asked: 1) *What are the JSLs' prior understanding of the atomic theory and its structure?* 2) *How can JSLs'' understanding of the atomic theory be developed through integrating ICT simulations?* and 3) *What are the JSLs' views on ICT simulations integration in teaching atomic theory and its structure?* In addition, the chapter provides a critical reflection on the ICT simulation intervention, and the limitations of this study are highlighted thus pointing to the rationale not to generalise these findings. In conclusion, this chapter will outline some implications for professional practice and recommendations for future research.

6.2. Answering the research questions

As highlighted in the review of literature, not much research has been conducted on the use of ICT simulations when teaching the atomic theory and its structure. This study provided affordances of ICT integration on the topic in a South African classroom context, specifically in a township setting. Similar studies have been conducted but in a different context, as the study by Dunn and Ramnarain (2020) focused on South African grade 8 learners in a previous model-c school, Nkadimeng and Ankiewicz (2022) narrowed down their study to a specific ICT tool (video games) use to teach atomic structure and Suryelita et al. (2019) conducted a relatively similar to Nkadimeng and Ankiewicz (2022) study but in the Indonesian context. This study is mainly focused on utilising a range of ICT tools (video animations, voice-annotated simulations, PhET simulations) to develop the JSLs' understanding of the atomic theory and its structure in a rural South African disadvantaged school.

Research question 1: What are the JSLs' prior understanding of the atomic theory and its structure before the ICT-simulation intervention?

This study revealed that the JSLs had several erroneous prior understandings about the atomic theory and its structure. The diagnostic conceptual test revealed about 14 of these erroneous prior understandings which were not scientifically correct. These were grouped into three categories. These were (i) knowledge of the subatomic particles, (ii) knowledge of assumptions regarding atomic models and (iii) knowledge of the microscopic nature of the atom.

Whilst the diagnostic conceptual test revealed these understandings, it also showed that not all concepts were difficult. Some concepts were found to be easy by the JSLs before the ICT intervention. These included concepts linked to the questions about the atomic structure such as recalling the names of the subatomic particles in question 1.7 of the diagnostic conceptual test (see Appendix A). Some questions were found to be difficult for participants, and these included the question based on the Rutherford experiment in which none of the JSLs could answer these questions before the intervention.

Research question 2: How can JSLs' understanding of the atomic theory be developed through integrating ICT simulations?

This study revealed that using technology such as ICT simulations can improve the quality of instruction, especially in addressing some JSLs' misconceptions about the atomic theory concepts. The JSLs that were exposed to the ICT simulations intervention scored higher in the post-test (after the ICT intervention) than in the pre-test (before the ICT intervention). This proved that ICT simulations can enhance the conceptual understanding of the atomic theory concepts.

The understanding that showed a greater improvement after exposure to ICT simulations was the interpretation of the Rutherford experiment. For example, they could make conclusions about the experiment such as understanding why the alpha particles deflected when shot through the gold foil and why most of the alpha particles were able to pass through. Thus, the JSLs understood the discovery of the nucleus through the Rutherford's experiment. Furthermore, the analysis of data showed that some misconceptions were inadequately addressed by ICT simulations, especially the ones that involved atomic mass and chemical properties of atoms. The observations made from this study revealed that no idea or concept in the topic of atomic theory should be taken for granted during instruction. For example, teachers may think that the learners understand the subatomic particles concept as the basic concepts of the atomic theory and its structure, only to discover that learners hold misconceptions about it.

This study also confirmed the significant role of TPACK as a form of pedagogical support in teaching atomic theory in the constructivist classroom. Different dimensions of TPACK were proven to increase the quality of meaningful learning through the use of ICT. TPACK and the Activity Theory framework provided an opportunity to address the JSLs' misconceptions by including them in the process and allowing them to take charge of their knowledge development.

Research question 3: What are the JSLs' views on ICT simulations integration in teaching atomic theory and its structure?

The interviews conducted after the intervention revealed that ICT simulations encourage learners' engagement. The JSLs expressed that ICT simulations were interesting and encouraged attentiveness and motivation. Positive attitude and optimistic behaviour were evident in their expressions. It was also observed that ICT simulations and learning with technology foster collaboration among participants. The interview results showed that some participants who had no confidence in using computers or manipulating the PhET simulations preferred working in groups and asking for assistance from their peers. Lastly, it was observed that ICT simulations foster independent thinking and critical thinking skills among the groups of JSLs during collaborative learning, especially since a constructivist approach to teaching was implemented in this study.

6.3. Critical Reflection on the Research Methods

6.3.1 Conducting an Action Research

This study followed an action research plan as alluded to in Chapter 3. The research was conducted in two cycles and each cycle contained four phases, (i) planning, (ii) acting, (iii) observing and (iv) reflecting. The planning phase included observing and identifying the problem, which was the JSLs' lack of conceptual understanding and their poor performance on the topic of the atomic theory and its structure. With the recommendation of the supervisor, the study was piloted using a group of learners in the same grade but from another school. Doing this pilot study helped me as a researcher to get the insight and initial techniques of grading the conceptual test. Doing this study exposed me to this research approach for the first time. At first, it was difficult to make sense of the whole research design. The support I received from the supervisor and other platforms like seminar cohorts was valuable in developing my knowledge of action research. Conducting this action research proved to be time-consuming. A lot of time was spent planning, observing, recording information, and reflecting. As such, I have learnt to keep a reflective journal to navigate the ups and downs of doing this research and managing my daily duties as a full-time teacher.

Given the opportunity to re-do this study, I would rather use the self-study approach and reflect deeply on how I develop the knowledge for teaching meaningfully with ICT.

6.3.2 Implementing the ICT intervention

The process of ICT intervention included the five planned lessons, and each lesson incorporated an ICT simulation. Lesson one which was based on the history and development of the atom was delivered using voice-annotated simulation, and the other four lessons utilised the PhET and ChemThink simulations specifically designed for each topic. The use of different simulations was to ensure the variety of the tools. The major challenge for implementing the ICT intervention was the insufficient or lack thereof of necessary resources that were required to make this study a success. This includes the lack of computers and internet access. The researcher used her personal computer, an overhead projector and a Wi-Fi router for internet connection to conduct the lessons. Some learners used their mobile phones while others took turns using the researcher's personal computer. Therefore, this implies that learners were insufficiently exposed to computers and thus could not receive adequate training on how to operate computers or do ICT simulations. The lack of teacher training was also a constraint for the researcher. Lastly, the ethical dilemma posed by the research design meant that the participants' group (one grade 10 class) was going to learn through the ICT intervention while the other classes received traditional instruction. Other learners were invited to participate but there was not enough floor space for them all. This implies that the other learners of the same grade lost out on the advantages of ICT simulations.

6.4 Limitations

Apart from the already mentioned challenges, other constraints resurfaced during this study. These constraints include the instrument used to collect data, and the diagnostic conceptual test. The test contained multiple choice questions which Cohen et al. (2007) argued may compromise the quality of the instrument since participants may guess the answers. Also, some of the open-ended questions contained in the instrument were difficult for the JSL grade level though they were benchmarked with the DBE assessments.

Time constraint is one of the critical issues experienced in this study, both for the researcher and the participants. According to the 2023 annual teaching plan (ATP), the atomic theory and its structure were scheduled for term 2 while the researcher started with the research in term 1, therefore improvisions had to be made. For the JSLs, there was not enough time to work with ICT simulations since the syllabus had to be taken into consideration.

As expected, JSLs were distracted by their smartphones since they were provided with the internet access. They would open social media apps and stream videos unrelated to what was learnt in class. However, the prominent limitation of this research study is that it was conducted in a single school with learners from the same income bracket. This does not provide a variety of contexts and the number of participants was too small to gather enough data. This study used a sample of 30 participants who were bound in a specific context. As a result, the findings that are made in this study are therefore not generalised but interpreted with the context in which the study was conducted.

6.5 Recommendation for Future Research

One of the prevalent limitations of this study is the small data generated since the study was focused on one school. The researcher strongly recommends further extensive research on the topic that covers more schools within the same geographic location as well as in different settings and contexts within South Africa. Considering the outcomes of this study, further recommendations for future research were made by the researcher. It is noted that the concepts of atomic theory and its structure are some of the challenging concepts in Chemistry, not only among South African learners, but globally. Research on this topic undertaken across the world produced similar results to the results from this study. Recommendations suggested are based on learners' classroom activities integrating ICT tools, TPACK integration in teaching practice for meaningful learning, and improvements in educational policy speaking on technology integration in science education in South Africa.

Firstly, it is suggested that in their lesson planning, teachers are aware of the misconceptions that the learners hold about the topic of the atomic theory and its structure. This would inform classroom activities that should be incorporated into lessons. Using ICT-based activities in the classroom would ensure that the level of misconceptions and misunderstandings about the topic is reduced. Secondly, the findings of this study demonstrated the successes and benefits of utilising ICT simulations when teaching the topic. TPACK has proven to have a positive impact on pedagogy and meaningful learning. Therefore, it is recommended that TPACK be employed for effective teaching and learning of abstract concepts and conceptual understanding of the atomic theory and its structure. Lastly, at a policy level, the topic of atomic theory and its structure forms a basic foundation for Chemistry topics that are poorly performed in the national end-of-year examinations. This contributes to the overall poor performance in Physical science as demonstrated in Chapter 1, Table 1.2. Integrating ICT in teaching and learning abstract Chemistry concepts can help overcome this challenge. However, the objectives of the South African 2004 White Paper on e-Education and those of the National Integrated ICT Policy White Paper of 2016 have not materialised. It is recommended that extensive research is conducted to follow up on the implementation and progress of these policies.

6.6 Final Piece

Developing JSLs' comprehension of atomic theory has the potential to play a substantial role in enhancing their performance in Chemistry. This, in turn, could result in a demonstrably improved overall performance in the broader field of Physical Science. The development of grounded and adequate theoretical frameworks that can inform the integration of emerging technology-orientated theories such as TPACK and Activity Theory in a constructivist classroom has proven its paramount value. Therefore, it is crucial that technology integration is encouraged in pedagogy to overcome learning difficulties and motivate learners to work productively and achieve the best results.

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8. Appendices

Appendix A.1:Diagnostic conceptual test

QUESTION 1: MULTIPLE-CHOICE QUESTIONS

FOUR options are provided as possible answers to the following questions. Each question has only ONE correct answer. Choose the answer and write ONLY THE LETTER

1.1 True or False- Protons and Neutrons have about the same mass

Properties of Protons, Neutrons, and Electrons

	Electron	Proton	Neutron
Symbol	e–	p	n
Charge	1–	1+	0
Location	electron cloud around the nucleus	nucleus	nucleus
Relative mass	1/1,840	1	1

A. True- They have about the same mass
B. False – They do not have about the same mass
C. False – They do not have about the same charge
D. None of the above (2)

1.2 Niels Bohr suggested that electrons…

A. are found in specific orbits
B. electrons are scattered throughout the atom
C. electrons move according to their energy level
D. electrons are positive (2)

1.3 The central region of an atom where its neutrons and protons are is its

A. Electron cloud
B. Nucleus
C. Core
D. Centre (2)

1.4 What is the difference between the atomic mass and the mass number?

A. The atomic mass is always a whole number
B. The atomic mass equals the atomic number
C. The mass number is the rounded atomic mass-always a whole number
D. Electrons (2)

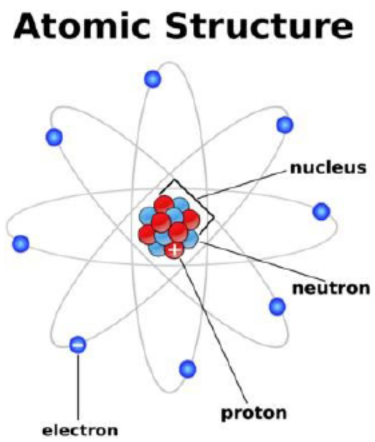
1.5 Which of the following causes the mass of the nucleus to increase?

A. Adding an electron
B. Adding a neutron
C. More orbitals
D. Adding negatively charged particles (2)

1.6 What happens to an atom if the number of electrons is changed?

A. Changing the number of electrons changes the isotope.
B. Changing the number of electrons changes only the mass.
C. Changing the number of electrons changes the identity of the element.
D. Changing the number of electrons changes the charge of an atom. [2]

1.7. Which two sub-atomic particles make up the nucleus of an atom?



A. Protons and Electrons
B. Neutrons and Electrons
C. Electrons and Protons
D. Protons and Neutrons (2)

[14]

STRUCTURED QUESTIONS

QUESTION 2

2.1. An atom of iron is represented as $^{56}_{26}\mathbf{Fe}$

Give the number of protons, neutrons, and electrons in this atom of iron.

2.1.1 Number of protons………………………… (1)

2.1.2 Number of neutrons………………………… (1)

2.1.3 Number of electrons………………………… (1)

2.1.4 Would you regard **Fe** as an atom of metal, non-metal, or metalloid? (1)

2.2 Element X has an atomic number of 18. State the electronic configuration of an atom of element X (2)

2.3 Elements are made of atoms. The table below shows the atomic numbers and mass numbers of three atoms.

Atom	Atomic number	Mass number
1	12	24
2	12	25
3	12	26

2.3.1 Explain, in terms of the number of subatomic particles, why the atomic numbers are the same and mass numbers of the three atoms are different. (2)

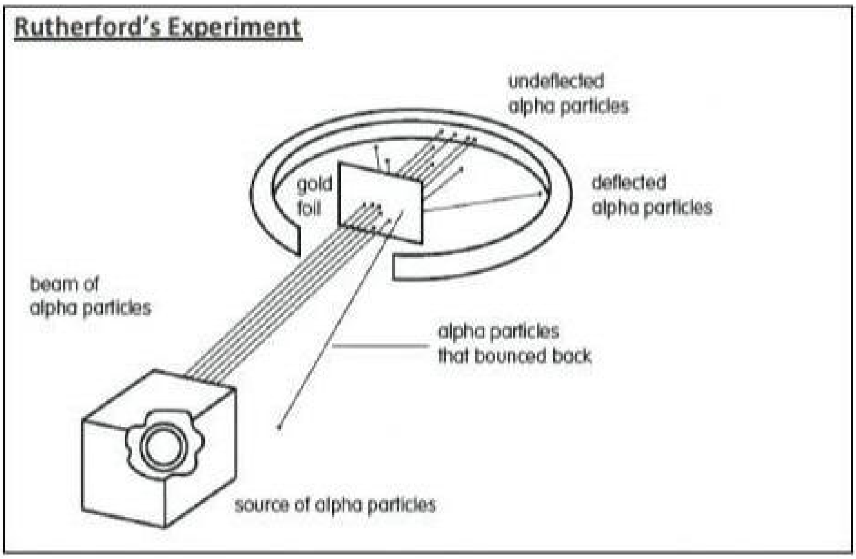
2.4 The diagrams show the electronic structure of four different atoms.

2.4.1 Why is atom A unreactive? (1)

2.4.2 Which two of these atoms have similar chemical properties? Give a reason for your answer. (2)

QUESTION 3

Ernest Rutherford carried out an experiment to investigate the structure of the atom. He fired alpha particles at a thin gold foil and observed the path of the alpha particles. From the results, he developed a new model of the atom.



Observation 1: **most of the alpha particles went straight through the gold atoms undeflected.**

Observation 2: **a few of the alpha particles rebounded (bounced back) from the gold atoms.**

3.1. Use observation 1 to describe what Rutherford concluded about the structure of the atom (2)

3.2. Explain the conclusion made in 3.1 (2)

3.3. Use observation 2 to describe what Rutherford concluded about the nucleus of an atom (2)

3.4. Explain the conclusion made in 3.3 (2)

TABLE 3: THE PERIODIC TABLE OF ELEMENTS

KEY/*SLEUTEL*

Atomic number / *Atoomgetal*: 29

Electronegativity / *Elektronegatiwiteit*: 1,9

Symbol / *Simbool*: Cu

Approximate relative atomic mass / *Benaderde relatiewe atoommassa*: 63,5

1 (I)	2 (II)	3	4	5	6	7	8	9	10	11	12	13 (III)	14 (IV)	15 (V)	16 (VI)	17 (VII)	18 (VIII)
1 2,1 H 1																	2 He 4
3 1,0 Li 7	4 1,5 Be 9											5 2,0 B 11	6 2,5 C 12	7 3,0 N 14	8 3,5 O 16	9 4,0 F 19	10 Ne 20
11 0,9 Na 23	12 1,2 Mg 24											13 1,5 Aℓ 27	14 1,8 Si 28	15 2,1 P 31	16 2,5 S 32	17 3,0 Cℓ 35,5	18 Ar 40
19 0,8 K 39	20 1,0 Ca 40	21 1,3 Sc 45	22 1,5 Ti 48	23 1,6 V 51	24 1,6 Cr 52	25 1,5 Mn 55	26 1,8 Fe 56	27 1,8 Co 59	28 1,8 Ni 59	29 1,9 Cu 63,5	30 1,6 Zn 65	31 1,6 Ga 70	32 1,8 Ge 73	33 2,0 As 75	34 2,4 Se 79	35 2,8 Br 80	36 Kr 84
37 0,8 Rb 86	38 1,0 Sr 88	39 1,2 Y 89	40 1,4 Zr 91	41 Nb 92	42 1,8 Mo 96	43 1,9 Tc	44 2,2 Ru 101	45 2,2 Rh 103	46 2,2 Pd 106	47 1,9 Ag 108	48 1,7 Cd 112	49 1,7 In 115	50 1,8 Sn 119	51 1,9 Sb 122	52 2,1 Te 128	53 2,5 I 127	54 Xe 131
55 0,7 Cs 133	56 0,9 Ba 137	57 La 139	72 1,6 Hf 179	73 Ta 181	74 W 184	75 Re 186	76 Os 190	77 Ir 192	78 Pt 195	79 Au 197	80 Hg 201	81 1,8 Tℓ 204	82 1,8 Pb 207	83 1,9 Bi 209	84 2,0 Po	85 2,5 At	86 Rn
87 0,7 Fr	88 0,9 Ra 226	89 Ac															
				58 Ce 140	59 Pr 141	60 Nd 144	61 Pm	62 Sm 150	63 Eu 152	64 Gd 157	65 Tb 159	66 Dy 163	67 Ho 165	68 Er 167	69 Tm 169	70 Yb 173	71 Lu 175
				90 Th 232	91 Pa	92 U 238	93 Np	94 Pu	95 Am	96 Cm	97 Bk	98 Cf	99 Es	100 Fm	101 Md	102 No	103 Lr

Appendix B.1 :Memorandum for A.1

QUESTION 1

1.1 A✓✓
1.2 A✓✓

1.3 B✓✓

1.4 A✓✓

1.5 B✓✓

1.6 D✓✓

1.7 D✓✓

QUESTION 2

2.1.1 36✓

2.1.2 30✓

2.1.3 26✓

2.1.4 Metal ✓

2.2 $1S^2 2S^2 2P^6 3S^2 3P^6$ ✓✓

2.3.1 The atoms have equal number of protons but different number of neutrons in the nucleus. ✓✓

2.4.1 Full outer energy level✓
2.4.2 B and C. Both have one electrons in their outermost shell ✓✓

QUESTION 3

3.1 The atom has a helium nucleus or two protons and two neutrons✓✓

3.2 The centre of the atom consists of the same number of positively charged particles and neutral particles ✓✓

3.3 The nucleus must be positively charged because the alpha particles repel AND the nucleus must be dense to cause the alpha particles to rebound✓✓

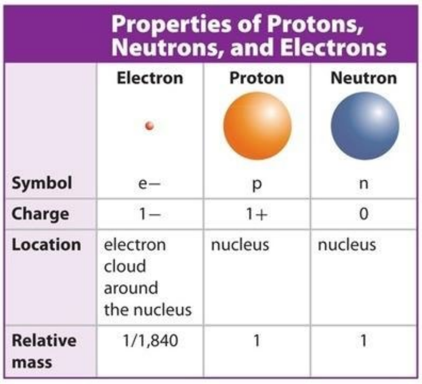
3.4 The centre of the atom is positively charged and has negative charges orbiting around it.✓✓

Appendix A.2:Diagnostic conceptual test (Pilot Study)

QUESTION 1: MULTIPLE-CHOICE QUESTIONS

FOUR options are provided as possible answers to the following questions. Each question has only ONE correct answer. Choose the answer and write ONLY THE LETTER

1.1 True or False- Protons and Neutrons have about the same mass



Properties of Protons, Neutrons, and Electrons

	Electron	Proton	Neutron
Symbol	e–	p	n
Charge	1–	1+	0
Location	electron cloud around the nucleus	nucleus	nucleus
Relative mass	1/1,840	1	1

E. True- They have about the same mass
F. False – They do not have about the same mass
G. False – They do not have about the same charge
H. None of the above (2)

1.2 Niels Bohr suggested that electrons…

E. are found in specific orbits
F. electrons are scattered throughout the atom
G. electrons move according to their energy level
H. electrons are positive (2)

1.3 The central region of an atom where its neutrons and protons are is its

E. Electron cloud
F. Nucleus
G. Core
H. Centre (2)

1.4 What is the difference between the atomic mass and the mass number?

E. The atomic mass is always a whole number
F. The atomic mass equals the atomic number
G. The mass number is the rounded atomic mass-always a whole number
H. Electrons (2)

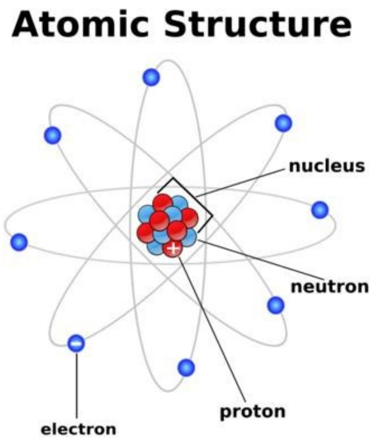
1.5 Which of the following causes the mass of the nucleus to increase?

E. Adding an electron
F. Adding a neutron
G. More orbitals
H. Adding negatively charged particles (2)

1.6 What happens to an atom if the number of electrons is changed?

E. Changing the number of electrons changes the isotope.
F. Changing the number of electrons changes only the mass.
G. Changing the number of electrons changes the identity of the element.
H. Changing the number of electrons changes the charge of an atom. [2]

1.7. Which two sub-atomic particles make up the nucleus of an atom?



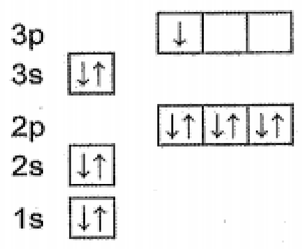
E. Protons and Electrons
F. Neutrons and Electrons
G. Electrons and Protons
H. Protons and Neutrons (2)

[14]

STRUCTURED QUESTIONS

QUESTION 2

2.1. The following is an Aufbau diagram of an atom, X.



2.1.1 How many energy levels does this atom have? (1)

2.1.2 In which orbital do we find the electron with the highest energy (1)

2.1.3 Would you regard X as an atom of metal, non-metal, or metalloid? (1)

2.1.4 Write down the formula of X when it forms an ion. (2)

2.2. Draw a diagram showing Dalton's Representation of an atom (2)

2.3. What was the major shortcoming of Dalton's atomic theory? (1)

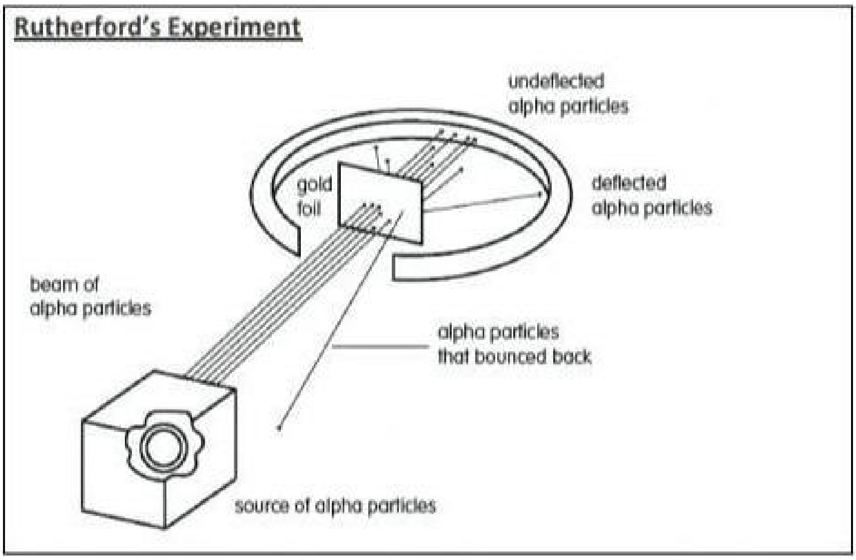
2.4. Write the electron configuration of the Carbon atom ${}^{12}_{16}C$ based on electron configuration of Bohr atomic theory (2)

2.5 Lithium atom has the notation of ${}^{7}_{3}Li$, Draw the atomic model of this atom based on Bohr atomic theory (3)

[13]

QUESTION 3

Ernest Rutherford carried out an experiment to investigate the structure of the atom. He fired alpha particles at a thin gold foil and observed the path of the alpha particles. From the results, he developed a new model of the atom.



Observation 1: **most of the alpha particles went straight through the gold atoms undeflected.**

Observation 2: **a few of the alpha particles rebounded (bounced back) from the gold atoms.**

3.1. Use observation 1 to describe what Rutherford concluded about the structure of the atom (2)

3.2. Explain the conclusion made in 3.1 (2)

3.3. Use observation 2 to describe what Rutherford concluded about the nucleus of an atom (2)

3.4. Explain the conclusion made in 3.3 (2)

TABLE 3: THE PERIODIC TABLE OF ELEMENTS

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1 (I)	2 (II)	3	4	5	6	7	8	9	10	11	12	13 (III)	14 (IV)	15 (V)	16 (VI)	17 (VII)	18 (VIII)
1 2,1 H 1																	2 He 4
3 1,0 Li 7	4 1,5 Be 9											5 2,0 B 11	6 2,5 C 12	7 3,0 N 14	8 3,5 O 16	9 4,0 F 19	10 Ne 20
11 0,9 Na 23	12 1,2 Mg 24											13 1,5 Aℓ 27	14 1,8 Si 28	15 2,1 P 31	16 2,5 S 32	17 3,0 Cℓ 35,5	18 Ar 40
19 0,8 K 39	20 1,0 Ca 40	21 1,3 Sc 45	22 1,5 Ti 48	23 1,6 V 51	24 1,6 Cr 52	25 1,5 Mn 55	26 1,8 Fe 56	27 1,8 Co 59	28 1,8 Ni 59	29 1,9 Cu 63,5	30 1,6 Zn 65	31 1,6 Ga 70	32 1,8 Ge 73	33 2,0 As 75	34 2,4 Se 79	35 2,8 Br 80	36 Kr 84
37 0,8 Rb 86	38 1,0 Sr 88	39 1,2 Y 89	40 1,4 Zr 91	41 Nb 92	42 1,8 Mo 96	43 1,9 Tc	44 2,2 Ru 101	45 2,2 Rh 103	46 2,2 Pd 106	47 1,9 Ag 108	48 1,7 Cd 112	49 1,7 In 115	50 1,8 Sn 119	51 1,9 Sb 122	52 2,1 Te 128	53 2,5 I 127	54 Xe 131
55 0,7 Cs 133	56 0,9 Ba 137	57 La 139	72 1,6 Hf 179	73 Ta 181	74 W 184	75 Re 186	76 Os 190	77 Ir 192	78 Pt 195	79 Au 197	80 Hg 201	81 1,8 Tℓ 204	82 1,8 Pb 207	83 1,9 Bi 209	84 2,0 Po	85 2,5 At	86 Rn
87 0,7 Fr	88 0,9 Ra 226	89 Ac															

58 Ce 140	59 Pr 141	60 Nd 144	61 Pm	62 Sm 150	63 Eu 152	64 Gd 157	65 Tb 159	66 Dy 163	67 Ho 165	68 Er 167	69 Tm 169	70 Yb 173	71 Lu 175
90 Th 232	91 Pa	92 U 238	93 Np	94 Pu	95 Am	96 Cm	97 Bk	98 Cf	99 Es	100 Fm	101 Md	102 No	103 Lr

Appendix B.2:Memorandum for A.2

QUESTION 1

2.1 A✓✓
1.2 A✓✓

1.3 B✓✓

1.4 A✓✓

1.5 B✓✓

1.6 D✓✓

1.7 D✓✓

QUESTION 2

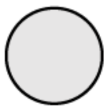
2.1.1 3 energy levels✓

2.1.2 3p✓

2.1.3 Metal✓

2.1.4 X^{3+}✓✓

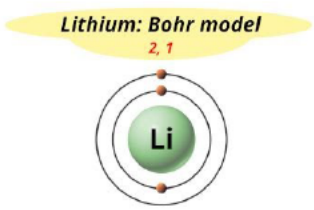
2.2



✓✓

2.3 Dalton's theory states that atoms are indivisible/ all atoms of the same element have the same masses✓. ANY ONE

2.4 $1s^2 2s^2 2p^2$✓✓
2.5



✓✓✓

QUESTION 3

3.1 The atom has a helium nucleus or two protons and two neutrons✓✓

3.2 The centre of the atom consists of the same number of positively charged particles and neutral particles ✓✓

3.3 The nucleus must be positively charged because the alpha particles repel AND the nucleus must be dense to cause the alpha particles to rebound✓✓

3.4 The centre of the atom is positively charged and has negative charges orbiting around it.✓✓

Appendix C: TPACK Lesson Plan

Lesson title : The Rutherford's experiment

Grade : 10

Subject : Chemistry

Time allocation : 60 min

Learning Objectives :

Learners will be able:

- Describe the plum pudding model of the atom and its limitations.
- Explain Rutherford's scattering experiment and its results.
- Conclude the structure of the atom based on Rutherford's experiment.

Materials

- Whiteboard or projector
- Computer/ laptop (with internet access for simulations)
- Textbooks
- Worksheets

PROCEDURE:

1. **Introduction (10 minutes)**

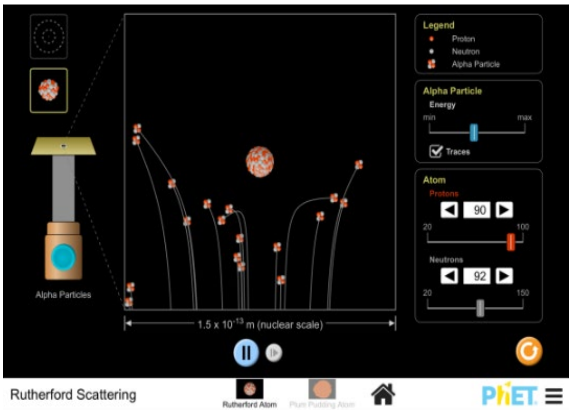
- The teacher will begin by engaging learners asking the following questions
    - What is an atom?
    - What did we previously think about the structure of the atom?
    - Why is understanding the structure of the atom important?

- The teacher will then revisit the plum pudding model of the atom from lesson 1, which was the prevailing model at the time of Rutherford's experiment. The teacher will the plum pudding model and its key features, such as a positively charged sphere with negatively charged electrons embedded in it.

2. **Development (30 minutes)**

In this stage, the teacher will explain Rutherford's scattering experiment, including the equipment used and the experimental setup.

- The teacher will discuss the expected results based on the development from the plum pudding model.
- The PhET simulation will be used to demonstrate Rutherford's scattering experiment.



- The teacher will show learners the actual results of Rutherford's experiment, with alpha particles bouncing off the gold foil. Then highlight the unexpected results, particularly the large deflection angles
- The teacher will lead learners to conclude that the atom must have a dense, positively charged nucleus at the centre, with electrons orbiting around it. This is the Rutherford model of the atom.

3. **Application (10 minutes)**
   - The teacher will provide students with practice problems to calculate the deflection angle of alpha particles using Rutherford's formula. (Not part of the curriculum requirements/ not examinable)

4. **Assessment (10 minutes)**

Formative

✓ Ask students to summarise the key points of Rutherford's scattering experiment and its implications.

✓ Have students draw a diagram of the Rutherford model of the atom.

✓ Engage students in a discussion about the limitations of the Rutherford model.

Summative

- ✓ The teacher will administer a worksheet to assess students' understanding of Rutherford's scattering experiment and the Rutherford model of the atom

TPACK Aspects of the lesson

Technology integration:

- Utilize a projector to display diagrams and animations.
- Employ PhET simulations or videos to demonstrate Rutherford's scattering experiment.
- Use the PhET simulations for interactive activities and practice problems.

Pedagogical strategies:

- Inquiry-based learning: Encourage students to ask questions, explore concepts, and analyze data to draw conclusions.
- Cooperative learning: Engage students in group activities to discuss and collaborate on problem-solving.
- Visual aids: Utilise diagrams, animations, and simulations to enhance understanding.

Content knowledge

- Atomic structure
- Rutherford's scattering experiment
- Rutherford model of the atom

Technological Pedagogical Content Knowledge (TPACK)

- Effective use of technology to enhance student learning and engagement.
- Integration of technology to support enquiry-based learning and collaborative activities.
- Selection of appropriate technology tools to align with learning objectives and content.

Differentiation :

- For students who need additional support, provide scaffolding and guided practice.
- For advanced students, offer the teacher more challenging problems and encourage them to research extensions of the Rutherford model.

Reflection:

- The teacher will consider the effectiveness of the lesson in promoting student understanding and engagement.
- The teacher will evaluate the appropriateness of the chosen teaching strategies and technological integration.
- The teacher will identify areas for improvement and modifications for future implementation.

Appendix D:Lesson Observation Schedule

Teacher: ____________________________ **Date:** __________________________

Subject: ____________________________ **Topic:** _________________________

Instruction: Please tick the appropriate answer/box

Question	**Good**	**Adequate**	**Needs attention**
1. Is the lesson well prepared?			
2. Is the teacher knowledgeable about the content?			
3. Does the teacher speak loud and clear?			
4. Does the teacher use the board for explanations?			
5. Are the simulation pictures clear?			
6. Is the simulation sound audible?			
7. From the learners' reaction, is the use of simulations effective?			
8. Does the teacher hold and maintain learners' attention?			
9. Are the learners actively involved?			
10. Are the questions asked stimulating and challenging?			
11. Is the lesson conducted respectfully?			

Comments/suggestions:

____

____

____

____

____

____

Appendix E: Rubric for assessing meaning learning with ICT

Dimension	1	2	3	4
Active	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 a 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 to support transmission and reproduction of subject matter without meaning-making	ICT used to support convergent knowledge expression by learners with respect to the subject matter.	ICT used to support 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
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.
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 of the subject matter are being diagnosed by teachers or peers.	Learners self-diagnose their learning gaps of the subject matter by using ICT tools/resources.	Learners use ICT tools/resources to self-diagnose their learning gaps of the subject matter. Thereafter, they are to fix these learning gaps.
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.

Appendix F: Interview Schedule I (One-on-one)

1. Do you believe that using modern technology in your learning can develop a better understanding of your knowledge about atoms? Why?

2. Have you ever used simulations before in your learning?

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

4. Do you think ICT simulations can help improve your understanding of concepts? Why?

5. Would you like to learn using ICT simulations in all subjects?

6. How does the lack of access to modern ways of learning (technology) affect your understanding of abstract concepts in Physical Science?

Appendix G: Interview Schedule II (Focus group)

1. Tell me about the experiences of lessons you had

2. Is there any improvement needed in our lessons?

3. Did you enjoy the use of simulations during our lessons?

4. Was the learning environment positive, welcoming, and friendly?

5. Did you participate fully during the group activities?

6. What was most challenging about using simulations? Why?

Appendix H:Ethical Clearance

UNIVERSITY OF KWAZULU-NATAL
INYUVESI YAKWAZULU-NATALI

30 March 2023

Nobuhle Mvundla (211528133)
School Of Education
Edgewood Campus

Dear N Mvundla,

Protocol reference number: HSSREC/00005317/2023
Project title: Developing junior secondary learners' understanding of the atomic theory using information and communication technology simulations.
Degree: Masters

Approval Notification – Expedited Application

This letter serves to notify you that your application received on 27 February 2023 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 30 March 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:** https://research.ukzn.ac.za/Research-Ethics

Founding Campuses: Edgewood Howard College Medical School Pietermaritzburg Westville

INSPIRING GREATNESS

Appendix I: Informed consent letter: for parents

Science and Technology Cluster,
School of Education,
College of Humanities,
University of KwaZulu-Natal,
Edgewood Campus, KwaZulu -Natal

INFORMED CONSENT LETTER: FOR PARENTS

Dear Parents/Guardians

My name is Nobuhle Mvundla. 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 **'Developing Junior Secondary Learners' Understanding of the Atomic Theory Using ICT Simulations'.**

The literature review suggests that there is a rapid development of emerging technologies and pressures to incorporate Information and Communication Technology (ICT) in teaching and learning. In this way, I have found an opportunity to research the impact of integrating ICT simulations in developing learners' understanding of atomic theory as an abstract concept. This research will assist in developing a better understanding of learners, provided the socio-economic context of the school where modern technology is rarely integrated into pedagogy.

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 recording and discussions with learners. I, therefore, seek permission to invite your child to participate in this research study since the child is in grade 10 Physical science class.

Please note the following:

- Your child’s confidentiality will be guaranteed. All data from this study will be kept as private as possible. Pseudonym will be used instead of your child’s real names.
- The discussion, 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. 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 Dr Bongani Prince Ndlovu. He is located at the School of Education, College of Humanities, Edgewood Campus, and University of KwaZulu-Natal. Dr 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. And 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 **'Developing Junior Secondary Learners' Understanding of the Atomic Theory Using ICT 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**

kzn education
Department:
Education
KWAZULU-NATAL

Appendix J: Permission from DoE

Application for Permission to Conduct Research in KwaZulu Natal Department of Education Institutions

1. Applicants Details

Title: Miss

Surname: Mvundla

Name(s) Of Applicant(s): Nobuhle

Email: 211528133@stu.ukzn.ac.za

Tel No: N/A

Fax: N/A

Cell: [redacted]

Postal Address: P.O Box 567

Amanzimtoti

4126

2. **Proposed Research Title:** Developing Junior Secondary Learners' Understanding of the Atomic Theory using ICT Simulations.

3. Have you applied for permission to conduct this research or any other research within the KZN DoE institutions?	**Yes**	~~**No**~~

If "yes", please state reference Number: The application is under review

4. Is the proposed research part of a tertiary qualification?	**Yes**	~~**No**~~

If "yes"
Name of tertiary institution: University of KwaZulu-Natal

Faculty and or School: College of Humanities School of Education

Qualification: Master of Education
Name of Supervisor: Dr. B.P Ndlovu **Supervisors Signature** [redacted]

If "no", state the purpose of research: ______________________________

____

5. Briefly state the Research Background:

The literature review demonstrates that research in science education indicates that technology- integrated learning can aid to address the challenges of learning and understanding difficult and abstract concepts (Johnson et al., 2016; Potgieter et al., 2005). Due to the rapid development of emerging technologies and pressures to teach remotely in recent years, the integration of Information and Communication Technology (ICT) has increasingly impacted the implementation of education curricula across the globe (Wang, 2021). Correspondingly, Vasudevaiah (2016) points out that teachers and learners have adapted many new skills connected with using ICT tools, including conducting experiments online and developing a deeper understanding of abstract concepts using virtual technology. Learners in the 21st century must be equipped with relevant skills that will enable them to thrive in competitive and technology inclined environment.

It has been observed that learners experience learning challenges on the topic of atoms, atomic structure and the periodic table as a result of relying on teachers to present and elaborate the abstract concepts without any assistance tools (Kumpha et al., 2014). However, with the integration of ICT into our teaching practices, pedagogy can shift from teacher-centred to learner-centred since learners can explore and engage in their learning process (Kapur, 2019). Therefore the overall purpose of the proposed study is to develop the learner knowledge and understanding of atomic theory using ICT simulations. Two kinds of chemistry simulations (ChemThink and PheT) will be used as tools in this study. The study aims to use the visualization of abstract and complex concepts associated with the atomic theory in developing the Junior Secondary Learners (JSL's) understanding of atomic theory and related concepts through the utilization of mentioned ICT simulations

6. What is the main research question(s)

1. What are the Junior Secondary Learners' prior understanding of atomic theory?
2. How can JSL's understanding of the atomic theory be developed through integrating ICT simulations?
3. What are the JSL's understandings of the atomic theory after the ICT-based intervention?

7. Methodology including sampling procedures and the people to be included in the sample:

The proposed study is conceptualized under the interpretivist paradigm. This research paradigm has the intention of understanding the world of human interaction and the social construction of knowledge (Cresswell & Cresswell, 2018). Hence the researcher aims to use a qualitative approach for data collection and analysis. A qualitative study is primarily based on non-numerical data collection such as interviews, observations, visual data analysis, etc. This research approach gives voice to the participants in the study. It permits the participants to share their experiences (Cohen & Marion, 1994).

A case study research design will be established to provide answers to the research questions of this study. In this context, the case study approach as a research design will be used to evaluate how the incorporation of simulations in pedagogy can assist to develop the Junior Secondary Learners (JSL) knowledge of atomic theory using the technological pedagogical content knowledge (TPACK) theoretical framework.

The action research method will be adopted for this study to plan, act, observe and reflect on the researched phenomenon. The first step of planning starts with a research question or an observation about a researched phenomenon. After identifying the problem area and narrowing it down, the developmental process continues as the action plan to investigate the problem (Cohen & Marion, 1994). This will involve gathering data and evidence to support the solution to the problem. Then lastly, there will be an opportunity to reflect on the effectiveness of the intervention to the problem. For example, administering post- tests to learners and conducting interviews after post-ICT-simulation-based lessons.

The research activities will be carried out in a school situated in a historically disadvantaged community and poor socio-economic background. Since this is a qualitative based study, the type of sampling that will be used is non-probability sampling. In this type of sampling, selecting participants will be subjective rather than random. The sample will consist of grade 10 Physical Science pupils.

8. What contribution will the proposed study make to the education, health, safety, and welfare of the learners and the education system as a whole?

This study aims to achieve the goal of South Africa's 2004 White Paper on e-Education which was to ensure that every learner in the country is ICT capable, and for teachers to use ICT to enhance teaching and learning. Also, the proposed study is in line with the goal of the National Integrated ICT Policy White Paper of 2016 which outlines the government's commitment to building a more inclusive society to eliminate poverty and reduce inequality in the country. Both these policies take a holistic view of the integration of ICT into the schooling system to provide equal opportunities for every South African citizen regardless of their socio-economic status.

KZN Department of Education Schools or Institutions from which sample will be drawn – If the list is long please attach it at the end of the form		
Esizibeni Comprehensive High School		

9. Research data collection instruments: *(Note: a list and only a brief description is required here - the actual instruments must be attached)***:**

Data collection instruments include:

- Pre/ post-tests
- Focused group interviews/ discussions.
- Classroom observations
- Audio/ Video recording

10. Procedure for obtaining the consent of participants and where appropriate parents or guardians:

To ensure that ethical standards are maintained, there are several ethical considerations for this particular research project in place, namely, acquiring ethical clearance from the university (UKZN), acquiring permission from the school principal, and calling a parents meeting to acquire consent from the parents of the learners who will be participating in the research, acquiring consent from participants and be open about voluntary participation

(see attached consent forms)

11. Procedure to maintain confidentiality (if applicable):

Permission letters to the parents of the learners who will be participating in the research, voluntary participation, and the right to withdraw from the project as well as protection of anonymity and confidentiality will be ensured by concealing the name of the school and using pseudonyms for participants.

12. Questions or issues with the potential to be intrusive, upsetting, or incriminating to participants

(If applicable):

Not applicable

13. Additional support available to participants in the event of disturbance resulting from intrusive questions or issues (if applicable):

Not applicable

14. Research Timelines :

STEPS	**DATES**
Submission of Proposal to Higher Degrees	November 2022
Data collection instruments	November 2022
Ethical Clearance Application	December 2022
Data collection	January 2023-April 2023
Transcription and Data analysis	May 2023- August 2023
Writing of Thesis	September 2023- April 2024
Submission for internal marking	April 2024
Writing corrections	May –June 2024
Submission of final Thesis	June 2024

15. Declaration

I hereby agree to comply with the relevant ethical conduct to ensure that participants' privacy and the confidentiality of records and other critical information.

I <u>Nobuhle Mvundla</u> declare that the above information is true and correct

[redacted] 09 November 2022

Signature of Applicant **Date**

16. Agreement to provide and to grant the KwaZulu Natal Department of Education the right to publish a summary of the report.

I/We agree to provide the KwaZulu Natal Department of Education with a copy of any report or dissertation written on the basis of information gained through the research activities described in this application.

I/We grant the KwaZulu Natal Department of Education the right to publish an edited summary of this report or dissertation using print or electronic media.

[redacted] ________________ _09 November 2022________

Signature of Applicant(s) **Date**

Return a completed form to:
Sibusiso Alwar
The Research Unit; Resource Planning; KwaZulu Natal Department of Education

Hand Delivered:
Office G25; 188 Pietermaritz Street; Pietermaritzburg; 3201
Or
Ordinary Mail
Private Bag X9137; Pietermaritzburg; 3200
Or
Email
[redacted]

Appendix K: Permission from Gatekeepers

Esizibeni Sivananda Vaswani Comprehensive High School

Telephone: 031 976 1021
fax: 031 976 8656/
[redacted]
E-mail: [redacted]l@gmail.com

PO Box 567
Amanzimtoti
4145

NPO/PBO Number 9633601175
Principal: M.S Gumbi

DO IT NOW

Developing Junior Secondary Learners' Understanding of the Atomic Theory Using ICT Simulations.

School Principal Consent Letter

This letter confirms that I give consent for you to use the school facilities and involve grade 10 Physical Sciences learners to participate in the research.

I have read and understand that:

- The role of the school is voluntary
- I may decide to withdraw the school's participation at any time without penalty
- Grade 10 Physical Science learners will be invited to participate and permission will be sought from their parents/guardians
- All information obtained will be treated in strictest confidence.
- The school name and learners' names will not be used and not be identifiable in any written reports about the study.
- Participants may withdraw from the study at any time without penalty.
- A report of the findings will be made available to the school.
- Further information on the project may be sought from Nobuhle Mvundla on 081 756 2604.

.[redacted].....
Principal

Signature ..[redacted]........

Date 25-01-2023

ESIZIBENI SIVANANDA
VASWANI COMPREHENSIVE
HIGH SCHOOL
2023 -01- 25
KZN DEPARTMENT OF EDUCATION
P.O. BOX 567, AMANZIMTOTI, 4125
TEL: 031 976 1021
PRINCIPAL SIGN:..............................

DECLARATION OF CONSENT

I ....Gumal M.S.. **(Full names of the school principal) hereby confirm that** I have been informed about the study titled **'Developing Junior Secondary Learners' Understanding of the Atomic Theory using ICT Simulations'. I understand the contents of this document and the nature of the research project, and I consent for the school and learners 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 recordings	✓	
Discussions	✓	

ESIZIBENI SIVANANDA VASWANI COMPREHENSIVE HIGH SCHOOL

2023 -01- 25

KZN DEPARTMENT OF EDUCATION
P.O. BOX 567, AMANZIMTOTI, 4125
TEL: 031 976 1021
PRINCIPAL SIGN:..............................

.....[redacted]...........

Signature of Principal

25.01.2023

Date

Appendix L: Participants consent form

INFORMED ASSENT/CONSENT: LEARNER PARTICIPATION

Title of Research: Developing Junior Secondary Learners' Understanding of the Atomic Theory Using ICT Simulations

My name is N. Mvundla. 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 **'Developing Junior Secondary Learners' Understanding of the Atomic Theory Using ICT Simulations'.** I would like to kindly request your participation in this research study.

It is important to note that, before agreeing to participate in this research study, you need to read the following explanation of the study. This statement describes the purpose, benefits, risks, discomforts, and precautions of the study. Your right to withdraw from this research project will be described and note that no guarantees or assurances can be made as to the results of the study. The following information will be explained to you again by the researcher in detail and in terms that are easier to understand.

Explanation of Procedures

This research will assist to develop a better understanding of atomic theory using ICT simulations, provided the socio-economic context of the school where modern technology is rarely integrated into pedagogy.

The research will consist of two phases. In the first phase validated pre-test will be used to gather information. Thereafter, lessons where ICT simulations are integrated will be conducted. You will then be invited to one-on-one interviews with the researcher and focused group discussions/interviews. Interviews will be recorded on a voice recorder.

Risks and Discomforts

No intentional risks or harm are anticipated as a result of your participation.

Benefits

This study will be beneficial by contributing to our knowledge of ICT integration in teaching and learning to assist with better understanding of the atomic theory.

Confidentiality

The information gathered during this research project will at all times remain confidential. Participants' and school's name will not be disclosed during the research or publication of the results. Information obtained via the research will be used for research purposes only. Feedback on the results of the study will be given to the principal of the participating school. The research results will be presented in the format of a thesis that will be submitted to the University of KwaZulu-Natal, Edgewood Campus, for examination.

Withdrawal without repercussions

Participation is voluntary and refusal to participate in this study will involve no penalty. Each participant is free to withdraw consent and discontinue participation at any given moment in time.

Costs or Payments

There will be no costs involved for taking part in this research study. No participant will receive any payment to participate in this research project.

Questions

Participants may contact Miss N Mvundla (211528133@stu.ukzn.ac.za) if they have any questions concerning this research study.

This study will be supervised by Dr Bongani Prince Ndlovu. He is located at the School of Education, College of Humanities, Edgewood Campus, and University of KwaZulu-Natal. Dr 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 +27312604557

Email: HSSREC@ukzn.ac.za

Agreement

This agreement states that you have read and received a copy of this informed consent. Your signature below indicates that you understand the parameters of your participation and agree to take part in this research study.

Signature of Participant (Learner) ____________________

Date ____________________

Participant's Name [redacted]

[redacted]

Date ____________________

ASSENT FORM (for learners)

Title of Research

Developing Junior Secondary Learners' Understanding of the Atomic Theory Using ICT Simulations

- ☐ I confirm that I have read and understand the information given in the Informed Consent for above mentioned study
- ☐ I have had the opportunity to consider the information, ask questions about it and have had them answered satisfactorily.
- ☐ I understand that my participation is voluntary and that I am free to withdraw at any time and without giving a reason,
- ☐ I understand that the data gathered from this study will be accessible to other professionals at the University of KwaZulu-Natal and that the results will be published.
- ☐ I agree to take part in this research project.

Signature of Participant (Learner) ____________________

Date ____________________

Participant's Name [redacted]

[redacted]

Date ____________________

DECLARATION OF CONSENT

I ………………………………………………………………………… (Full names of the participant) hereby confirm that I have been informed about the study titled 'Developing Junior Secondary Learners' Understanding of the Atomic Theory Using ICT 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 M: Reflective journal entry

Date. Page.

Date: 08/05/2023
Time: 10:30
Location: Grade 10 C
Topic: History and development of the atomic theory and its structure

Today was the first day of the second phase of the research plan. The first lesson was based on the history and development of the atom. I had challenges putting together the necessary equipment and tools for the lesson such as the overhead projector and the whiteboard. The lesson went well, the YouTube video I chose explained clearly the history of the atom. I believe the voice-annotated simulation was effective to meet the lesson objectives.

Date. Page.

Action Plan

- For the next lesson, I will try to collect materials in time
- I will allow learners to engage more with the technology
- I will ask the learners for feedback on the teaching and learning activities done.

Date. Page.

09/05/2023

Time: 9:40

Location: Grade 10 C

Topic : Rutherford's Experiment

Today was the second lesson of the ICT intervention. Reflection on the first lesson was successful and learners were aware of the different atomic theories. The focus on today's lesson was the Rutherford's experiment. A PhET simulation called the Rutherford scattering was used. At first I had struggled to demonstrate the simulation for learners to understand what had to be done but I was able to manouver it. This lesson took longer due to shortage of resources, learners who had their mobile phones were able

Date. Page.

to use them for simulations and others took turns with the P.C. It was an interesting lesson because learners become inquisitive and engaged compared to the first lesson. But learners could not clearly understand the intention and conclusions of the Rutherford's experiment.

Action plan

- For the second cycle, this lesson should be repeated
- I need to incoporate more activities to test knowledge on this simulation

Date. Page.

10/05/2023

Time: 14:30

Location: Grade 10 C

TOPIC: Structure of the atom and Sub-atomic particles

Today I had no period with grade 10 C on our day-to-day timetable so I had to make arrangements to meet them after school hours. The attendance was not good since some participants complained about transport arrangement. However the lesson went well. By now, the participants are familiar with the simulation

Date. Page.

using subatomic particles, neutrons, protons and electrons. This simulation had different learning goals such as identifying the element, determine the mass and charge and also generate an isotopic symbol and ion

Reflection

The collaborative strategy used in the lesson was successful, learners were more inquisitive.

What can be done better?

In the next lesson, learners need to [illegible]

Date. Page.

11/05/2023

Time : 09:40

Location : Grade 10C

Topic : Representation of the atom using notation

This lesson was a continuation of the previous lesson. Learners could represent the atom of the atom using the notation of the symbol, atomic number and atomic mass.

Reflection

The lesson was assessment based, learners were given more activities to work on the previous topic and current topic on the atomic structure and its representation.

Date. Page.

12/05/2023

Time : 10:00

Location : Grade 10C

Topic : Isotopes and atomic mass

This was the last lesson of the first cycle. From the observations learners were more active, constructing knowledge independently, they were able to relate the prior information to the current information and work collaboratively with other learners. The sims incorporated for this lesson is from PhET and called Isotopes and Atomic Mass. It was reinforced by ChemThink sims and YouTube animations.

Reflection

This was the most easily navigated lesson. For the second cycle, lesson 2 will be repeated.

Appendix N : Language certificate

Registered with the South African Translators' Institute (SATI)

Reference number 1000686

02 December 2023

Developing Junior Secondary Learners' Understanding of the Atomic Theory Using Information and Communications Technology Simulations

This confirms that I edited substantively the above document, including a Reference list. The document was returned to the author with various tracked changes to correct errors and clarify meaning. It was the author's responsibility to attend to these changes.

Yours faithfully

[redacted]

Dr. K. Zano

Ph.D. in English

[redacted]

Appendix O: Turnitin Report

MEd Thesis draft 2

ORIGINALITY REPORT

10%	10%	6%	0%
SIMILARITY INDEX	INTERNET SOURCES	PUBLICATIONS	STUDENT PAPERS

PRIMARY SOURCES

1	link.springer.com Internet Source	1 %
2	repository.nie.edu.sg Internet Source	1 %
3	www.mdpi.com Internet Source	1 %
4	aff.org.au Internet Source	1 %
5	hdl.handle.net Internet Source	1 %
6	www.elaw.org Internet Source	1 %
7	www.researchgate.net Internet Source	<1 %
8	wrap.warwick.ac.uk Internet Source	<1 %
9	Ilias Karasavvidis. "Activity Theory as a conceptual framework for understanding teacher approaches to Information and	<1 %