GRADE 10 LEARNERS' SCIENTIFIC REASONING SKILLS IN CHARACTERISING STATE OF MATTER USING PHYSICS EDUCATION TECHNOLOGY (PhET) AT SEOTLONG CIRCUIT, SEKHUKHUNE EAST DISTRICT IN LIMPOPO, SOUTH AFRICA

by

RADINGWANA TM

DISSERTATION

Submitted in fulfilment of the requirements for the degree of

MASTER OF EDUCATION

in

SCIENCE EDUCATION

in the

FACULTY OF HUMANITIES

(School of Education)

at the

UNIVERSITY OF LIMPOPO

Supervisor : Dr M Maumela

Co- supervisor 1 : Prof SK Singh

Co- supervisor 2 : Prof ZB Dhlamini

YEAR: 2024

DEDICATION

This work is dedicated to the Almighty God that I serve, who protected me by his grace throughout this journey. The dedication is also to my lovely parents, Radingwana Makgafetje William and Radingwana Diarona Blantina, and my three sisters and three brothers namely: Radingwana Julia, Radingwana Tebogo, Radingwana Mercy and Radingwana Jeffery, Radingwana Johannes and Radingwana Justice.

DECLARATION

I Radingwana Tshegofatso Mike, declare that the dissertation entitled "**GRADE 10 LEARNERS' SCIENTIFIC REASONING SKILLS IN CHARACTERISING STATE OF MATTER USING PHYSICS EDUCATION TECHNOLOGY (PhET) AT SEOTLONG CIRCUIT, SEKHUKHUNE DISTRICT IN LIMPOPO, SOUTH AFRICA"** submitted to the University of Limpopo is my own work and altogether the sources that I have utilised are acknowledged by means of a complete reference. Over more the dissertation has not been submitted in any institution.

26/08/2024

Mr Radingwana TM   Date

ACKNOWLEDGEMENT

I would like to thank the Almighty GOD for strengthening me, protecting and guiding me throughout the journey.

I would like to thank all Grade 10 learners who participated in this dissertation.

I would like to thank my supervisor Dr Maumela M for giving me support, helping and motivating me throughout the study. I want to take this opportunity to thank you for your guidance and support throughout my master's degree.

I would like to thank my Co- supervisor Dr Dhlamini ZB for helping me throughout the study. He motivated me all the time when things became tough. Your mentorship has been crucial to my development as a researcher and scholar. Your feedback helped me to refine my ideas and produce a piece of work that I am truly proud of. Your support has had a profound impact in my academic journey, and I am immensely grateful for your encouragement and dedication. I hope to continue making strides in my career and to make you proud of my achievements.

I would like to thank my Co-supervisor Prof SK Singh for trusting me and supporting me throughout the study. When I needed information related to the study, he was there for me. I want to take this opportunity to thank you for your guidance and support throughout my master's degree.

I would like to thank my family for always supporting me in this study.

I would like to thank Tebogo Antonia Ramafalo for giving me support and caring throughout the study.

I would like to thank my peer Reinhard Selowa for giving me academic motivation in this study.

I would like to thank my sister Moipone Kgasago for giving me academic motivation on how to obtain a master’s degree.

I would like to thank my friend Mr Moukangoe Kwena Nelson, for formatting the document after myself.

Last, Prof SJ Kubayi for your professional work done in editing this document.

ABSTRACT

In Grade 10, learners had difficulty in characterising the three states of matter, solid, liquid and gas. Subsequently, the change in states of matter is too abstract and the behaviour of the particles is microscopic in nature. Due to lack of relevant resources in the school where I am teaching in Sekhukhune East District, physics education technology (PhET) simulations were used to visualise the behaviour of the particles. This assisted learners to track the behaviour of the particles that was too impossible to see with the naked eye. The theory that guided this study was the scientific discovery as dual search (SDDS) which has three tenets: the search hypothesis, the search experiment and evaluating the evidence. The qualitative approach was employed under the auspices of the exploratory case study by Merriam. At the same time, Grade 10 learners (n=40) were purposively sampled. Three instruments were used to collect data such as documents, semi-structured interviews and observations. Furthermore, data were coded using axial coding to come up with a coding scheme. Inductive thematic analyses were employed and themes emerged. The results were evaluated using the literature and theoretical framework, and principal findings were generated as follows: learners were able to exhibit scientific reasoning skills by visualising the behaviour of the particles. Subsequently, through the use of PhET simulations, the behaviour of the particles that were unclear was now visualised by learners. On the one hand, it is now clear that learners exhibit, predict, analyse, interpret, evaluate and make informed inferences when learning states of matter using PhET simulations. On the other hand, they were unable to characterise the states of matter when confronted with the simultaneous use of prediction, analysis, interpretation, evaluation and making inferences. Based on the findings of the study, the following recommendations were made. First, it was suggested that the teaching and learning of states of matter should use PhET simulations to visualise microscopic properties of states of matter. Second, there should be learning intervention that will address the simultaneous achievement of scientific reasoning skills. Hence, future studies should focus on how learners can be capacitated with the necessary knowledge to exhibit scientific reasoning skills concurrently.

Key concepts: Scientific reasoning skills, PhET, change in states of matter, behaviour of the particles, arrangements of the particles, temperature, cooling curve, heating curve and SDDS.

Table of Contents

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1

ORIENTATION TO THE STUDY

1.1 Introduction

The main goal of this study was to explore scientific reasoning skills of state of matter using physics education technology (PhET). In this chapter, I present the background of the study followed by problem statement, the purpose of the study, research questions, research methodology, significance of the study and research setting.

1.2 Background and motivation

Firstly, the background of this study will explain three states of matter, solid, liquid and gas. The similarities and differences between the three states of matter will be addressed. Subsequently, characteristics of the three states of matter will be stated on subtopics such as particles, volume, temperature, size, pressure and density for each state. Secondly, the importance of states of matter in a real-life situation will be stressed. Thirdly, scientific reasoning skills will be explained in detail. Fourthly, scientific reasoning skills such as prediction, analysis, interpretation, evaluation and making inferences and benefits of developing scientific reasoning skills and other related skills will be explained in detail. Fifthly, PhET simulations, the importance e of PhET, how PhET has been used and why there is PhET simulation in the learning three states of matter will be discussed.

Sustainable development goals (SDG) are plan of action for people, planet and prosperity (Guang-Wen et al., 2023). The study is aligned with sustainable development goals of ensuring inclusive, equitable quality education and promote lifelong learning opportunities for all. First, inclusive is when all learners are included and participate in the learning process regardless of background and disability (Shutaleva et al., 2023). Second, equitable quality education is when learners are treated the same in the teaching and learning, in this study the school is using WIFI and the gadgets of the school to observe the behaviour of the particles (Sánchez-Santamaría et al., 2023). Subsequently, through the use of PhET simulations learners are able to receive equitable quality education. At the same, they are able to observe the change in states of matter through PhET simulation. Results in learners achieving the goals of ensure inclusive, equitable quality education and promote lifelong learning opportunities for all. To use PhET simulation in the learning, all learners are included in the learning process. Consequently, all learners were not allowed to buy data to access the PhET simulation. Additionally, the school is responsible to buy data to access the PhET simulation to include all learners in the learning and teaching process. PhET simulation help learners at Seotlong Circuit, Sekhukhune East District, in Limpopo South Africa to learn the change in states of matter easily. All in all, learners were achieving the sustainable development goals of ensure inclusive, equitable quality education and promote lifelong learning.

1.2.1 States of matter

Solid, liquid and gas in various agglomeration states differ from each other in terms of mechanical and other properties like the behaviour of the particles (Clerc et al., 2020). Different states of matter came into existence due to varied forces on particles. The various states of matter consist of particles that are microscopic, and therefore cannot be observed with the naked eye (Treaqust et al., 2010). However, the use of suitable microscopes can allow a much clearer observation of particles. At the same time, when the temperature is applied on the experiments related to solid, liquid and gas, there are transitions in state of matter. Therefore, the state of the particles depends on the temperature they are exposed to. For example, a solid-state particle can transit to liquid state at elevated temperature. Moreover, when the temperature keeps on increasing, the liquid state particles can further be converted into gaseous state (Cockrell et al., 2021). Additionally, liquids have a finite cohesion energy, and gas occupies all available volume, and occupies a finite volume within a container. This shows that when the temperature increases, there is a simultaneous increase in kinetic energy: the more kinetic energy, the more particles occupy large space (Trachenko et al., 2021). Kinetic energy posits the amount of work that accelerates particles from stationary positions to quantified velocities (Kalhor & Mehrparvar, 2020).

One of the most important prerequisites for a change of state of matter to occur is a change in the temperature of a substance (Zheng & Zhang, 2023). Apart from this, state of matter is a topic in chemistry whereby learners require in-depth knowledge of the particular nature of matter to understand the actual processes that take place at a sub-microscopic level (Mahanan et al., 2021). Additionally, Mahanan et al. (2021) indicated that the learning of states of matter can be meaningful if they are engaged in a STEM activity that allows them to relate the conceptual knowledge with real-life experiences. Learners have to understand the behaviour of particles in liquid states, as well as the motion, the size and dispersion of the particles in liquid. Consequently, solid states can be observed whether learners meet those expectations or not. Even so, to teach the state of matter, teachers use a mind map since the topic is too abstract to teach without performing experiments (Ganiev, 2021).

Solid

“Solid" can refer to a state of matter where particles are tightly packed together and maintain a fixed volume and shape (Weart, 2019). In this state, atoms or molecules are closely bonded and have little freedom of movement. Subsequently, solids generally have definite shapes and volumes, and resist changes in shape and volume when subjected to external forces (Schmidt et al., 2019). Examples of solids include ice, wood, metal, and rock. In the context of states of matter, "solid" refers to one of the three primary phases alongside liquid and gas. Solids have a definite shape and volume, meaning they maintain both the shape and volume of their container (Martin, 2019). The particles in a solid are closely packed together and have limited mobility, vibrating around fixed positions. This arrangement results in a rigid structure. Common examples of solids include ice, wood, metal and stone.

Liquid

A liquid is one of the three fundamental states of matter alongside solid and gas. Liquids have a definite volume but take the shape of their container (Wiltgen, 2022). In contrast with solids, the particles in a liquid are not arranged in a fixed pattern but are still close together and have more freedom of movement compared to solids (Weart, 2019). This allows liquids to flow and take the shape of their container. The particles in a liquid are in constant motion, but they are still attracted to each other, giving liquids their characteristic ability to maintain a surface tension (Cockrell et al., 2021). Examples of liquids include water, oil, milk and alcohol but differ with viscosity.

Gas

In the context of states of matter, "gas" refers to one of the three primary phases alongside solid and liquid (Cassidy et al., 2023). Consequently, gases have neither a definite shape nor a definite volume (Guo & Pfau, 2021). Instead, a gas expands to fill the entire volume of their container, taking on its shape. The particles in a gas are much more spaced out compared to those in solids or liquids, and they move freely in all directions (Michael et al., 2020). Furthermore, gases are highly compressible and can expand indefinitely when not confined. Examples of gases include oxygen, nitrogen, helium and carbon dioxide.

Significance of solid, liquid and gas in Physical Sciences

Solid, liquid and gas states of matter are fundamental concepts in physical sciences due to their distinct properties and behaviours (Proctor, 2020). Understanding these states is crucial for a variety of reasons:

Solids

Solids have a fixed shape and volume. Their molecules are closely packed in a regular pattern, giving them structural rigidity and resistance to deformation. This makes them crucial for studying materials science, crystallography and mechanics.

Liquids

Liquids have a fixed volume but no fixed shape, conforming to the shape of their container. Their molecules are close together but can move past one another, making them essential for studying fluid dynamics, hydrodynamics and various chemical reactions.

Gases

Gases have neither a fixed shape nor volume, expanding to fill their container. Their molecules are widely spaced and move freely, which is key for studying thermodynamics, aerodynamics and kinetic theory.

Phase Transitions

Understanding how matter transitions between solid, liquid and gas (e.g., melting, freezing, evaporation, condensation) is crucial for studying thermodynamics, heat transfer, and energy changes in physical and chemical processes.

Material Properties

Different states of matter exhibit unique physical properties. For example, density, viscosity and compressibility. These properties are essential for designing and utilising materials in engineering, manufacturing and technology development.

Behaviour of Matter

The behaviour of solids, liquids and gases under various conditions (e.g., temperature, pressure) is fundamental for understanding natural phenomena and processes in chemistry, physics and earth sciences. This includes weather patterns, geological formations, and the behaviour of different substances in different environments.

Applications in Technology and Industry

Many industrial processes rely on the manipulation of solids, liquids and gases. For instance, metallurgy involves solid-state reactions, petrochemical refining deals with liquid mixtures, and gas laws are crucial for the design of engines and refrigeration systems.

Biological Systems

Biological systems rely on the properties of all three states of matter. For example, the human body contains solid structures (bones), liquids (blood) and gases (oxygen and carbon dioxide), each playing a vital role in physiological processes.

Scientific Research

Research in physical sciences often involves studying the properties and interactions of matter in different states to develop new materials, understand natural phenomena and create innovative technologies.

In summary, the states of matter, solid, liquid and gas are fundamental to the physical sciences due to their distinct properties and the critical role they play in natural processes, technological applications and scientific research. Understanding these states and their transitions provides a foundation for exploring and manipulating the material world.

1.2.2 Scientific reasoning skills

Scientific reasoning skills involve analysing or problem solving, planning experiments, drawing conclusions, making inferences, generalising, evaluating and proving (Mariana et al., 2018). Learners need to develop the above-mentioned skills. Furthermore, a scientific reasoning skill is significant in research pertaining to science since it guarantees the efficient execution of experiments, testing of hypotheses, data analysis, and the derivation of conclusions (Zulkipli et al., 2020). Specifically, the study used a scientific inquiry to explore scientific reasoning skills in learning the behaviour of particles in state of matter. More, Kundariati and Rohman (2020) highlighted that the scientific approach requires coherence between observing skills, asking, gathering and analysing information, associating and making inferences. In this study, learners explored scientific reasoning skills such as observing, asking questions and making inferences on the behaviour of the particles in state of matter using PhET simulations. These skills are seen as significant with regard to scientific education as well as the framework of cognitive development (Nyberg et al., 2020). Scientific reasoning is a multifaceted concept that encompasses various elements like conducting experiments, analysing data, and comprehending the essence of science, and has been suggested as being a kind of problem-solving. In this way, it solved why the topic of state of matter is too abstract to teach and learn, specifically the behaviour particles of solid, liquid and gas (Khan & Krell, 2021).

Scientific reasoning may include thinking skills involved in research, experimentation, evaluation of evidence, inferences and discussions made for conceptual changes and academic understanding (Zimmerman, 2019). It is the application of scientific reasoning skills to support a specific finding in research (Zimmerman, 2019). If learners can harness scientific reasoning skills, they will be able to grasp the change in state of matter. Furthermore, learners are enabled for experimentation, verifying hypotheses and interpreting data (Zimmerman, 2007). At the same time, in their early grades, learners are required to make logical connections between experiments, data and hypotheses (Zhou, 2016). Therefore, scientific reasoning skills involve many aspects such as analysing problems, planning experimentations, conjecturing, generalising proofs and reaching conclusions (Mariana et al., 2018). The current study focused on a few scientific reasoning skills such as prediction, data interpretation, analysing, evaluating, making inferences and drawing conclusions.

> Scientific reasoning skills such as prediction, analysis, interpretation, evaluation and making inferences should be exhibited by learners

In this study, the focus is on prediction, analysis, interpretation, evaluation and making inferences as scientific reasoning skills, which includes thinking and reasoning skills involved in a scientific inquiry for knowledge development and revision, such as the ability to systematically explore a problem, formulate and test hypotheses, manipulate and isolate variables, and observe and evaluate consequences (Bao et al., 2022). Consequently, the evaluation of evidence as bearing on the tenability of a theory is another important process skill necessary for scientific investigation (Zimmerman, 2007). Additionally, scientific reasoning in this study refers to a rational thinking process based on prediction, analysis, interpretation, evaluation and making inferences, as aspects of reasoning competence (Yanto et al., 2019). Hence, learners need to execute scientific reasoning skills to be able to solve physical sciences assessments.

Importance of scientific reasoning skills in physical science

Critical Thinking

Prediction, analysis, interpretation, evaluation and making inferences help individuals evaluate information critically, question assumptions, and make informed decisions (Luo et al., 2020). More importantly, this is essential not only in scientific research but also in everyday problem-solving and decision-making.

Evidence-Based Understanding

Scientific reasoning skills emphasise the importance of evidence. It teaches individuals to rely on empirical data rather than anecdotal evidence or personal beliefs, leading to more accurate and reliable conclusions (Shah et al., 2017).

Problem-Solving Abilities

Developing scientific reasoning skills enhances one's ability to approach problems methodically (Rahman, 2019). This involves formulating hypotheses, designing experiments, analysing data and drawing conclusions. Learners can be able to solve any problem when applying scientific reasoning skills.

Adaptability

Science is constantly evolving. Individuals with strong scientific reasoning skills are better equipped to adapt to new information and technologies, stay current with advancements and integrate new knowledge effectively (Kalantzis & Cope, 2012).

Innovation and Creativity

Scientific reasoning skills foster creativity by encouraging exploration and experimentation (Higuera Martínez et al., 2021). This can lead to new discoveries, innovations and improvements in various fields from technology and medicine to environmental science and engineering.

Communication Skills

By developing scientific reasoning skills, learners should be able to develop communication skills. Good scientific reasoning includes the ability to communicate findings clearly and concisely. This is important for collaborating with others, educating the public, and influencing policy and decision-making (Kulgemeyer, 2018).

Informed Citizenship

In a world where science and technology play a significant role in societal issues, from climate change to healthcare, possessing scientific reasoning skills enables individuals to participate more fully in public discourse and make informed decisions about policies and practices (Grabe & Myrick, 2016).

Resilience Against Misinformation

With the prevalence of misinformation, especially on social media, scientific reasoning skills help individuals discern credible sources from unreliable ones, reducing the spread and impact of false information (Rodrigo & Arakpogun, 2024).

In summary, scientific reasoning skills are foundational for personal development, professional success, and active, informed participation in society. They equip individuals with the tools needed to navigate an increasingly complex and scientifically driven world.

1.2.3 Physics education technology in learning states of matter

Learners fail to connect the state of matter and its temperature with the main challenges associated with changing the state of matter. (Kampeza & Delserienys, 2020). Even if they are familiar with changes in state of matter, it is difficult for them to visualise the behaviour of the particles in those different states. Sanchez et al. (2019) highlighted that learners pose the inability to visualise the behaviour of particles in solid, liquid and gas when temperature is increased. This study uses physics education technology (PhET) to help learners to visualise the movement of particles when the state of matter is changing from one state to another. Globally, PhET simulations cannot be doubted in improving science learning (Banda & Nzabahimana, 2021). In the teaching and learning process, PhET increases student interest in the course and improves academic performance (Mrani, 2020). Additionally, PhET is affordable and user-friendly. By using PhET, learners were able to observe and visualise what happened in particles in terms of the behaviour in state of matter when it changes from solid, liquid or gas to another phase. Therefore, physics education technology will be used to attain scientific reasoning in state of matter in this study. Batuyong and Antonio (2018) found that learners perform significantly better in physics assessments when they complete the electromagnetism section in their PhET.

1.2.4 Development of scientific reasoning skills in learning states of matter using physics education technology

Learners find it difficult to grasp scientific reasoning skills and should construct the reasoning for themselves (Adey & Csapo, 2012). Morris et al. (2015) concurred with the study above that effective scientific reasoning requires both deductive and inductive skills. Both studies are similar because for learners to be able to reason inductively, they need to observe the movement of the particle. Moreover, individuals should understand how to assess what is currently known or believed, develop testable questions, test hypotheses, and draw appropriate conclusions by coordinating empirical evidence and theory. At the same time, they should be able to achieve these aspects by simulating the concept using PhET. Furthermore, lessons that promote scientific reasoning provide plenty of opportunities for social construction (Adey & Csapo, 2012). That is to say, learners are encouraged to talk meaningfully to one another, to propose ideas, to justify them and to challenge others in a reasonable manner. Harlen (2013) has shown that the adoption and use of inquiry-based science learning has the potential to inculcate scientific reasoning and thinking skills required in the 21st century.

Learners are unable to characterise the state of matter as consequence of the insufficient reasoning skill when analysing the three states of matter (Sebatana & Dudu, 2022). To repeat, learners lack a clear understanding of the behaviour of particles or substances during phase transition (Aboagye et al., 2019). Similarly, in both studies learners are unable to analyse the phase transition when the temperature changes

(Aboagye et al., 2019; Graham, 2019). Similarly, they find it difficult to make a transition between the three states of matter (Nyanhi et al., 2012). Their reasoning at particle level is always appropriate (Daridowitz & Chittleborarough, 2009). Both studies show that learners were unable to make informed inferences. Grade 10 Physical Science learners do not clearly understand the behaviour of particles (Gift & Ce, 2013). For example, "learners who got correct responses did not have correct justification, they relied mostly on guessing". This shows that for them to be able to have the correct justification, they need to observe the behaviour of the particle.

1.2.5 Learning scientific reasoning skills in state of matter

Learners need scientific reasoning skills to engage in the different activities during science concepts specifically in experiment topics (Bruckermann et al., 2023). Another study found that learners stated that they generally use reasoning skills in thinking about the solution to the problem (Özdeniz et al., 2023). Both studies reveal that learners need to harness scientific reasoning skills to be able to grasp particular concepts. Hence the two studies are similar to each other, but learners still do not grasp the change in states of matter because of the lack of scientific reasoning skills to solve science concepts. In contrast with both studies, learners learn scientific reasoning skills better when learning stereochemistry because they use multimedia to visualise concepts (Kusumaningdyah et al., 2023). Similarly, in this study, learners used PhET to visualise the change in state of matter to observe what is unseen using the naked eye. Therefore, they were able to conclude about the behaviour of particles in three states of matter through PhET. Contrary to this, another study showed that learners were able to work on the category of scientific reasoning well, especially in the correlational reasoning pattern using case base learning (Wati & Sunarti, 2020). This shows that they learn effectively if there are effective tools to deliver the concept state of matter. Hence, the case-based learning (CBL) was used to learn scientific reasoning skills to understand the sound of simple harmonic vibration. Similarly, learners visualised three states of matter using PhET simulation. In another study, learners stated that quiz-based interactive questions of measuring scientific reasoning skills were very interesting in learning impulse and momentum (Malik et al., 2021). Contrary to the study, their scientific reasoning skills improved using memorisation rather than discerning content through understanding to differentiate whether a substance is an acid or base (Zulkipli et al., 2020). Learners need to harness scientific reasoning skills in the visualisation of the concept.

Scientific reasoning refers to the rational thinking process based on analysis, evaluation and creation as aspects of reasoning competence (Yanto et al., 2019). The study applies three levels of inquiry, namely, structured, guided and open inquiry to enhance students' scientific reasoning competency levels to analyse, evaluate and create based on contextual issues. This study is supported by Arslan (2014), who argues that the three inquiry models have significant effects on increasing students' learning outcomes. According to Zubaidah et al. (2017), there are many obstacles that only use one level of inquiry in a particular topic without accommodating the level of learners' development. For learners to develop scientific reasoning skills, they need to observe what is being taught. Hence, scientific reasoning is often described as the collection of cognitive abilities engaged in higher-order thinking (Bhaw et al., 2023). The fact that learners were grappling to figure out the consistency of correct responses to the Lawson's classroom test of scientific reasoning (LCTSR) indicates students' reliance on intuitive reasoning instead of an explanatory scientific framework (Kriek et al., 2023). Both studies can show that scientific reasoning skills were very low when learners were learning science topics.

Scientific reasoning skills posit various attributes such as analysis of the problem, experimentation, conjecturing and proving generalisations (Mariana et al., 2018). These scientific reasoning skills are still low in the conservation of matter by learners (Yediarani et al., 2019). Contrary to percentages of the higher conservation of matter and volume, some learners have been able to use reasoning when it comes to field of shapes. In another study, findings pointed to majority of learners (61, 38%) with challenges in reasoning skills (Kanrzmozhi & Ganesan, 2017). Similarly, they are unable to provide scientific reasoning skills to understand fluid (Putri et al., 2020). This is a justification that the lack of reasoning skills can make the topic to be more abstract. A quasi-experiment study that used observations and essay tests found that scientific reasoning skills increase the ability by learners to analyse aspects in biology education (Yanto et al., 2019). These scientific reasoning skills are regarded significant for science learning as well as the setting of cognitive development (Nyberg et al., 2020). Furthermore, Kundariati and Rohman (2020) advised that the scientific approach entails striving for coherence in scientific reasoning skills.

1.2.6 Benefits of developing scientific reasoning skills in learning state of matter

Learning scientific reasoning skills using the traditional method of learning help learners to develop scientific reasoning skills (Abate et al., 2020). Correspondingly, studies have also revealed that lack of high-level reasoning is related to learners' positivist view which propagates objective reality (Niaz, 2017). Both studies emphasise that learning scientific reasoning skills in state of matter is not all about recalling and remembering what the teacher taught but is about constructing reasoning through visualisation. Indeed, science topics need to be demonstrated to improve learners' scientific reasoning skills (Hartmann et al., 2015). Similarly, in this study, PhET was used to demonstrate the behaviour of state of matter to improve scientific reasoning skills. Contrarily, problem-based learning (PBL) has been used to improve scientific reasoning skills (Wulandari & Shofiyah, 2018). In comparison, the learning of PBL focuses on the problems that make students to develop their own knowledge, and their inquiry and critical thinking skills (Saiful et al., 2020). Surprisingly, this problem-based learning was used to improve scientific reasoning skills, but it will be difficult to visualise the behaviour of the particles. The increased scientific reasoning may be due to the students who are accustomed to the discovery-based learning (Novia & Riandi, 2017). Scientific reasoning skills were developed in learners using a learning activity especially regarding issues of social science (Santika et al., 2018). Alternatively, learners need to visualise the behaviour of state of matter because the concept is microscopic in nature.

1.3 Research problem

During learning, the properties in state of matter, solid, liquid and gas should be recognised in terms of behaviour (Samarapungavan et al., 2023). At the same time, the behaviour of solid particles is very attracted to each other. Particles are attracted to each other in liquids, but not as strongly as in solids. Also, in gases, particles are slightly attracted to each other (Suman et al., 2019). In addition, the increase or decrease in temperature makes solid, liquid and gas to change from one state to another. Moreover, the particles will be gaining kinetic energy and move faster. Interestingly, learners should grasp the behaviour and properties (particles) of the three states of matter, especially cases of varied temperature. Furthermore, the behaviour of particles is too abstract to learn and because particles are macroscopic in nature, it becomes too impossible to visualise their behaviour in different states of matter. However, linking macroscopic observation of particles to behaviour is key in learning concepts of the state of matter (Olsen et al., 2020). On one note, to understand the behaviour and properties has been explained in terms of macroscopic conventions (Samarapungavan et al., 2023). On another note, learners generally experience difficulty in conceptualising physical changes from solid to liquid and gas. Nevertheless, these changes of state are premised on the microscopic character of the properties (Harrison, 2022). Since the state of matter is too abstract to learn, learners should use scientific reasoning skills such as hypothesis, analysis deduction and drawing inferences to grasp the concept clearly (Meyer et al., 2014).

In most classrooms, kinetic energy of the particles in state of matter is misguided by the learners' failure to define solid, liquid and gas (Massalha, 2015). In the same way, it is impossible for learners to visualise the behaviour of particles which lead to the failure to grasp the kinetic molecular theory, which explains the properties in solid, liquid and gas (Mullis et al., 2016). Similarly, learners grapple to characterise the dynamic properties of particles in state of matter (Banawi et al., 2019). In fact, it becomes difficult for them to characterise the behaviour in states of matter when temperature is applied (Baydere, 2021). The difficulty is posed by lack of visualisation of the microscopic nature of the physical changes (Zhan et al., 2019). In a similar manner, it was impossible for my Grade 10 learners in a school in Seotlong circuit, under Sekhukhune East District to visualise the behaviour of the particles in three different states of matter. Due to lack of relevant resources in my school laboratories, PhET was used to clearly display the behaviour of the particles when temperature is applied. In a similar manner, learners experience challenges of figuring out the behaviour of the three states (Budimaier & Hoff, 2022). On one hand, they lack scientific reasoning skills which are essential for the learning state of matter (Kambeyo & Csapo, 2018). On the other hand, they see it as a major obstacle to visualise the behaviour of particles due to the lack of science laboratories and gadgets to perform experiments practically and virtually (Huang et al., 2019; Zhang et al., 2020). However, when PhET is used for learning, learners develop thinking skills, conceptual analysis, creativity and innovation skills (Banda & Nzabahimana, 2021). Thus, they need to harness their scientific reasoning skills when learning towards the state of matter. In addition, the use of PhET encourages learners to think scientifically and to have conceptual understanding (Najib et al., 2022). Yet with the literature review that I conducted, there is a dearth of literature on the use of PhET in this discourse (Batuyong & Antonio, 2018). Hence, this study intends to explore learners' scientific reasoning skills in characterising the state of matter using PhET. The study focuses more on adding knowledge in the utilisation of PhET simulations contribution to harness scientific reasoning skills of the state of matter.

1.4 Purpose of the study

The purpose of the study was to explore scientific reasoning skills of state of matter using physics education technology (PhET).

1.5 Research Questions

Main research question

1.5.1 How does the use of PhET enable Grade 10 learners' scientific reasoning skills to characterise the state of matter?

Sub research questions

1.5.2 What are the learners' scientific reasoning skills of state of matter when using PhET?

1.5.3 Why do learners exhibit these particular scientific reasoning skills?

1.6 Research methodology

I adopted the qualitative approach in this investigation. Through the study of specific people or locations, qualitative research is a subset of social science research that gathers and analyses non-numerical data with the goal of interpreting meaning to better understand social life (Ashley et al., 2021). In this study, learners explored scientific reasoning skills to characterise states of matter using PhET simulations. Merriam's (1998) case study was employed in this study. This is an exploratory single case. The case study was used to develop an initial understanding or phenomenon of interest characterising state of matter (Ponelis, 2015). The case study enabled the collection of data using observation, documents and interviews (Yazan, 2015). Purposive sampling enabled me to judge the selection of units of study (participants) and data to be studied (Rai & Tshapa, 2015). Hence, 40 learners from Grade 10 registered for Physical Science participated in the study. The study used thematic analysis to analyse qualitative data in a deductive way. Additionally, Scientific Discovery Dual Search was used as a frame to analyse data collected from written activities and interviews and through observation. I ensured rigour in the analysis by attending to confirmability, dependability, credibility, authenticity and transferability as recommended (Treharne & Riggs, 2015).

1.8 Data collection

The study used three data collection methods namely: document analysis, classroom observation and semi-structured interviews as recommended in case studies.

1.8.1 Documents

Participants of the study worked on tasks on the state of matter. I prepared the tasks and measured learners' scientific reasoning skills in state of matter. The learners' written responses to these tasks served as data from documents that were analysed. All learners in Grade 10 took the task. While learners were busy writing the tasks, the teacher monitored the learning progress. The questions were designed in such a way that I could see the scientific reasoning skills of state of matter. Closed-end questions were used.

1.8.2 Observations

During class time, learners performed experiments related to state of matter using PhET. I was a participant observer, viewing learners as they work on related activities (Fry et al., 2017). An observation schedule as a systematic approach to the collection of data will be used during class time (Vermeirsch et al., 2021). I designed the observation schedule focusing on learners' scientific reasoning skills on the concept of state of matter.

1.8.3 Semi-structured interviews

Semi-structured interviews, according to Mahat-Shamir et al. (2021), are the best data collection instruments if you do not have multiple interview opportunities. Open-ended questions with prompts in state of matter that need to be covered will be generated. The data was collected in five (5) days, and interviews were taking place face to face. A voice recording was used to capture the responses from the learners. The recording was done in English.

1.9 Significance of the study

From the literature, no one used PhET simulation to describe a solid, liquid or gas according to the kinetic molecular theory. Thus, PhET was used in electromagnetism to improve the academic performance of students (Batuyong & Antonio, 2018). My contribution to the existing literature is to use PhET simulation to improve scientific reasoning skills in state of matter. The importance of this study is to encourage learners and teachers to use PhET in learning since the world is changing (fourth industrial revolution). The use of PhET simulation helped learners to visualise the behaviour of particles in change of state of matter. At the same time, the PhET helped schools that do not have physical laboratories to demonstrate experiments such as change in state of matter. Furthermore, learners harnessed scientific reasoning skills since they were able to observe the behaviour of particles using PhET simulation. In the same way, PhET supported physical science teachers to demonstrate concepts to harness the learning objectives. Indeed, PhET simulation is the easiest and most effective way of empowering the scientific reasoning skills of learners (Ruwiyah et al., 2021). Additionally, the advantage of PhET simulation can be an approach of learning which requires engagement and interaction with learners, and which educates learners so that they have a constructivism paradigm (Gani et al., 2020). The PhET simulation helped learners' visual representations of physics concepts that cannot be directly observed (Eveline et al., 2019). Learners of this study were able to visualise the change in state of matter by using PhET simulation. In fact, the use of PhET simulation helped them to develop scientific reasoning skills to understand the state of matter better.

Apparently, this PhET helped teachers to teach learners to learn the change in state of matter without challenges. Additionally, PhET simulations are not only educational but also engaging, making the learning process more interactive and stimulating for students (Olugbade et al., 2024). Interestingly, learners who were involved in learning using PhET experienced a higher increase in understanding compared to students who did not use this simulation (Gunawan et al., 2023). Therefore, the integration of simulation technology such as PhET can be an invaluable tool in improving the quality of learning chemistry in the classroom.

1.10 Research setting

The participants were Grade 10 learners at a school under Seotlong circuit in Sekhukhune east District, Limpopo Province, South Africa. The school has Sepedi-speaking learners from nearby and around the school location, and offers science and general subjects. It has one class offering Physical Science because many learners are doing Geography.

1.11 Structure of the study

This dissertation is structured in this way: background and motivation, literature review, methodology, analysis and interpretation, conclusion and recommendation.

1.11.1 Chapter 1

The study begins with an overview and historical context of the research. At the same time, what learners can or cannot do was clearly outlined. Problem statement**:** learners were unable to adopt scientific reasoning skills due to lack of observation of particles in state of matter. Due to lack of visualisation of the abstraction of the topic, learners ended up failing to make inferences, analyse, make judgement and draw conclusions on the change in state of matter. PhET simulation was used to display the movement of the particles and kinetic molecular energy. Furthermore, the purpose of the study, research questions and significance of the study were discussed.

1.11.2 Chapter 2

Chapter 2 focused on the literature review relevant to the study, and was divided into subtopics. The focus was on what learners can or cannot do related to the change in states of matter. There was a dearth of literature on how learners' reason on the change in states of matter.

1.11.3 Chapter 3

Chapter 3 outlined the research methodology. This includes the research approach used in the study, research design, sampling, methods of collecting data and data analysis. The issues of credibility, dependability and transferability as quality criteria as well as ethical considerations are also discussed in this chapter.

1.11.4 Chapter 4

In Chapter 4, the data is presented, analysed and interpreted. The chapter also discusses the results, as well as the findings of the study.

1.11.5 Chapter 5

This chapter reflects on the research questions raised in chapter one of the study. I present the conclusions of this dissertation by responding to the research questions. Then I outline the limitations of the study, and make recommendations.

1.12 Summary of the chapter

This chapter gives us the background to the study. This is followed by the problem statement, purpose of the study, research questions, research methodology, the significance of the study and research settings. A precise summation of the chapters of the study is also given. Lastly, the chapter presents a summary of the study. The next chapter presents the literature review and theoretical framework of the study.

CHAPTER 2

LITERATURE REVIEW

2.1 Learning state of matter

The change in state of matter should be taught using PhET simulation because it contains abstract ideas which are difficult to grasp by learners (Ozmen & Alipasa, 2003), who found it difficult to learn the particles model to explain the change in state of matter (Merritt et al., 2008). Consequently, state of matter becomes difficult to learn without helping them to develop the ideas using PhET simulation. Similarly, Krajcik et al. (2006) found that learners had difficulty in explaining macroscopic phenomena of state of matter because of learning without a tool to visualise the concept. This implies that, some science concepts are mind on and hands on, learners need to observe what they are doing and draw conclusion. Consequently, the behaviour of the particles is too abstract to observe with the naked eye, however PhET can visualise the behaviour of the particles in 3-dimension. Furthermore, learners find it difficult to learn the change in state of matter since the concepts are microscopic in nature. For example, when the states of matter change from solid to liquid the particles are loosely packed and in gas the particles are far away to each other (Cole et al., 2022). In fact, learners should observe the change in states of matter from solid to liquid and liquid to gas to be able to understand the topic better. To observe the behaviour of particles in state of matter helps them to make inferences. For example, my Grade 10 learners are given the following multiple-choice questions to write from physical sciences Grade 10 Siyavula textbook (Adams et al., 2011). First, 1) Pick the appropriate response: during a substance transition from solid to liquid. Its particles travel in the following directions:

A) Closer together

B) With less kinetic energy

C) With weaker interparticle interact

D) With less movement

2) Choose the right response to the following statement: When a substance changes states.

A) The material doesn’t change

B) Its chemical makeup shifts

C) It transforms into a different material

D) The intensity of the interparticle interactions remains constant

The multiple-choice questions above can be difficult to answer if learners do not observe the movement of the particles. For Learners to understand these questions, they should be able to utilise the tenets of the theoretical framework (SDDS), which is searching hypothesis space. They should come up with the hypothesis related to change in state of matter. The hypothesis should be addressed in this way: when the increase in the temperature is applied, the particles in a solid-state change to liquid and liquid to a gas state. Due to the stated the hypothesis, data can be collected during an experiment related to the change in state of matter. After the collection of data, learners should be able to analyse and interpret the data, infer and draw conclusions. As a result of these processes, learners find the multiple-choice questions simple and easy to answer as the state of matter is too abstract in nature.

Learners find it difficult to apply scientific reasoning skills in characterising the change in state of matter (Alamina & Etokeren, 2018). More importantly, failing to characterise was attributed to inability to make inferences from observations. Furthermore, they should observe the change in state of matter on the kinetic energy and movement of the particles in each phase. For example, in my physical sciences class, learners were given the following class activity, “summarises the characteristics of the particles that are in each phase of matter in terms of the properties of the energy and movement of particles” (Adams et al., 2011). Most of them were not able to characterise the energy and movement of the particles in each phase. When assessing their responses, I found that they were guessing those transitions, solid to liquid and liquid to gas in state of matter due to unable to observe the movement of particles in each state. Similarly, Chophel (2022) found that the lack of inferences leads learners to experience difficulties in these concepts, matter structure, properties, matter phases and phase changes. Surprisingly, in Chophel (2022) no differences were found. The difficulty can be attributed to the lack of understanding of concepts in a macroscopic atom. Even if the PhET can be used some of the learners can play with the features of the PhET simulation without focusing on the change in states of matter. In summary, learning without visualising the change in state of matter coerces the concept to be abstract, thus difficult to learn.

Learners are unable to characterise the state of matter because of their inability to reason scientifically (Jenkins & Howard, 2019). Subsequently, they should develop scientific reasoning skills of prediction, analyses, prediction, evaluating the evidence and making informed inferences for them to characterise the three states of matter. To substantiate the idea, the scientific reasoning skills requires observation of the movement of the particles in the different change of states of matter. This results in them failing to conclude when state changes from one form to another (solid to liquid). In a similar manner, learners started to confuse the change in states of matter solid to liquid and liquid to gas (Benli Ozdemir, 2021). In a study conducted by Benli Ozdemir, results show that it is not easy to make judgement on the change in state of matter because the topic is too abstract to learn without the use of science, technology, engineering and mathematics (STEM). From the same source, the following question was posed to the learners (Benli Ozdemir, 2021), “suppose the temperature is applied on this solid state, what are the behaviour of the particles?” One of the learners responded in this way, “the behaviour of the particles remains the same in a solid state”. To substantiate the incorrect answer, learners are unable to visualise the behaviour (movement) of particles when temperature is applied. This results in them struggling to get the correct answer when they learn without visualising the behaviour of particles. The correct answer is supposed to be: the behaviour of particles starts to increase when the temperature is applied. Similarly, another study by Borghini et al. (2022) found that learners are unable to make connections between the kinetic energy of the particles and the temperature applied on the different state of matter. Hence, the kinetic energy of the particles and the temperature applied are the core concepts in learning states of matter. Finally, learners are unable to characterise the state of matter because of their inability to connect concepts such as kinetic energy of the particles and the temperature applied.

The inability to make connections between kinetic energy and temperature applied in learning states of matter results in learners making incorrect judgements of solid to liquid and liquid to gas (Kotur, 2023). A study by Kotur shows that the incorrect judgements committed by learners related to confusing “solid state as liquid state also liquid as gas”. The confusion is due to the lack of visualisation. In many cases, learners just imagine the arrangements of three states of matter solid, liquid and gas due to sophisticated laboratories. Hence, it justifies that learners might lack scientific reasoning skills such as prediction, analyses, interpretation, evaluation and making informed inference in learning state of matter. Similarly, a study by Guiselin et al. (2022) shows that learners found it difficult to characterise the three states of matter due to their inability to connect concepts such as kinetic energy and temperature applied. For example, from the same study, Guiselin et al. (2022) asked learners this question: “suppose the temperature is applied on solid states, what is the behaviour of the particles”? The question showed that the connection between temperature and kinetic energy of the particles were lacking. In addition, learners fail to characterise three states of matter. No differences were found and learners still experience difficulties to make inferences on states of matter using the kinetic energy of the particles (Zakharov & Zubkov, 2022), which helps them to characterise states of matter as solid, liquid and gas. In fact, the topic ‘states of matter’ is microscopic in nature because it is too difficult to see the particles with your naked eye. Over more, it was complex for learners to tell when the particles were packed closely together or widely separated (Archibong-Eso, 2020). Similarly, learners found it challenging to make inferences on the change of states when the temperature is applied (Baydere, 2021). Additionally, when the temperature is applied, the states of matter can change from one phase to another phase. In both studies, it was difficult to tell if the state of matter changes from solid to liquid and gas. The reason was that they were unable to visualise the concept. Surprisingly, if learners are unable to visualise, it can lead them not to possess scientific reasoning skills to learn the change in states of matter. For example, I visited (class visit) my friend's class in Grade 10 at a particular school in Sekhukhune east district. The question was posed to the learners: "how do particles move in the solid state". The question was difficult to answer when they do not visualise the movement of the particles. All in all, the state of matter is too abstract to teach without an effective tool.

2.2 Introduction of scientific reasoning skills of state of matter

It is important to apply scientific reasoning skills in the learning process to equip learners with critical thinking and decision-making skills (Yanto et al., 2019). Meanwhile, Shaw (2010) defined the process of scientific reasoning as the linking of evidence and facts to come with the final conclusions. Also, scientific reasoning skills helps learners to understand the state of matter in depth and promote learners' critical thinking in solving real-life problems (Han, 2013). Scientific reasoning skills are the mental strategy, plan or rule used to process information and to derive conclusions that go beyond direct experiences (Tajudin, 2015). Similarly, in this study, skills such as prediction, analysis, data interpretation, inferences and evaluation are outlined clearly in the following sub-headings.

2.2.1 Prediction of hypothesis when states change from liquid to gas

Learners often have difficulty in understanding interactions between particles and structure-property relationship in boiling and melting points (Karakoyun & Asiltürk, 2022). Furthermore, they could not make accurate predictions when states change from one form to another in a melting and boiling process. To substantiate an inaccurate prediction, learners do not perform experiments with the hypothesis formulated (Löffelsender et al., 2021). The hypothesis was formulated by learners from a study by Löffelsender et al. as follows, "when the water is boiled the states of matter will change from liquid to gas". After the hypothesis, learners made an incorrect prediction of the behaviour of particles when liquid changes to gas. Consequently, they were unable to understand the behaviour of the particles during the states of change. Over more, all questions related to the behaviour of particles were not answered correctly. For example, from a study by Löffelsender et al. the question was as follows, "How does the temperature affect the particle behaviour?" Out of 40 learners, only 5 learners got the question correct while 30 did not even attempt to answer the question. Instead of talking about the particles and temperature, the remaining 5 learners were interested in the steam of water. This shows that they were unable to predict when the states of matter change from liquid to gas. It strikes me that they did not see the kinetic energy of the particles when the temperature was applied on the water. They only see the steam going up without visualising the movement of the particles. This results in an inaccurate prediction. Similarly, to both studies, Jasien (2018) provided an example as follows in Figure 2.1 “temperature vs kinetic energy graph.”

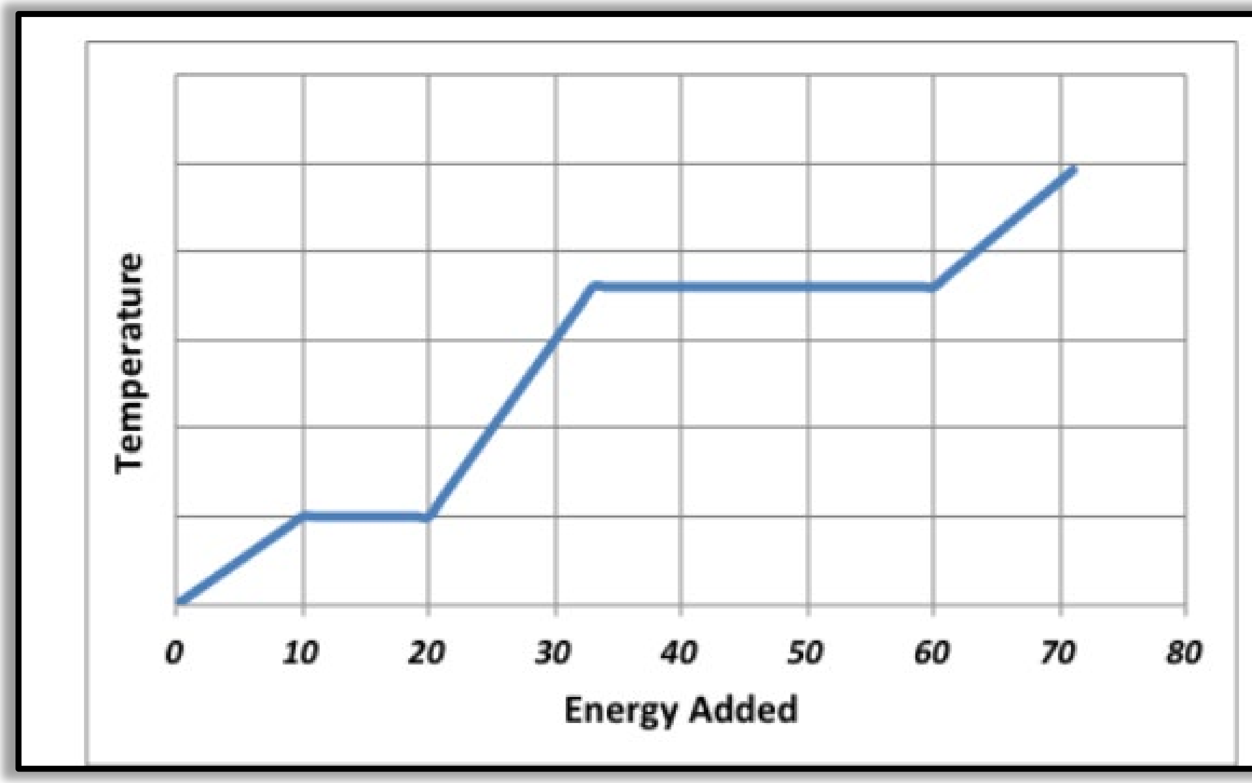


Figure 2.1: The relationship between temperature and kinetic energy of the particles (Jasien, 2018, p. 3)

“The phases of the substance most likely to exist in the region between 20 and 33 units of energy being added is/are”. Afterwards, Jasien (2018) indicated that kinetic energy depends on temperature. More importantly, learners to develop scientific reasoning skill of prediction need to visualise the relationship between kinetic energy and temperature applied for them to make informed inference of the change in state of matter. Subsequently, learners were unable to find the relationship between kinetic energy and temperature when answering the questions related to "Temperature vs Energy Added". Jasien (2018) found that learners were unable to infer from the behaviour of the particles when the temperature keeps increasing. From studies by Jasien (2018) and Löffelsender et al. (2021), they failed to analyse the graph in this way, and when the temperature increases, kinetic energy of the particles also increases. Briefly, the difficulty of interactions between particles and temperature results in learners’ failure to predict the change in state of matter.

2.2.2 Analysing of graphs in processes of states of matter

Learners need to improve scientific reasoning skills in learning states of matter in Grade 10 science classrooms (Kocagül & Çoban, 2022). Meanwhile, Abate et al. (2020), indicated that children face difficulty in generating evidence and drawing conclusions with the lack of scientific reasoning skills. Surprisingly, the review indicated challenges experienced by learners in utilising scientific reasoning skills to characterise the three states of matter by observing the behaviour of particles (Vieira & Morais, 2021). Firstly, to show that learners experience challenges in characterising three states of matter from Vieira and Morais (2021), they were given three boxes with different dots inside to represent the behaviour of the particles when temperature is applied. It was difficult for 12 out of 40 learners to characterise the three states of matter as solid, liquid and gas. Subsequently, they only observe the particles in each state of matter not in 3-D dimensions and without the movement of the particles. This results in their inability to analyse since they did not visualise the movement of the particles. Similarly, in another study, learners were confused when states of matter change from solid to liquid and from liquid to gas (Benli Ozdemir, 2021). This confusion is caused by lack of visualising the movement of the particles in three states of matter. Secondly, they found it difficult to analyse when the particles were not moving. They only visualise the drawn dots inside the box on the chalkboard when states change from one state to another (Borghini et al., 2022). In this way, learners were not able to use scientific reasoning skills such as analysis. Ultimately, the inability to characterise the state of matter is due to insufficient visualisation of the movement of the particles of three different states of matter (Jenkins & Howard, 2019). Subsequently, the inability to analyse results in learners' inability to come up with the final conclusion on the change of state of matter.

Analysis is a skill that learners should have when learning the change in states of matter. To analyse the topic of states of matter is to chunk the information in this way; first when a graph is given, learners should analyse if it is a cooling curve or a heating curve; like the one below, which is a heating curve (Tangerine Education, 2017).

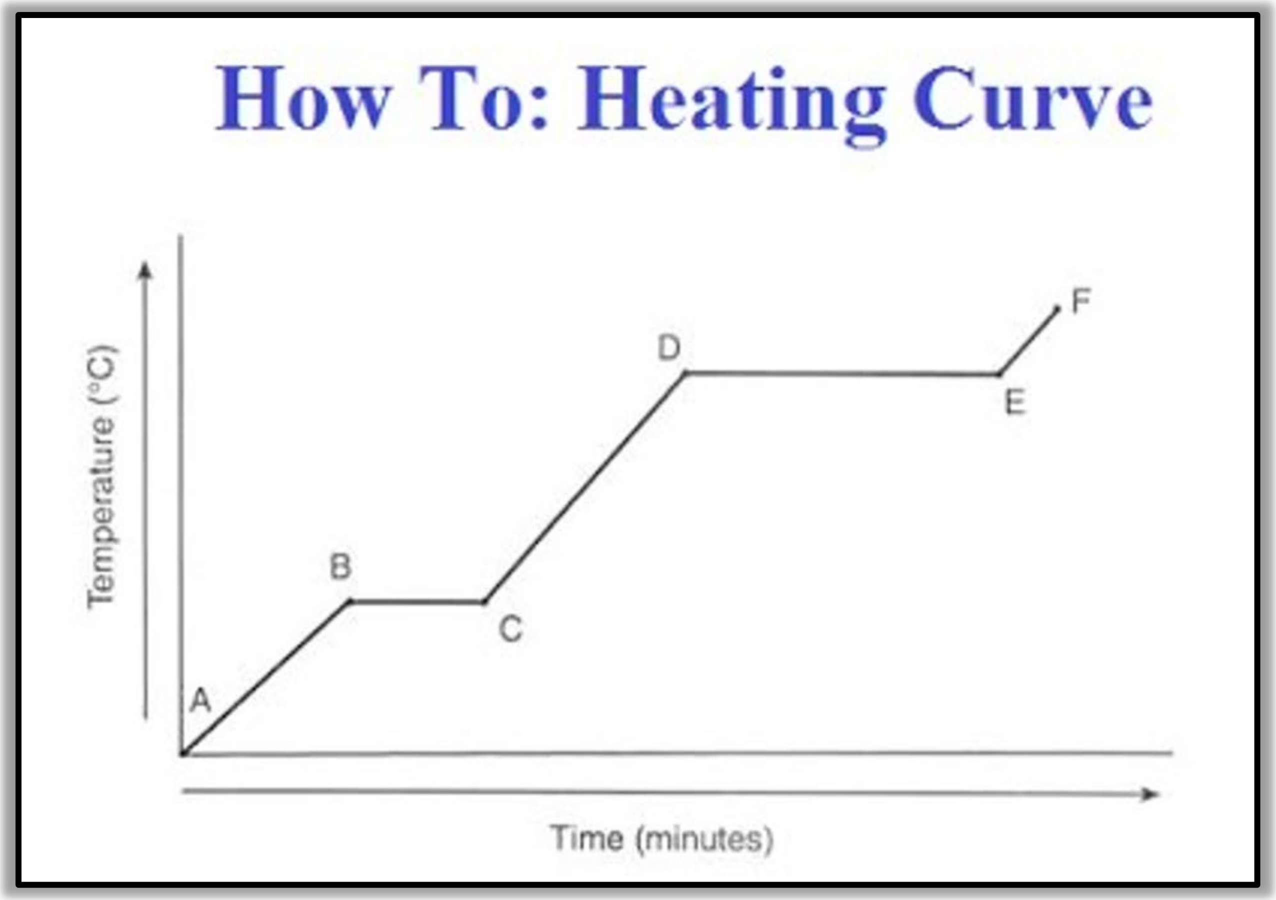
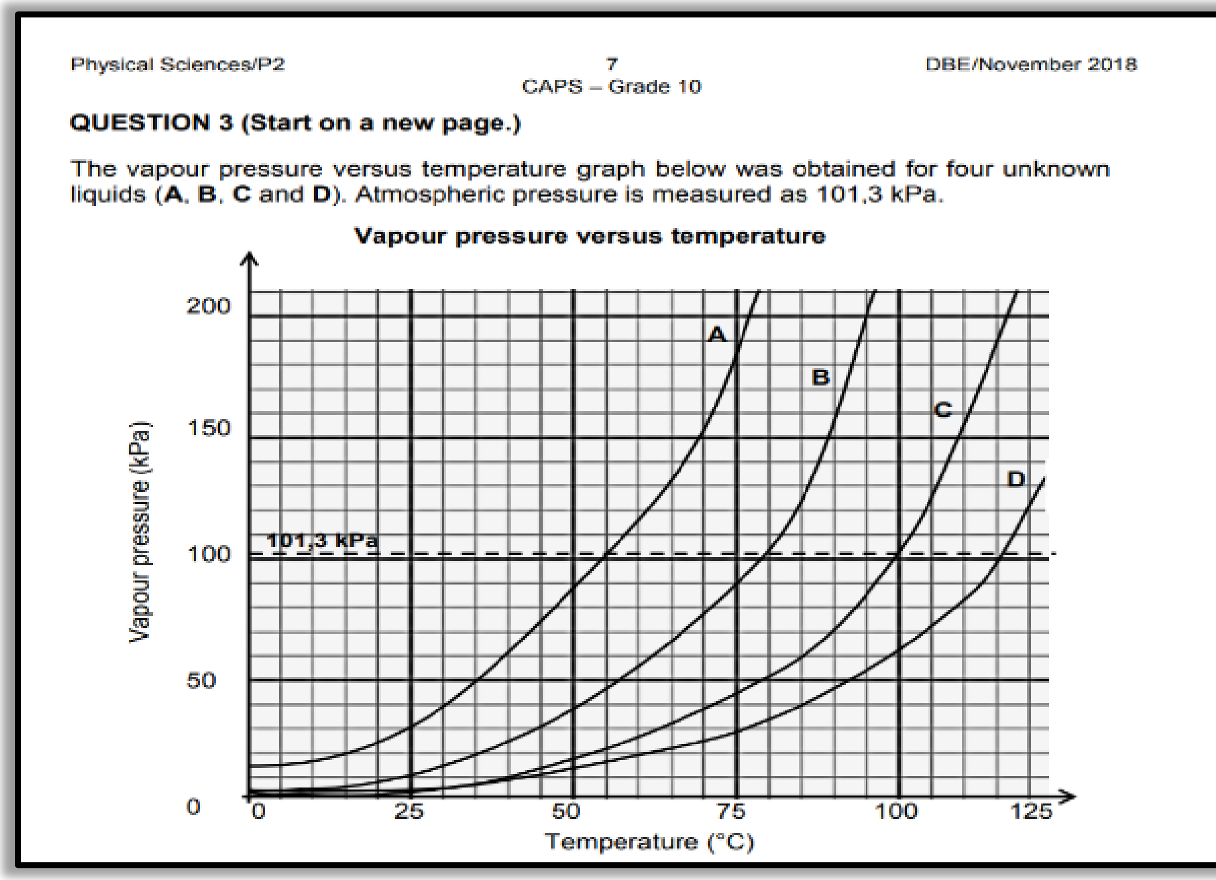


Figure 2.2: Heating Curve, relationship between temperature and time (Borghini et al., 2022, p. 8)

A study by Borghini et al. (2022) shows that learners did not harness analyses as scientific reasoning skills when learning states of matter. The results from Borghini et al. show that they also find it difficult to use a graph to answer questions such as the relation between vapour pressure and the temperature in state of matter. The difficulty emanated from when their inability to make connections (directly proportional) of these concepts' kinetic energy of the particles and the temperature applied on different states of matter. These concepts, kinetic energy and temperature help learners to characterise states of matter as solid, liquid and gas during analysis. In fact, the topic 'states of matter' is microscopic in nature. Over more, it was too complex for learners to tell when the particles were packed closely together or widely separated (Archibong-Eso, 2020). All in all, after analysing the behaviour in three states of matter, learners need to interpret and come up with conclusions on the change in states of matter.

2.2.3 Data interpretation from analyses of graphs in processes of states of matter

Learners are supposed to interpret this graph from the physical science/P2 November 2018 at a particular school. It seems that learners are unable to analyse and interpret the given graph in Figure 2.3.


Physical Sciences/P2 7 DBE/November 2018
CAPS – Grade 10

QUESTION 3 (Start on a new page.)

The vapour pressure versus temperature graph below was obtained for four unknown liquids (**A**, **B**, **C** and **D**). Atmospheric pressure is measured as 101,3 kPa.

Figure 2.3: Vapour pressure versus temperature from Grade 10 Physical Sciences paper 2 November, 2018 (DBE, 2018)

Learners found it challenging to interpret a graph given on the change of states when the temperature is applied (Baydere, 2021). To substantiate challenges, learners did not visualise the vapour pressure verses the temperature graph through experimentation. Subsequently, they interpreted (analyses of the question and graph, chunk the questions into variables) the graph without analysing the properties of unknown liquids by checking the trends of the liquid's behaviour. Graphs need to be interpreted by learners before answering the question that followed (Inaltekin & Akcay, 2021). Additionally, when the temperature is applied, the states of matter can change from one phase to another (Wazzan & Ahmed, 2024). In both studies, it was difficult to tell if the state of matter changes from solid to liquid and liquid to gas. In this way, interpretation as a skill played a vital role in learning the state of matter. It showed that learners did not grasp scientific reasoning skills such as data interpretation on change of states of matter. The reason for the difficulty is the inability to analyse the relationship between temperature and vapour pressure. Surprisingly, if learners are unable to analyse the relationship between two variables in Figure 2.2, it can make them unable to interpret data. For example, from the question paper above in November 2018, the following question was posed to the learners, "what is the relationship between vapour pressure and temperature." No learner got the question correct. Most of them did not even attempt to answer it. This shows that the question is complex to answer because they were required to interpret the relationship between vapour pressure and temperature of unknown liquids to get the correct change in state of matter when the temperature is applied. It strikes me that for learners to understand the topic of states of matter, they need to interpret the data and analyse the change in state of matter. Learners to develop scientific reasoning skills of interpretation and analyses need to be engaged in performing the experiments in science education (Koyunlu Ünlü et al., 2024). Indeed, through the usage of PhET learners develop how to interpret and analyse the behaviour of the particles in three states of matter.

2.2.4 Evaluating and making inferences of the change in state of matter

Learners struggle in learning state of matter because they do not have good resources to demonstrate the behaviour of the particles (Healy et al., 2021). From the same study by Healy et al. (2021), the difficulty emanated from the methods used to deliver the topic in Grade 10, such as diagrams in the textbook to show the difference in states of matter. Also, it was very difficult to learn three states of matter without visualising the behaviour of the particles (Lopez & Pinto, 2017). Contrarily to both studies, learners need to observe that the kinetic energy of the particles changes to be able to grasp the change in states of matter (Sun, 2023). For example, in a study by Sun, they were given "diagrams with particles for visualisation".

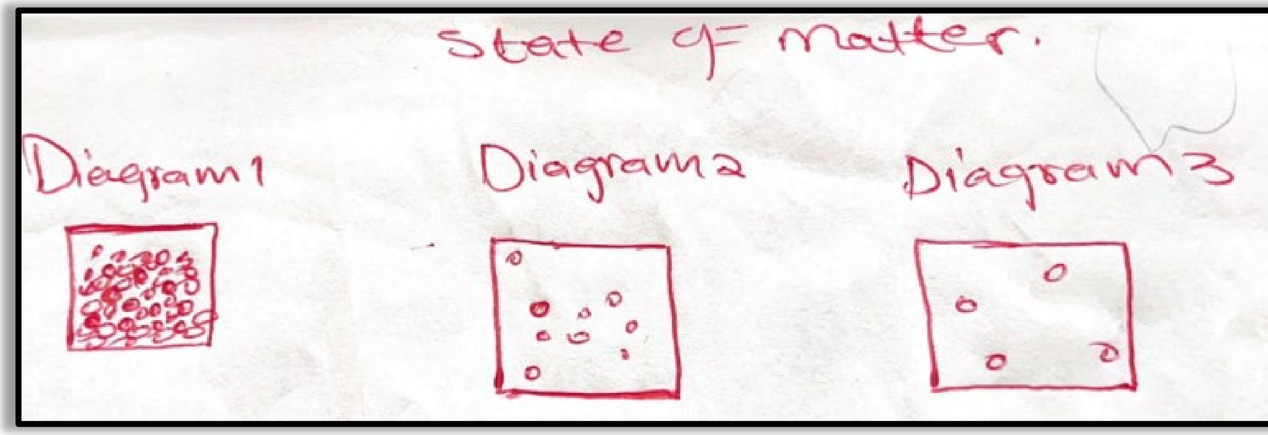


Figure 2.4: Interpreting the results of the particles for visualisation (Sun 2023, p. 18)

Now, learners can conclude on the final state of matter by visualising the behaviour of particles (Sun, 2023). Even if they did not see the particles moving, they were able to evaluate and answer the questions. In the same study by Sun (2023), still some of the scientific reasoning skills such as “data interpretation” were not achieved by learners due to failure to observe the particles moving, and if they did not observe, it was going to be difficult for them to make inferences. Over more, learners need an effective tool such as PhET to demonstrate the behaviour of the particles. In this study, PhET was used to perform an experiment, and was an effective tool to minimise the complexity of the topic ‘state of matter’. Briefly, if learners can observe the particles moving by using PhET, scientific reasoning skills such as evaluating and making inferences can be executed.

2.3 Physics education technology in learning states of matter

Learners realised that, given certain treatments, molecules will move or shift anywhere to reach an equilibrium state (Rahmawati et al., 2022). Consequently, learners from Rahmawati et al. (2022) also seem to agree that PhET simulations were clear and easy to follow. In other words, PhET provided learning experiences, and gave new learning opportunities that were absent in traditional laboratory settings (Salame & Makki, 2021). In a similar manner, PhET simulation makes learning easy because learners were able to analyse sub-microscopic depictions of several acids and the equal concentration of base solutions, it compares every sub-microscopic representation to achieve this (Nuraida et al., 2021). As Nuraida et al. has alluded, PhET simulation effectively enhances learners understanding of complex chemical concepts, such as phase changes of matter (Nkosi et al., 2024). Same way in this study PhET simulation enhance scientific reasoning skills in learning the change in states of matter. Subsequently, the concept is too abstract in nature. To substantiate the learning progress, Rahmawati et al. (2022) pointed out the following three examples to show learners who benefited and those who did not. Examples one (1) and two (2) benefited while example three (3) did not benefit in using PhET in learning molecules to achieve an equilibrium state. The examples are as follows:

1. "This simulation certainly helps. It makes it easier for me to understand that the molecule can move or move if given a certain treatment. To reach a state of equilibrium..."
2. "I can find out the factors that affect the direction of the shift in the equilibrium."
3. "I still do not understand the analogy used in these simulations" (Rahmawati et al., 2022).

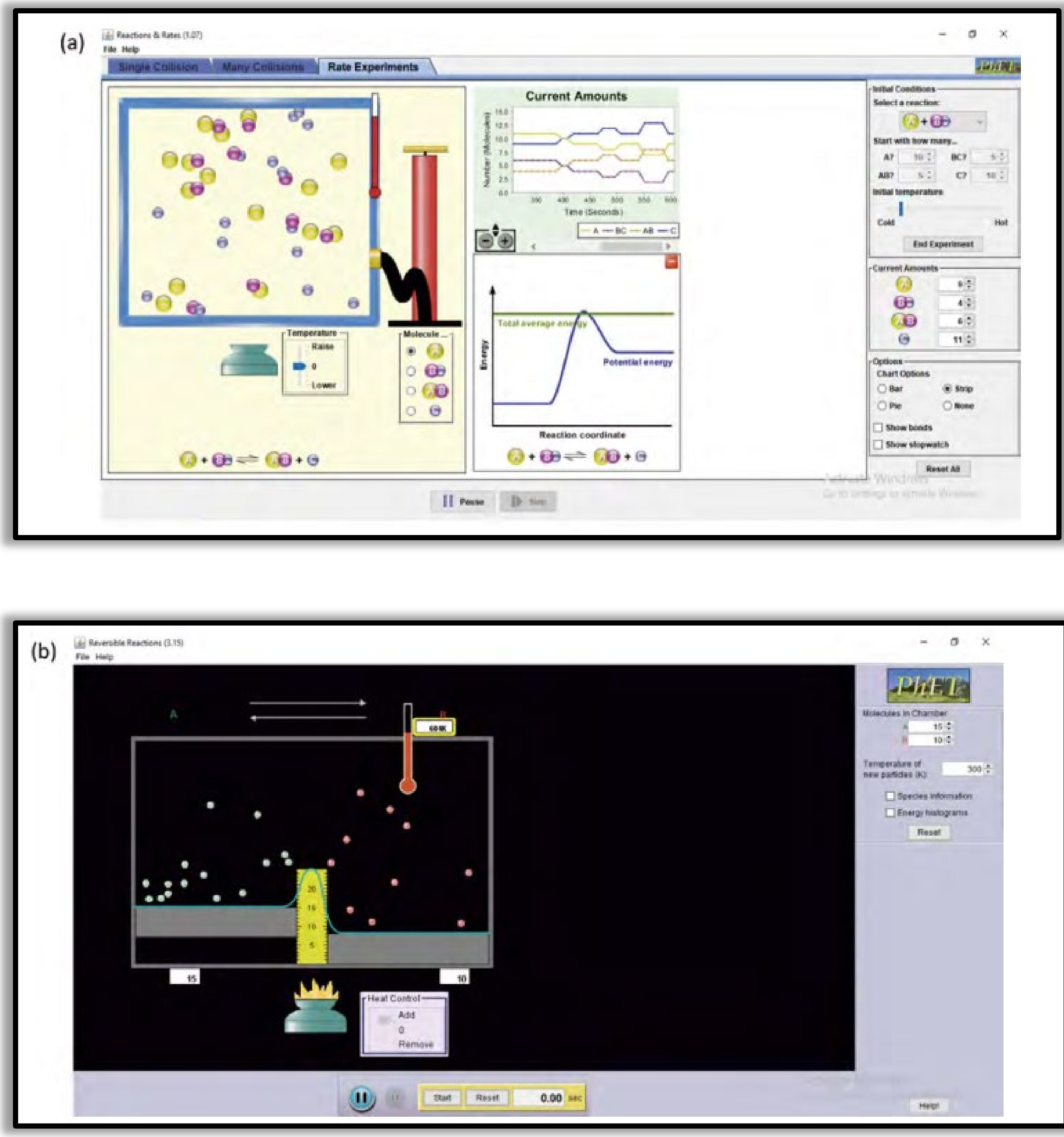


Figure 2.5: Behaviour of particles (Rahmawati et al., 2022, p. 13)

Similarly, from Rahmawati et al. (2022), examples two (1) and two (2) simulated experiments using PhET, and enabled learners to determine how wave quantities-amplitudes, tension, frequency, wavelength, and wave speed-related to one another (Yulianti et al., 2021). Moreover, the use of PhET simulation can enable them to understand the change in states of matter in the study. Contrary to both studies, in my school one teacher used PhET to teach momentum before collision and momentum after the collision in Grade 12. This showed that learners did understand how to operate PhET to learn. Despite using PhET to learn, as a teacher, you should remain as a facilitator. All in all, the use of PhET can help learners to learn physical science topics.

PhET was used in the topic of electricity to learn better where learners were able to visualise voltage, current and resistance (Abou Faour & Ayoubi, 2017). To substantiate the usefulness of PhET, scientific reasoning skills such as making inferences and evaluation were achieved by learners when learning electricity. Contrarily, in my observation as a physical sciences teacher, we did not teach science in the correct way because topics like these need learners' visualisation. For example, in Abou Faour and Ayoubi (2017), teachers give a conceptual definition of current and voltage without learners visualising electrons moving and the relationship between current, voltage and resistance. Formerly, to teach a conceptual definition is due to lack of visualising the relationship between current, voltage and resistance. In differing with a study by Abou Faour and Ayoubi (2017), the flipped classroom approach helps learners find an opportunity of engaging each other when learning change in state of matter to discuss with their teachers which is not a possible situation in a traditional approach (Schultz et al., 2014). Hence in these two studies, all learners can be engaged and learn better and understand state of matter. However, in Schultz et al. (2014), learners were unable to visualise when the particles are moving in state of matter and some of the predictions, analyses, inferences and interpretations were not achieved because it is where you conclude from what you observed. In Abou Faour and Ayoubi (2017), learners were visualising the voltage, current and resistance since the concepts were too abstract to learn without observing the electrons moving and the relationship between current, voltage and resistance. In both studies, the only difference was the tools used. A study by Abou Favour and Ayoubi (2017) used PhET simulation while a study by Schultz et al. (2014) used a flipped classroom. In fact, the better method was PhET because learners were visualising the processes of state of matter. Without visualising, learners found it difficult to grasp the concept of behaviour of particles in a gas state because they were assuming the behaviour of particles (Erceg et al., 2016). Nevertheless, learners need to observe what is unseen with the naked eye to be seen using a microscope. Consequently, PhET simulations offer learners the prospect to engage in interactive, virtual experiments that provide instant criticism (Alsalhi et al., 2024). Briefly, some topics such as state of matter are too abstract to learn without visualising the behaviour of the particles.

Learning process in waves and sounds using PhET as a virtual laboratory supported the learners' cohesiveness (Maulidah & Prima, 2018). Before using PhET from Maulidah and Prima (2018), learners had difficulties in determining base, peak point and oscillate in waves and sounds. Contrarily, the use of PhET simulation improved the learning of electrodynamics when assessing the learners (Jayanagara & Lukita, 2023). The improvement of learning emanated from the experiment performed using PhET simulation. Some of the learners in a study by Jayanagara and Lukita (2023) showed that physics-related information or concepts may not always be able to be constructed in a formal way using PhET simulations. This shows that the use of PhET simulation has limitations during learning. Despite this, according to the findings by Nyirahabimana et al. (2022), PhET simulation was a useful tool or software for raising learners' proficiency levels in the topic of physics. This is because of visualising physics topics. For instance, most learners found quantum topics challenging without understanding PhET due to the abstractness and mathematical complexities of the contents (Nyirahabimana et al., 2022). Surprisingly, learners were able to construct their understanding of the concept of photo electric effect and able to observe how electrons jump from metals in photo electric effect events (Supurwoko et al., 2017). Even in this study, it is too difficult to learn the behaviour of particles in solid, liquid and gas when different temperatures are applied. Particles in state of matter were displayed through the IoT system for smart lab to improve the learning of the behaviour of particles in state of matter (Chomanee et al., 2022). This shows that the learning of change in state of matter needs to be taught using electronical material to visualise the particles when the state changes from one state to another. Contrarily, a study by Treagust et al. (2010) found that to identify states of matter, the most important factor is the arrangement of particles. While it is impossible to arrange the behaviour of particles without demonstrating it with particles moving, this is the reason PhET was used in the study. PhET simulations have been successful in reaching large numbers of users in the K12 and college level with over 45 million runs per year and usage in all 50 states of the United States (Salame & Makki, 2021). Similarly to Salame and Makki (2021), “The help of simulations enhanced my understanding, and I was able to grasp topics that are difficult to understand because of PhET simulations” (Dy et al., 2024). In contrast, learners found it difficult to create a chemical formula to represent a compound, but through using PhET simulation it was easier for learners to imagine water compounds consisting of two hydrogen atoms and one oxygen atom (Meliniasari & Setyarini, 2024). All in all, using PhET to learn state of matter can make learners understand better.

Nuic and Glatar (2019) found that learners experience difficulty in classifying substances into state of matter. They also classify liquid easier than solid. They frequently struggle to grasp the innate movement of particles (Adbo & Taber, 2009). Similarly, they had difficulty in state of matter, specifically when the phase changes due to the abstract nature of atoms and molecules (Chomanee et al., 2022). Apart from this, state of matter is not always straightforward as seeing a water kettle boiling (liquid to gas). In support, learners need to visualise the particles in solid and change to liquid and further to gas when the temperature is applied. By visualising, they can be able to attain all scientific reasoning skills required. Similarly, they found it difficult to grasp why the state changes from one form to another in terms of the behaviour of particles (Budimaier & Hoff, 2022). Indeed, learners are unable to characterise the behaviour of particles into solid, liquid and gas because it is difficult to visualise the particles with the naked eye (Sopandi et al., 2017). Likewise, what is reported here is the inability to visualise particle behaviour in a state of matter.

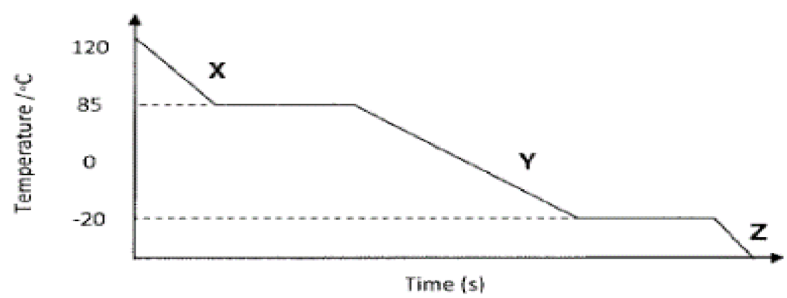
For example, the following questions are taken from physical sciences chemistry question paper of September 2019. It was not easy to attain all scientific reasoning skills to answer the following questions. The questions seem to be difficult to answer since learners did not visualise the topic ‘states of matter’. At the same time, they should be able to interpret the graph; but if they did observe the behaviour of particles when the temperature is decreasing, the questions were going to be simple. From the above paragraph, the concepts kinetic energy and the temperature applied were addressed as follows, “these concepts kinetic energy and temperature help learners to characterise states of matter as solid, liquid and gas when observing”. To illustrate this connection, check question 3.2 below. If learners could make the connection between kinetic energy of the particles and the temperature applied through observation, they were able to attain the skill interpretation because they can observe the margarine melting making intermolecular forces to be weak (kinetic energy). Also, the sun (temperature) makes the solid margarine to change its state to other states.

QUESTION 3

3.1 Define ***sublimation***. (2)

3.2 When you take a block of margarine out of the fridge, it is hard. However, after 30 minutes at room temperature it is soft enough to spread.
Use kinetic molecular theory to explain this observation? (2)

The diagram below, not drawn to scale, shows the physical changes of a substance at atmospheric pressure.



3.3 Is the diagram above showing a COOLING or HEATING curve? (1)

3.4 Name phase(s) of the substance at:

3.4.1 Point **X** (1)

3.4.2 -20 °C. (2)

3.5 Write down the stage of this substance at 85 °C. (1)

3.6 Write down the particle arrangement of this substance at:

3.6.1 Point **Z** (2)

3.6.2 Point **Y** (2)

3.7 The above substance is not water. By referring to the diagram, explain why this curve does not represent water? (2)

3.8 What happens to the temperature of the substance during a PHASE CHANGE?
Write down only INCREASES, DECREASES or REMAINS THE SAME.
Give a REASON for the answer. (2)

[17]

Figure 2.6: Grade 10 written task Physical Science paper 2 September 2019 (DBE, 2019)

2.4 Physics education technology simulations to improve scientific reasoning skills

PhET simulation has been used in mathematics to minimise the difficulty of quadratic function graph to find the turning point (de Sousa & Alves, 2022). At the same time, it is very effective and can improve learners' science process skills (Efendi & Sartika, 2021). It encourages scientific research, provides interactivity, makes visible what is invisible, shows visual mental models, and includes multiple representations such as motion object, graphics and numbers (Reis & Rehfeldt, 2019). PhET can also educate learners to have a constructivist mindset, where they can combine initial knowledge with virtual findings (Alfiyanti & Jatmiko, 2020). This is in accordance with the expression by Ramadan and Astuti (2020), who argue that learners think more critically when they use PhET simulation.

2.4.1 Physics education technology simulation to improve analyses as a skill

PhET simulation improves the interactive exchange process between learners. In this way, they were able to grasp how to analyse science concepts (Mrani et al., 2020). Ultimately, they used PhET to analyse the concept of saturation as it pertains to the point at which salt can no longer dissolve effectively in water (Rayan et al., 2023). For example, in Rayan et al. (2023), PhET was useful because it helps learners in this way:

"*Learners added salt gradually into the water, witnessing its dissolution. Eventually, there came a juncture when the salt particles began descending within the water. In response, the student introduced additional water, causing the sunken salt to re-dissolve. During this process, the student astutely noted that the added salt initially dissolved, followed by a phase of sinking. This precipitated salt later reverted to a dissolved state upon water addition. Furthermore, the learners discerned a correlation between the concentration of dissolved salt and the quantity of salt initially dissolved, observing that the concentration increased progressively until reaching a saturation point.*"

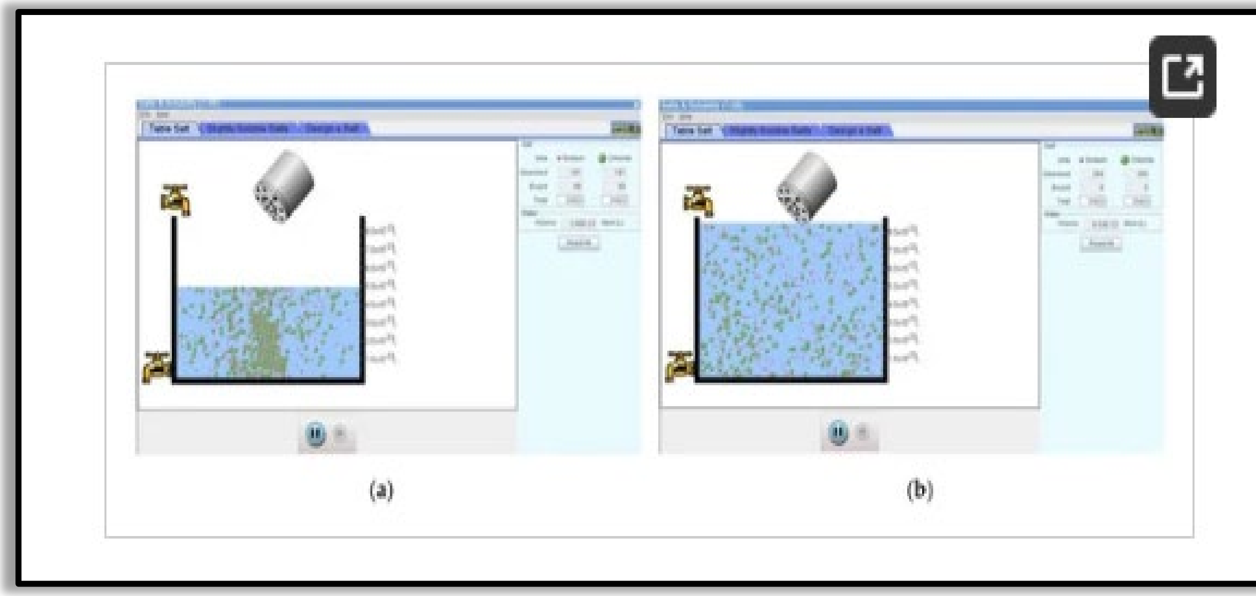


Figure 2.7: PhET simulation for the interplay between the volume of solvent and the quantity of solute. a) Precipitation of solute as result of oversaturation, b) dissolving of the solute as result of adding a solvent (Rayan et al., 2023, p. 7)

The example shows that by using PhET, learners were able to analyse if salt can be dissolved into water. Similarly, another study indicated that the use of PhET was helpful in learning how to construct simple, series, parallel and series-parallel circuits (Potane & Bayeta, 2018). In the same way, the use of PhET simulation can help learners to analyse various states of matter. To substantiate the usefulness of PhET simulation, in a study by Potane and Bayeta (2018), learners indicated that *"We have learned a lot in constructing simple, series, parallel and series-parallel circuits. It improved our study habits. Also, it enhanced our listening, problem-solving and technology skills".* The learning of science needs to be simulated since there is a lack of physical equipment in schools. Interestingly, the use of PhET helps learners to visualise what is difficult to see in the physical lab (Wieman et al., 2018). On the one hand, PhET was used to demonstrate gas behaviour because learners cannot observe the movement of particles without visualisation (Perkins et al., 2006). On the other hand, Arabacioglu and Unver (2016) have proven that the integration of virtual simulation PhET makes the learning process simple in gas properties. All in all, it is simple to make analyses from what you observed with your naked eye.

2.4.2 Physics education technology to interpret state of matter

The assessment of concepts understanding and critical thinking of learners in learning mechanics material has improved using PhET simulation (Putranta & Kuswanto, 2018). Doloksaribu and Triwiyono (2019) used PhET simulation to recognise problems and to visualise the topics that are invisible to the naked eye. More importantly, to blend PhET simulation in learning energy and change enables learners to experience interest in learning, and further stimulates their thinking potential (Maghan, 2017). To support interest in learning, learners wrote a pre-test and a post-test about calculating the initial velocity before collision. This shows that in the post-test, they improved than in the pre-test due to the usage of PhET (dan Zainul & Supardi, 2018). Similarly, in both studies, PhET was capable of dropping a mass on a spring, and viewing one of the graphs, learners rapidly noticed the “total Energy” (Fencl, 2013). In this way, they did not need much time to comprehend how to raise or lower the total energy level and which combinations of energy most efficiently accomplished this process. In Fencl’s (2013) study, learners comprehended how to raise or lower the total energy level. This shows that they develop interpretation as a skill when using PhET simulation. In a similar way, Doloksaribu and Triwiyono (2021) indicated that the use of PhET is equally helpful for learners to improve their ability to understand concepts and experiment virtually. Similarly, to the above mentioned, this PhET has a significant influence in understanding the concept of physics (Anisa & Astriani, 2022). Hence both studies show that learning using PhET has highly improved the scientific reasoning skills such as the interpretation of learners. Furthermore, it can be seen that the use of the inquiry model with the help of PhET virtual media helps improve learners how to interpret science concepts (Anisa & Astriani, 2022). In the same way, the use of PhET can simplify abstract topics such as the change in state of matter to be less abstract by visualising the behaviour of the particles moving.

2.4.3 Physics education technology to inferences

Learners had difficulty in understanding atomic structure material because its content is abstract (Sa'diyah & Lutfi, 2023). They learned the atomic structure using the lecture method. This affected them not to understand the atomic structure content. In the same study by Sa’diyah and Lutfi (2023), after the lecture method, PhET simulation was employed to compare which one can be more effective to help learners to understand the atomic structure better. The findings were that PhET helped learners to visualise the atomic structure, and the performance increased from 50.6% to 85.7%. Similarly, a study by Verawati et al. (2022) has proven that motion kinematics experiments using PhET virtual simulations have a significant impact on improving learners’ learning outcomes. This shows that for them to develop inference as a skill, they should observe the concepts through PhET simulation. In a similar manner, Ndihokubwayo et al. (2020) indicated that PhET simulation is effective in improving learners’ physics learning outcomes and is better when compared to learning that does not use PhET simulation. In the same way, it supports the cognitive processing of aspects of the material being studied and is more effective in supporting learning interactivity (Correia et al., 2019).

In developing scientific reasoning, research has shown that inquiry-based science instruction can promote scientific reasoning abilities (Adey & Csapo, 2012). Similarly, studies have shown that learners have higher gains on scientific reasoning abilities in inquiry classrooms over non-inquiry classrooms (Bao et al., 2009). On the one hand, learners have improved their scientific reasoning skills and can significantly influence the effectiveness of using inquiry methods in learning science courses (Lawson, 2001).

2.5 The use of Physics education technology in contemporary classroom to learn state of matter

Learners used molecular features more often in their descriptions and mental models after they had experienced the visualisation (Suits & Sanger, 2013). Similarly, Ashe and Yaron (2022) argue that simulations incorporating analogies involving everyday objects can help learners learn abstract concepts needed to organise their content knowledge. Both studies show that learning through PhET simulation minimises the complexity in state of matter. Again, it is not easy to carry out an experiment to investigate gas law in the classroom because it needs microscopic visualisation (Pratidhina & Sumardi, 2019). PhET may help learners in understanding the concepts of gas law and the theory of kinetic gas. Based on the elaborated discussion, it can be concluded that 33% of the learners have fully understood the ideal gas law section. However, 14 % of them have a lot of misunderstanding of the sub-material pressure and kinetic energy of gas. To illustrate the importance of PhET simulation, a study by Pratidhina and Sumardi (2019) indicated that:

“Simulation of experiment and concept animation helps learners to learn abstract concept such as kinetic theory of gas which included in the gas law topics. Other than that, guided simulation of experiments developed in our program has the potential to improve learners’ ability on data processing and graph interpretation. If we looked at the details, we found that in the post-test, the number of students who gave correct answer about problems related to data processing and graph interpretation is higher than in the pre-test” (Pratidhina & Sumardi, 2019).

Similarly, college students’ understanding of physics was found to be enhanced more by using simulated equipment (PhET) than by building actual circuits with wires, lights and meters (Tembrevilla et al., 2019). Indeed, virtual PhET simulation allows learners to observe what is impossible to visualise using the naked eye. In essence, it is impossible to directly examine the concepts of gas pressure and gas kinetic energy since they are minuscule (Nurhuda et al., 2017). Contrary to studies by Nurhuda et al. (2017) and Tembrevilla et al. (2019), Murphy (2022) shows that only one learner in learning kinetic energy of gas using PhET simulation was able to successfully answer the questions given in a class activity. Several learners from the traditional lecture group were able to successfully reframe their thinking and select the correct answer choice in the post-test assessment (Murphy, 2022). This shows that the use of PhET needs a facilitator to engage learners during the practical assessment. Surprisingly, even if PhET simulation can make learning easy, Barelli et al. (2019) found that learners’ weak awareness of epistemological issues was linked to a lack of trust and confidence about PhET simulations. Contrary to a study by Barelli et al. (2019), learners rarely appeared to be able to elaborate explanations by themselves using PhET simulations (Pratidhina & Sumardi, 2019). The use of PhET can be helpful in learning state of matter in the 4^{th} industrial revolution.

2.6 The importance of using Physics education technology to minimise the abstract in state of matter

Learners still struggled to analyse the results of the experiment, and concluded that it needs more mentoring (Sarwoto et al., 2020). Consequently, learning results using PhET simulations is more effective than a simple teaching instrument (Prihatiningtyas et al., 2013). Both studies indicated that the use of PhET minimises the abstraction of science topics. Even if the use of PhET is effective in learning, it needs the teacher to monitor the progress of the learners. At the same time, the PhET simulation approach is an effective teaching strategy in electricity and magnetism (Dantic et al., 2022). Similarly, Carpenter et al. (2016) indicated that PhET simulation emphasises connections between real world phenomena and the underlying science, and makes the invisible to be visible such as atoms, molecules, electrons and photons. Over more, learners highlighted that “We can also see the concept in much clearer detail because it presents even the smallest particle (electric charges) moving and behaving”. Similarly, learners who were learning through PhET simulations were considerably better on the post-test than those who received neither (Ndihokubwayo et al., 2020). Again, Ndihokubwayo et al. indicated that PhET simulations were shown in the present study to be far more effective in improving the conceptual understanding of geometric optics than usual teaching. For example, a study by Ndihokubwayo et al. (2020) interpreted the results to show how PhET improved the conceptual understanding of geometric optics:

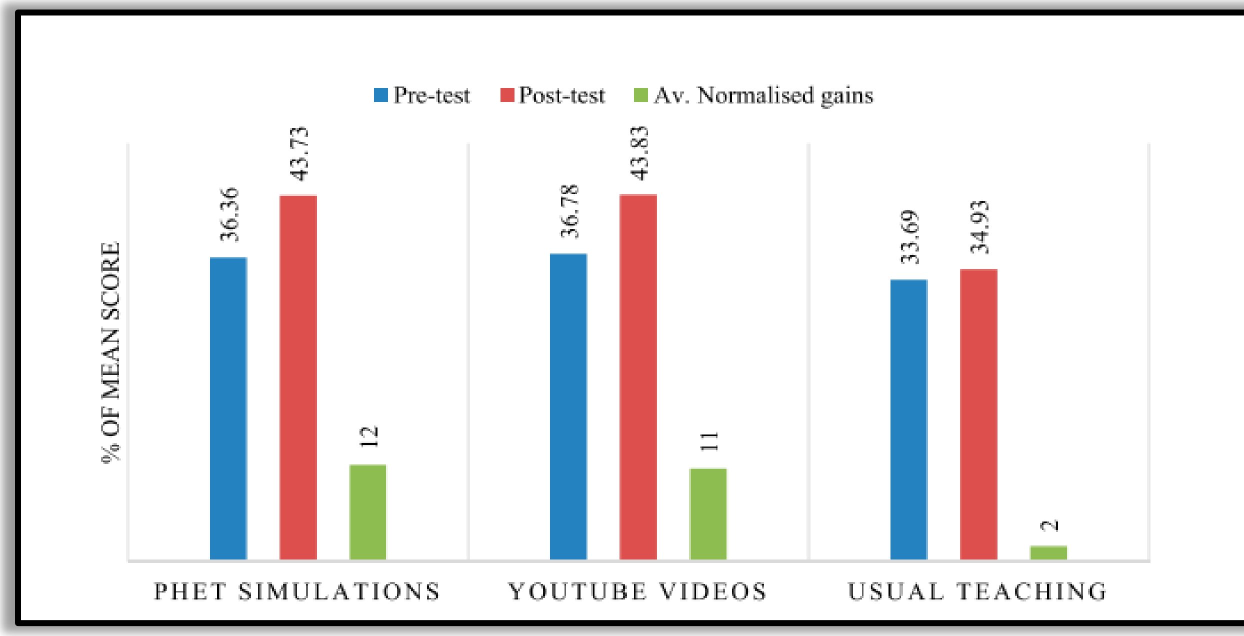


Figure 2.8: Interpreted results to show how PhET improved conceptual understanding (Ndihokubwayo et al., 2020, p. 8)

A pre-test performance was 36.36% while a post-test performance increased to 43.73%. The graph shows that the use of PhET helps learners to improve in learning geometric optics than usual teaching. Furthermore, another study found that PhET simulations make learning engaging when performing experiments (Science Education Research Centre, 2021).

PhET simulations help learners to see how molecules move or shift in order to reach an equilibrium state, and to comprehend the idea of chemical equilibrium (Rahmawati et al., 2022). In the same way, they highlighted this: “*learning with PhET interactive simulations makes it easier for students to be interested in learning by exploring directly and being able to experiment in a relatively short time.*” “*I also became more understanding, because every scientific explanation can be directly practiced through the media.*” Hence, this experience from the learners shows that the use of PhET can make learning more interesting and reduce the abstract nature of the topic ‘state of matter’. Similarly, PhET allows learners to visualise at the sub-microscopic level (Correia et al., 2019). In addition, most learners reported having positive learning experiences using PhET simulation. Similarly, another study found that simulation activities broaden teachers’ conceptual teaching, enable learners to visualise abstract concepts and encourage their conceptual understanding (Ogegbo & Ramnarain, 2022). Indeed, a perception from a teacher: *"I believe the content in the simulation would have been too difficult for the learners to understand at first, but I think being able to ask them questions based on how to move the test charge, their observation, and reaction to the values displayed on the screen also made the class more interactive"* (Ogegbo & Ramnarain, 2022). In support, while learners are busy observing the state of matter, the teacher should facilitate learning to help learners to observe the behaviour of the particles. Similarly, Saputri (2021) and Siahaan et al. (2017) found that PhET simulations can be used as a solution to deal with learners' low science process skills in science learning. Additionally, it can be argued that learners taught with PhET simulations have more opportunities to interact, observe, discuss and make interpretations in the learning process. It is the view of the findings of this study that PhET simulations and animations favoured more learner-centred learning, and by these learners were able to visualise the science topics (Beichumila et al., 2022).

Negative features, on the other hand, relate to unpleasant elements of the PhET simulation programs that were meant to be challenging (Taibu et al., 2021). Zacharia and Olympiou (2011), have discovered that using both virtual and physical laboratories together improves students' conceptual knowledge more than using just one type of experimentation. A study by Pyatt and Sims (2012) discovered that, in terms of students' cognitive and affective performance, virtual labs can be useful substitutes for actual labs. Chen et al. (2014) have maintained that virtual laboratories can be just as successful as real labs, although they have advised teachers that the former may lead learners to mindlessly plan and conduct experiments. Chen et al. (2014) also discovered that students enrolled in physical labs had somewhat more positive sentiments toward labs than those enrolled in virtual labs.

2.7 Learning using emerging technologies in state of matter

The behaviour of particles in states of matter and state changes have not been explained in any case animation (Yaseen & Aubusson, 2020). Subsequently, learners expressed a strong preference for simulations over the real equipment, and this PhET was used in an electric field line (Ogegbo & Ramnarain, 2022). This action allowed them to visualise the pattern of electric field lines for different charge configurations and interpreted activities indicating that:

"*Field lines which are also called lines of force become more spread out as they move further from a point charge. The dark part indicates the closeness of the lines of force and at this point, we experience a stronger electric field or greater force, while the magnitude of the charge will also increase. Thus, if the lines of force are closer together i.e. darker as seen on the screen, we say the electric field is closer to the charge and if the lines of force are weaker i.e. further separated, then the electric field is weaker than the charge*" (Ogegbo & Ramnarain, 2022).

In addition, Ogegbo and Ramnarin's (2022) picture to shows how PhET makes the learning of electric field simple.

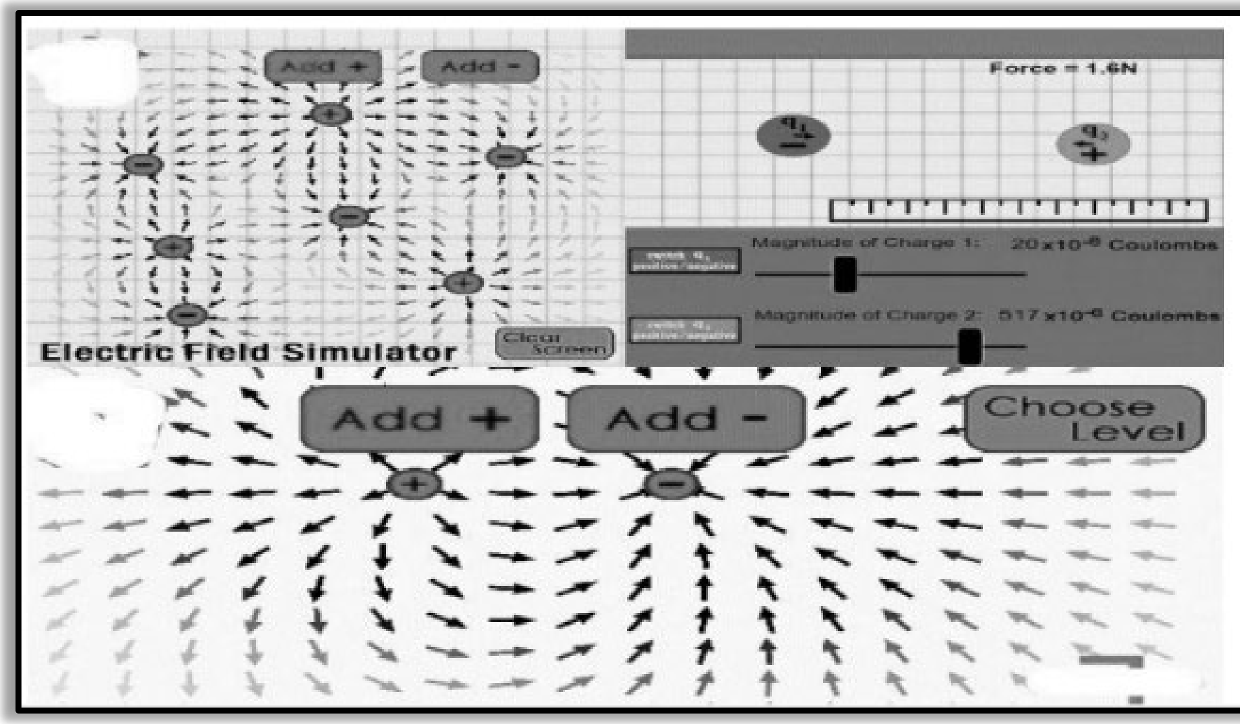


Figure 2.9: PhET makes the learning of electric field simple (Ogegbo & Ramnarin's, 2022, p. 4)

Another study found that by using PhET simulations, the invisible such as protons and electrons can be made visible and clear (Wiema et al., 2010). Similarly, a study by Najib et al. (2022) was conducted using PhET to show learners how to make predictions, analyse, interpret and evaluate the connection of concepts. In addition, Hardyadi and

Pujiastuti (2020) conducted a study to determine the effects of using PhET simulation in systems of living organisms. They found that the use of PhET simulation is significant in improving learners how to make predictions, analyses, interpretations and evaluations. Also, findings by Al-mashaqbeh and McLaughlan (2014) revealed that PhET simulations results in improved achievement in chemistry.

In contrast, Yunzal and Casinillo (2020) reported that less significance in using PhET in the learning of electrodynamics, although learners displayed interest playing with the simulations. Contrarily, results from Piyatissa et al. (2018) revealed that learning forces in physics using PhET worked well to support the textual and verbal explanations of scientific principles. Similarly, Beichumila et al. (2022) found that simulations improved learners' basic skills of observation, prediction, pattern analysis, and reasoning science process skills. In this study, PhET was used to explore scientific reasoning skills in state of matter specifically characterising the behaviour of solids, liquids and gas. In this way, it can help learners to grasp the abstract visualisation of particles in state of matter. PhET helps the learning of quadratic functions in mathematics, and explores simulations in a visual and interactive way (de Sousa & Alves, 2022). Similarly, in a study by Byrne (2020), learners better understand the physics concepts related to motion students and are spending far more time in front of screens (televisions/video games/cellphones) than ever before. Through the PhET, some modes of motion displayed in the simulation are more visualised and more interesting than the real conditions in a real laboratory (Verawati et al., 2022). This shows that PhET software creates abstract physics animation or cannot be seen by the naked eye, including atoms, electrons, protons and magnetic field (Susilawati et al., 2023). Similarly, Bandoy et al. (2015) found that 28% mentioned that using PhET is very effective and 72% said that it is effective. Additionally, they indicated that the simulations are very helpful, attractive and appealing. Over more, the use of PhET simulation can improve the critical and creative thinking skills of learners (Hasyim & Prastowo, 2020). In contrast, Yunzal and Casinillo (2020) highlighted that the results of their study show that PhET simulation has revealed a low improvement in the students' performance in the conceptual assessment in electrodynamics.

2.8 The benefits of integrating PhET simulation in learning states of matter

When PhET simulations are used for learning, learners improve in thinking skills, concept analysis, creativity, and innovation skills, and the ability to transfer and apply concepts and knowledge to a new learning environment (Banda & Nzabahimana, 2021). The study noted that PhET simulations present the information in multiple representations that engage the students and promote reasoning instead of memorising the concepts. PhET was also used in the learning of turning effect of the force in physics at a secondary school level and works well to support the textual and verbal explanations of scientific principles which are difficult to understand due to the lack of the tangible nature of this concept of force (Piyatissa et al., 2018). They indicated that this improved learners in this way. The net improvement of 25% achieved by the experimental group learners in the post-test administration of the assessment compared to the pre-test over the control group showed the capability of the new approach as a way of helping students to visualise the necessary content in the lesson turning effect of force. The abstract concepts of science are very difficult to visualise even in physics laboratories. For example, the generation of electricity is an invisible process that involves the movement of electrons (electrical charge carriers) through conductive metal wires. Therefore, it can be a difficult concept to learn and to be taught in real-world situations (Alatas et al., 2017). In the study, the research method was a quasi-experiment design with a non-equivalent control group. The research was conducted in two classes. The difficulty of this movement of electrons led the study to utilise PhET to simulate a simple electric circuit in meaningful learning for students. It was found that simulations improved students' skills in making observations, predictions, analysing patterns, and making inferences, which are basic science process skills (Beichumila et al., 2022). Furthermore, in this study, PhET was used to explore scientific reasoning skills in state of matter specifically characterising the behaviour of solids, liquids and gas. In this way, it helped learners to grasp the abstract visualisation of particles in state of matter.

Batuyong and Antonio (2018) found that there was a significant improvement in the physics assessment performance of the learners when tackling the section involving "electromagnetism" using PhET. Additionally, learners are able to improve learning in performing those experiments because they enjoy what they are doing using PhET simulation. In a similar manner, Yunzal and Casinillo (2020), found that learning electrodynamics using PhET simulations did not significantly improve learning, although learners showed interest in playing with the simulations. However, virtual laboratories enhance learners' problem-solving, critical thinking, creativity, conceptual understanding, science process skills, lab skills, motivation, interest, perception and learning outcomes (Taibu et al., 2021). Visualisation in chemistry can help to make chemistry at a particular level less abstract because the students can see these particles moving using PhET (Suits & Sanger, 2013). Furthermore, learners were able to describe solids, liquids, and gas using the kinetic molecular theory to describe the behaviour of particles through PhET simulation. Hardyadi and Pujiastuti (2020), conducted research intending to determine the presence or absence of a significant effect of the use of PhET simulation media on the learning achievements of the basic energy material in the life system. The study found that PhET simulation can improve learner' science process skills.

2.9 Difficulties in learning state of matter without PhET simulation

States of matter was difficult to learn without visualising the behaviour of particles in different states (Brazhkin et al., 2012). In comparison, to observe the behaviour of particles, learners need to visualise the movement of particles for better understanding of the topic (Liu et al., 2022). Both studies showed that in states of matter, you cannot see the behaviour of particles with your naked eye to execute final states of matter. In the same way, virtual laboratories were able to help learners to observe the behaviour of particles in state of matter (Herga et al., 2016). Alternatively, it was still difficult to grasp the concept of state of matter because learners were not able to engage themselves in the observing process (Dallaire & Gosselin, 2016). A study by Dallaire and Gosselin, showed that even if learners were able to visualise, engagement of the concept was important. Again, in Dallaire and Gosselin (2016), learners experienced this difficulty: "Ice molecules are colder than water molecules" instead of "Ice molecules have less kinetic energy than water molecules". This difficulty emanated from the lack of visualisation of the behaviour of particles in state of matter. However, the teacher needs to facilitate the learning process while learners are busy observing the behaviour of the particles. In summary, learning state of matter without visualising the movement of the particles becomes too difficult.

The use of virtual demonstration when learning state of matter by learners was encouraging (Sharma et al., 2015). In a similar manner, learners were able to observe the behaviour of different states of matter; in this way it helps them to develop scientific reasoning skills. In the same way, another study found that it was difficult to observe the movement of water particles when heated with the naked eye since it is microscopic in nature (Wibowo et al., 2016). Furthermore, when learning science, learners need to visualise the concepts that are microscopic in nature for better understanding. Learners needed to integrate temperature and kinetic molecular theory to be able to adapt scientific reasoning skills in characterising state of matter (Hadinugrahaningsih et al., 2017). Still, it becomes too difficult to learn state of matter without the PhET to visualise the concept. Similarly, the realisation of the crystalline state meant that it was difficult to characterise the change in states of matter. In fact, no melting point has been observed (Seredyuk et al., 2008). In fact, the melting point cannot be seen without visualisation. It is particularly interesting that the majority of the subjects do not seem to be able to approach the issue of change in the state of matter (Rodriguez & Castro, 2014). To repeat, state of matter is a type of concepts that require learners to apply hands on and mind on. Again, the reason for those states of matter is microscopic in nature; learners need to see the particles moving to be able to tell the change in states of matter. Similarly, to learn this concept, they need to familiarise themselves with PhET simulation.

2.10 Theoretical framework

The theoretical framework of this study is scientific discovery as dual search (SDDS) (Klahr & Dunbar, 1998). This framework poses attempts to evaluate concept-building approaches coherently (Zimmerman, 2007). The SDDS model defines scientific reasoning by integrating knowledge from various disciplines (Li & Klahr, 2006). Interestingly, it helps learners to generate testable hypotheses, and to perform experiments and evidence evaluation strategies. The prediction can help learners to develop the hypothesis, and prove if the hypothesis is correct or not. Moreover, by testing the hypothesis, evidence emerges and needs to be evaluated. Furthermore, it elucidates a set of interdependent process for coordinating search for truth through experimentation and hypotheses (Klahr et al., 1993). There are three main processes in this framework: searching the hypothesis space, searching experiments and evaluating evidence (Klahr & Dunbars, 1998). The aim of the search in the hypothesis space is to generate precise and testable hypotheses on the basis of existing data or observations (Schulte & Wegner, 2021). While in search of experiment space, learners should be able to collect data related to the behaviour of particles in state of matter; and in evaluating evidence space, they should be able to analyse and interpret data, make informed inferences and draw conclusions (Lobato & Zimmerman, 2018). Three processes of SDDS helped to analyse the collected data. At the same time, PhET was used to perform the experiment. From the experiment designed, learners should generate the hypothesis. For instance, when the temperature is applied, the state of matter changed from one phase to another. By so doing, learners were able to conduct the experiment. More importantly, scientific reasoning skills such as analysing, evaluating, interpreting, making inferences and drawing conclusions were emerged.

Scientists search in experiments space to design and carry out the process to prove or disprove the hypothesis (Klahr, 1989). In fact, according to SDDS, scientific creativity involves the interaction of hypothesis generation, experiment design and evidence evaluation process. Similarly, SDDS is a process of testing hypothesis, and involves designing an experiment appropriate to the hypothesis, making predictions and running the experiment (Klahr, 2000). This SDDS has been examined in detail using methods such as tensiometer, conductometry and fluorimetry (Ray et al., 2009). Indeed, Klahr and Dunbar (2013) found that the SDDS model offers a description of discovery learning as a problem solving-like search through two problem spaces: hypothesis space and experiment space. I discuss the following next, hypothesis space and experiment space.

Firstly, learners were able to search the hypothesis space, and used imagination to conclude on the behaviour of the particles. Secondly, they searched the hypothesis space. Thereafter, the use of PhET was complimented to test the hypothesis by observing the behaviour of the particles when the states change from one form to another. By observing the behaviour of the particles, the change in states of matter became less abstract. Before the use of PhET, learners wanted to know the change in states of matter from solid to liquid, liquid to gas. In short, they wanted to understand the cooling graph and heating graph. Before using PhET simulation, the concepts cooling graph and heating graph were too complex to analyse and interpret. After using PhET simulation, the learners were able to exhibit scientific reasoning skills such as prediction, analysis and interpretation. Moreover, the use of PhET simulation helped them to visualise the behaviour of the particles when the change in states of matter was happening. This results in the development of scientific reasoning skills. Evaluating the evidence is one of the tenets in this theoretical framework. Through PhET simulation, learners were able to evaluate the evidence because they evaluated what they observed. Subsequently, they exhibited scientific reasoning skills accordingly when writing the tasks related to the cooling curve and heating curve. Furthermore, the theory was used as a frame in this study. The tenets of the theoretical frame will be used to evaluate the results in chapter 4. The three tenets of the theoretical framework will be used to evaluate the results namely: searching the hypothesis space, searching experiments and evaluating evidence (Klahr & Dunbar, 1988). Through the written tasks, learners should come up with hypotheses. Subsequently, the hypothesis will help them to perform the experiments, and in this way, they will be searching experiments as one of the tenets. Through the experiment, they will be executing scientific reasoning skills such as prediction, analysis, interpretation, evaluation and making inferences. According to Klahr and Dunbar, exhibiting the scientific reasoning skills means that learners need to evaluate the evidence. They will be performing the experiment through the use of PhET simulation.

2.11 Summary of the chapter

The literature on learning states of matter, scientific reasoning skills in learning states of matter and learning states of matter through PhET simulations has been covered in this chapter. It shows how learners should develop scientific reasoning skills to learn the change in states of matter. Again, the literature demonstrates how they should develop scientific reasoning skills. Through PhET simulations, learners should be able to develop scientific reasoning skills. The chapter focuses on what learners can or cannot do when learning states of matter, as well as the difficulties that they encounter when learning the change in states of matter. The review provided the discussion on how to learn the change in states of matter and how to develop scientific reasoning skills. The literature contributed to the existing literature in this way: to learn the change in states of matter, learners should familiarise themselves with visualising the moving of the particles. Additionally, to visualise the movement of the particles when learning the change in states of matter is too difficult to see with the naked eye. Furthermore, to learn the change in states of matter is too abstract in nature and the concept is microscopic in nature. Hence, PhET simulations were used to minimise the abstract nature of the change in states of matter. Over more, through the use of PhET, learners were able to develop the change in states of matter. All in all, the chapter discussed the theoretical framework that guided the study. The following chapter presents a discussion of the methods employed to carry out the study.

CHAPTER 3

METHODOLOGY

3.1 Introduction

This chapter describes the research approach used in the study. It further addresses the design of the study, sampling, data collection methods and how data were analysed. Again, two written tasks, semi-structured interviews and observations were used to collect data in Grade 10 on scientific reasoning skills with PhET simulation intervention. Furthermore, thematic analysis was used to analyse the data. Additionally, the chapter describes the quality criteria and ethical considerations considered in the study.

3.2 Research approach

This study adopted the qualitative approach. Qualitative approach deals with meanings through language and action, and includes a wide range of materials (e.g., conversational data, images, observations and unstructured, semi-structured and structured interviews, among others). Qualitative data analysis is generally described as a nonlinear and iterative process (Lester et al., 2020) and relates to the classification and interpretation of linguistic (or visual) material to make statements about implicit and explicit dimensions and structures of meaning-making in the material and what is represented in it. According to Uwe Flick (2009), qualitative data may be used to describe a phenomenon in some or greater detail. Qualitative evidence syntheses, also known as systematic reviews of qualitative research, aim to explore people's perceptions and experiences of the world around them by synthesising data (Noyes et al., 2017). Qualitative evidence synthesis provides an in-depth understanding of complex phenomena while focusing on the experiences and perceptions of research participants and taking into consideration other contextual factors (Ames et al., 2019).

3.3 Research design

The study adopted the case study research design by Merriam. This is an exploratory single case of Grade 10 learners intending to explore the complexity of the state of matter (Hyett et al., 2014). A case study is the holistic description and exploration of finite phenomena in programmes, institutions, people, processes and social entities (Ebneyamini & Sadeghi Moghadam, 2018). The case study will be used to develop an initial understanding or phenomenon of interest characterising state of matter (Ponelis, 2015). Also, a case study enabled the collection of data using observation, documents and interviews (Yazan, 2015). The type of research questions that were used in the study are what, how and why. Consequently, the type of questions sought to find out why learners were struggling when answering the change in states of matter questions. The boundary for this study was exploring Grade 10 learners' scientific reasoning skills when PhET was used and when it was not. The type of study was a single case study to test a theory or a multiple case study to develop a rich theory. In this study, an understanding of learners' change in states of matter was gained by conducting a single case study of a class. Merriam asserts that the three aspects assist researchers to use a variety of data-collection methods to document enough data about learners' behaviour. In this study, the three aspects of an exploratory case study enabled the researcher to recognise difficulties that hinder learners from exhibiting scientific reasoning skills before and after PhET simulation.

The concept of a case study has been variously defined as a process, a unit of study, or an end product (Merriam, 1998). Scholz and Tietje (2002) define a case study as an empirical inquiry that investigates a contemporary problem within its real-life context. A case study is appropriate when the researcher is interested in how, what and why questions. Three types of case studies can be undertaken: explanatory, exploratory and descriptive case studies (Yin, 2003). Merriam conceives a qualitative case study as "an intensive, holistic description and analysis of a bounded phenomenon such as a program, an institution, a person, a process, or a social unit" Her discussion includes conducting literature review, constructing a theoretical framework, identifying a research problem, crafting and sharpening research questions and selecting a sample (purposive sampling). Merriam's approach in a case study design is not close to either Yin's or Stake's; it is a combination of both approaches.

3.4 Sampling

Sampling is a method of deciding on a portion of the population which represents the whole population (Kothari, 2004). Merriam (1998) suggests that purposive or purposeful sampling usually occurs before the data are gathered, whereas theoretical sampling is done in conjunction with data collection. According to Taherdoost (2016), sampling is used to make conclusions regarding the population of a particular study. Two types of sampling techniques in research are: non-probability sampling and probability sampling (Taherdoost, 2016). In this study, SBL Secondary School at an education circuit in Limpopo was selected purposively as it is convenient for the researcher who teaches there. Purposive sampling enabled me to judge the selection of units of study, (participants) and data to be studied (Rai & Tshapa, 2015). Hence, 40 learners from Grade 10 who registered for Physical Science participated in the study. According to Merriam (1998), an exploratory case study should be guided by purposive sampling, not population since it is suitable for collecting qualitative data. Thus, the study used purposive sampling which is a form of selection whereby the researcher relies on their own judgment when choosing participants (Palinkas et al., 2015). The school lacked resources, and chalkboards are still used during the process of teaching and learning. The school has 239 learners comprising 156 males and 83 females supported by 8 staff members. To be specific, Grade 10 class has 40 learners who all participated in the study. In terms of language, the school is Sepedi-speaking. This was a great way of exploring a variety of scientific reasoning skills exhibited by learners when the states of matter change from one form to another. In terms of two written tasks, the researcher purposively selected three changes in states of matter from previous question papers, which require learners to exhibit scientific reasoning skills.

3.5 Data collection

The study used three data collection methods namely: document analysis, classroom observation and semi structured interviews as recommended in case studies by Merriam. Creswell (2018) highlighted that data-collecting methods should be in line with the research approach. The collection of data took two weeks. In the first week, written task 1, sections A and B were used to collect data, and in the second week, written task two was implemented. Firstly, I started with the first written task, sections A and B. Vignettes were collected for marking purposes while observing and conducting the interview. Secondly, the second written task was administered while I was observing and conducting the interview. Two written tasks were used to collect data with the intervention of PhET, and to check if the learners' scientific reasoning skills on the change in states of matter can be developed. Through the use of PhET simulation, most learners were able to observe the behaviour of particles to develop scientific reasoning skills such as prediction, analysis, interpretation, evaluation and making inferences.

3.5.1 Observation

During class time, learners performed experiments related to state of matter using PhET. I was a participant observer, viewing learners as they work on related activities (Fry et al., 2017). An observation schedule as a systematic approach to the collection of data was used during class time (Vermeirsch et al., 2021). An observation schedule was designed focusing on learners' scientific reasoning skills on the concept of change in state of matter. I was observing and noting what they can or cannot do when writing the written tasks related to change in states of matter. Most learners were able to articulate scientific reasoning skills such as prediction, analysis, interpretation and making inferences. The three methods are relevant to the current study as they required them to represent their scientific reasoning skills in written tasks through interviews and observation by me in multiple ways. Hence, the three methods allowed the researcher to analyse the exhibited scientific reasoning skills using the three tenets of scientific discovery of dual search (SDDS) theory. Additionally, learners were able to develop scientific reasoning skills since they were able to observe the behaviour of the particles when temperature increases and decreases. While observing, they were able to characterise the states of matter because it was easy for them to visualise when the particles form solid part, liquid part and gas part. There are three links on (**APPENDIX J)**, to show when learners were using PhET simulation to characterise the three states of matter, solid, liquid and gas. Also, the voices of learners were merged with the videos on PhET simulation to find out why learners are executing scientific reasoning skills of prediction, analyses, interpretation, evaluation and informed reference.

3.5.2 Documents

Participants worked on tasks on the state of matter. The prepared tasks measured learners' scientific reasoning skills in characterising the states of matter. The learners' written responses to these tasks serve as data from documents analysed. All learners in Grade 10 took the tasks while the teacher monitored the learning progress. The questions were designed in such a way that I could see the scientific reasoning skills of state of matter. Closed-end questions were used.

Two written tasks were implemented to collect data. With the use of PhET simulation, two written tasks were given. In the first written task, learners were given questions to answer taken from previous question papers. Most questions were about the change in states of matter, and the relationship between the behaviour of the particles and the temperature applied, also if the graph of the process of states of matter is heating curve or cooling curve. The task was written under the researchers' supervision for 30 minutes such that each learner could exhibit his or her own scientific reasoning skills. This was also a way of ensuring that they do not copy from each other. The first written task contained five questions. The first question required them to define melting point, meaning it was necessary for the learners to mentally understand what melting point is. Again, the process of melting point was to assess learners in terms of the behaviour of the particles if the temperature is applied. This is a process of using scientific reasoning skills to the written task. Through written task 1, learners were able to execute scientific reasoning skills. They were expected to develop scientific reasoning skills while writing the task. To substantiate the development of these skills, they were able to execute skills such as analysis and interpretation. For example, they were supposed to understand that when the temperature increases, the behaviour of the particles also increases, and the states change from one form to another. After 30 minutes, all scripts were collected and marked using a marking guideline.

As the learning proceeded, learners were given feedback on the first written task so that they could know what they were expected to do. Thereafter, written task 1, section A was given for 45 minutes to develop scientific reasoning skills when writing the change in states of matter. This indicates that learners were expected to use their scientific reasoning skills to acquire the concept of the change in states of matter. Most importantly, they were allowed to use any source, textbook, study guide, or internet to obtain different ideas. During this process, I acted as a facilitator of learning to observe as learners worked and clarify their difficulties related to the change in states of matter. Written task 1, section A had eight (8) questions. The first question required learners to explain what sublimation is. The second was about finding the relationship between temperature and the behaviour of the particles. The third and the fourth questions were about naming the states of matter by analysing the graph given. The fifth question expected them to interpret the graph given and answer the question. In this way, as a teacher I checked if they could use scientific reasoning skills or not. The questions that followed were to assess if learners can articulate scientific reasoning skills.

After written task 1, sections A and B, learners were given written task 2. Still, they were expected to show their scientific reasoning skills when writing task 2 to visualise the behaviour of the particles. Furthermore, the intervention of PhET simulation was to check if they can develop scientific reasoning skills. Indeed, many of them were able to develop scientific reasoning skills such as prediction, analysis, interpretation, evaluation and making inferences through PhET simulation. Learners were monitored such that each could exhibit his or her scientific reasoning skills. Briefly, the two written tasks when PhET was used responded to the first research question. This allowed me to capture learners' scientific reasoning skills exhibited through access to relevant concepts required in change of states of matter. This was a way of showing them that they cannot develop scientific reasoning skills without visualising the particles in motion. Thereafter, all vignettes were collected, marked and grouped based on their similarities and differences in scientific reasoning skills using the theoretical framework SDDS. The two written tasks enabled learners to notice that to visualise the behaviour of the particles was important in learning the change in states of matter.

3.5.3 Interview

Semi-structured interviews, according to Mahat-Shamir et al. (2021), are the best data collection instruments if you do not have multiple interview opportunities. Open-ended questions with prompts in state of matter that need to be covered were generated. The data was collected in (two) weeks, and interviews were conducted face to face. A voice recorder was used to capture responses from the learners. The interviews were conducted in English.

After classifying learners' written responses in each written task, semi-structured interviews were used for approximately 5 minutes to probe the reasons why learners exhibited these particular scientific reasoning skills on the topic about the change in states of matter. Semi-structured interviews refer to a way of asking a few pre-determined questions while the rest of the questions arise from the interviewee's responses. This indicates that the interview questions were based on individual responses to the given written tasks. The interviews were conducted such that the sampled learners included those with inappropriate and appropriate scientific reasoning skills. Learners with inappropriate scientific reasoning skills are those with the inability to mentally imagine the behaviour of the particles when the temperature is applied. During the interviews, the researcher was given a name called Justice whereas alphabets were used to represent learners. For example, learner A. From the transcripts in chapter 4, learners were able to reason out why they executed those scientific reasoning skills such as prediction, analysis, interpretation, evaluation and making inferences. Some, were able to develop scientific reasoning skills of analysis and interpretation when using PhET simulation to visualise the behaviour of the particles. All in all, by using the three instruments of interview, documents and observation to collect data helped to notice that the concepts state of matter is too abstract in nature. Learners were able to develop scientific reasoning skills of prediction, analyses, interpretation, evaluating the evidence and making informed inferences. Subsequently, for them to develop scientific reasoning skills mentioned, with the auspices of PhET simulation learners were able to develop scientific reasoning skills in learning the change of state of matter.

3.6 Data analysis

This research study implemented thematic analysis as a process of encoding and identifying patterns and themes (Terry et al., 2017). Thematic analysis was used to analyse all collected data in the form texts (Braun & Clarke, 2021; de Farias et al., 2021). Through thematic analysis, I was able to explore scientific reasoning skills of prediction, analysis, interpretation, evaluation and making informed inferences in characterising the states of matter (Scharp & Sanders, 2019). The type of coding that was implemented in this study is axial coding, which was used to generate, refine and categorise themes (Williams & Moser, 2019). Hence, organised and classified data were labelled using axial coding to put it in a meaningful way. For instance, it can be labelled as letters or symbols. In fact, coded data fitted into the frame inductively to form themes (Varpio et al., 2020). Therefore, the study adopted the inductive approach because data is a frame, and themes emerged from the coded data. Furthermore, theoretical framework (SDDS) and literature evaluated the results from the data. Furthermore, the tenets of the theoretical framework stress that learners should come with hypotheses and find space to visualise the behaviour of the particles (experiment space) through PhET. By visualising, learners were able to evaluate the evidence. For example, they indicated that when the temperature increases, kinetic energy of the particles also increases.

Moreover, thematic analysis maintains the richness, rigour and natural setting of the original data. In analysing the data, I first engaged myself with it by re-reading textual data from the two written tasks. Again, I familiarised myself with two written tasks with the use of PhET simulation. Secondly, while learners were writing the tasks, I was observing if they can execute scientific reasoning skills such as prediction, analysis, interpretation, evaluation and making inferences. Thirdly, transcripts of verbal data from interviews were analysed deeply, and I made sense of the ideas that emerged. Through transcript, I did not listen to the audio of the interview once, but several times to come up with the correct coding from the data. I coded the ideas and arranged them into categories. Lastly, I noted the themes which were described as final results through the thematic analysis process (Braun & Clarke, 2006). Therefore, the themes (patterned responses) were described and interpreted for their meanings, and were presented in the results section of the study report. According to Braun and Clark (2006), there are six steps of inductive thematic analyses moving to a stage of assigning preliminary codes to the data. In this study, data were categorised and grouped according to the same characteristics. For example, from my learners who did not know what to write, those who did not give themselves enough time to think, and those who failed to execute scientific reasoning skills were classified into the same codes per question in written task 1, sections A and B. In this way, data was classified in terms of different codes per question. Secondly, seeking patterns or themes in the codes among different written tasks, observation and interviews followed, culminating in a review of themes generated, definitions and names of the themes, and the production of analysis report (Braun & Clarke, 2006). In my study, one of the themes that emerged with PhET intervention was the inappropriate use of scientific reasoning skills such as prediction, analysis, interpretation, evaluation and making inferences. The following subtopics also emerged: (1) undocumented reasoning in the change of states of matter; (i) not knowing what to write; (ii) particles are too abstract to see with the naked eye; (iii) inability to think in a short period of time; (2) lack of making prediction in state of matter; (3) inability to analyse and interpret graphs in processes of state of matter; (4) inappropriate connections between kinetic energy and temperature and undocumented reasoning in the change of states of matter, (i) not knowing what to write, (ii) particles are too abstract to see with the naked eye, (iii) inability to think in a short period of time; and (5) appropriate use of scientific reasoning skills such as prediction, analysis, interpretation, evaluation and making inferences. Learners were able to find the relationship between kinetic energy of the particles and the temperature applied. Subsequently, they were able to find the relationship because of the visualisation from the PhET simulation. To illustrate that I coded some of data as GGGM1, this can be explained as “Correct relationship between the temperature applied and the behaviour of the particles, ability to infer and evaluate the written task 3". I was able to tell if the scientific reasoning skills have improved with the intervention of PhET simulation.

Themes emerged from the coded data after the use of PhET simulation as follows: 1) appropriate connections between kinetic energy and temperature; 2) ability to analyse and interpret graphs in processes of state of matter; 3) making the correct prediction in state of matter; 4) developing scientific reasoning skills and understanding of the change in states of matter; and 5) inappropriate use of scientific reasoning skills such as prediction, analysis, interpretation, evaluation and making inferences. Furthermore, the analysis report was produced. After the analysis, the tenets of theoretical framework evaluated the results of the study with PhET.

3.7 Quality criteria

A central issue in qualitative research is to ensure that results are trusted (Lincoln & Guba, 1985). Five key concepts are used to evaluate the trustworthiness of qualitative research (Treharne & Riggs, 2015).

3.7.1 Credibility

I ensured that the research results are credible by engaging in a long-term relationship with participants, building trust and ensuring that the results are consistent with what is happening in the research setting (Wojcieszak, 2021). Data were collected using various methods to answer the how, why and what research questions. Firstly, data were collected using the written task about change in states of matter task to answer the how and what questions. Lastly, data were collected by conducting semi-structured interviews and observations to respond to the why question. The three methods allowed me to comprehend learners' challenges and their causes. Moreover, the methods allowed me to confirm that they exhibit different scientific reasoning skills when given the change in states of matter during observations and semi-structured interviews.

3.7.2 Transferability

I provided rich descriptions of the research site and participants' responses as well as my interpretations to make ensure that lessons can be drawn from the current study (Neyshabur et al., 2020). Thus, to ensure transferability of this study, the results may be cautiously transferable to other classrooms to address the scientific reasoning skills of the change in states of matter. However, I was cautious when interpreting the data of the purposively sampled participants to avoid generalisations. For better management, Justice was used to represent the researcher 's name, and Learner A, B etc were used to represent participants. This enabled me to explore their scientific reasoning skills. Therefore, while using data from the study in other contexts, there might be different opinions and findings due to the strategic sampling chosen.

3.7.3 Dependability

Will other people do similar studies and get similar results? Between-researcher triangulation can be used to study reliability (Bagchi et al., 2019). Audit trails were performed so that other researchers can follow the audit trail created by the original researcher. The research procedures should be well documented to allow others to follow the process. In this study, dependability is attained through an inquiry audit which is a way of examining the process and products of research in the absence of the researcher (Hoepfl, 1997). However, for a detailed explanation of how the data was analysed, it is a priority to conduct an inquiry audit. For instance, in this study, data were analysed by the appointed coders into phases. 1) They read and explored the textual and transcribed data in detail; and 2) they categorised the data based on their similarities and differences. Different categories were coded, and five themes emerged from the codes due to the application of the inductive approach. Thereafter, the data were analysed, and the results were generated for discussion in the current study (Tracy, 2010).

3.7.4 Confirmability

One question to address was: are the findings a product of participants' responses and not the researcher's 'biases, motivations, interests or perspectives? In this study, an audit trail was used to evaluate the findings (Lim et al., 2022). A more transparent display of findings (reflectivity marked) facilitates the assessment of identifiability. In this study, the results are real and can be corroborated by others. There were a number of strategies of enhancing confirmability. I checked and rechecked the data throughout the study. PhET was obtained from the department of education to be used in the learning and teaching of physical science.

3.7.5 Authenticity

This study represents different perspectives on this subject. Hence, it is important to ensure that results are trusted (Lincoln et al., 2011). The originality of the results was verified by the participants. Also, science education practitioners verified the accuracy of the results based on its appropriateness to science education (Valsesia & Diehl, 2022). I did not create my own data; it was collected through two written tasks, observations and semi-structured interviews. The study was worthwhile and contributed to the field of chemistry.

3.8. Ethical consideration

3.8.1 Informed consent, assent and voluntary participants

Informed consent is permission granted in full knowledge of the possible consequences in which learners can give important information, including risks and benefits (Pietrzykowski & Smilowska, 2021). The first letter of permission to request data collection at school was sent to the Department of Education Limpopo Province. Participants were given a request letter prior to the interview so that they can take the time during the interview to indicate whether they would like to participate in this study. The letter was written in such a way that the participants consented to take part in the interviews. Also, the assent form was given to the learners. Assent form is an act of agreeing to something after a thoughtful consideration (Moyer et al., 2022).

3.8.2 Respect, dignity and standard care

Participants were not allowed to use their real names to protect their dignity (Bilginoğlu et al., 2019). Their rights as minors were observed, respecting their decisions and protecting them from harm. Also, efforts were made to secure their well-being. During data collection, learners, colleagues and the principal of the school were respected. Before going to the class, I alerted the teacher who is going to the class after my period not to be surprised when I take some of their minutes due to data collection. To alert the teacher in that manner is to show respect. During the collection of data, I showed that learners are important, and I care about them.

3.8.3. Permission to carry out the study

Permission to get access to an organisation to conduct research in a particular field is important (Quennerstedt & Moody, 2020). Approval obtained from the Limpopo Basic of Education. After obtaining permission, I requested parents of the learners to fill the consent form for permission to use them in the study. I applied for ethical clearance from Turfloop Research and Ethics Committee (TREC). After receiving the letter, I applied for an approval letter from Limpopo department of education. I sent the proposal via email to the department of education and I received the approval letter after 3 weeks of submission. Then, I started collecting data.

3.8.4 Confidentiality and Privacy

Confidentiality and privacy refer to a condition in which a researcher knows the identity of the research subject but takes steps to protect that identity from being discovered by others (Dwork et al., 2020). The participants were guaranteed that their identity will not be revealed by the researcher. Learners and the selected school are referred to as school A and learner A, B, etc. All hard copies of data were handed to the supervisors for safe keeping at the university, and data in soft copies were protected using a password which was known only to the supervisors and myself. Everything related to the collected data was protected by me and my supervisors. I did not discuss with anyone the data collected, but with my supervisors only.

3.8.5 Benefits and harm

Learners participated voluntarily, and can withdraw anytime when they are uncomfortable to continue with the study (Hoffmann & Del Mar, 2017). Participants were given an open explanation of reasons and benefits for participation. They were informed about reasons why they were selected to participate in this research study. I did not promise participants any source of income or finance when conducting the study. Learners were free and aware that they will not receive any award.

3.9 Summary of the chapter

This chapter described the research methodology such as research approach, design, sampling, and how data were collected and analysed. The chapter further discussed the quality criteria and ethical considerations of the study. The next chapter focuses on data analysis and presentation, interpretation of results and discussion.

CHAPTER 4

ANALYSIS, DATA PRESENTATION AND INTERPRETATION OF RESULTS

4.1 Introduction

The previous chapter presented the methodology of the study where the research design, population and sampling techniques, data collection, data analysis, ethical considerations and quality criteria were discussed in detail. This chapter will focus on data analysis, presentation and interpretation of results and discussion. Furthermore, the chapter will be categorised into two parts: analysis, data presentation and interpretation of results and discussion. The main purpose of this study was to explore scientific reasoning skills of state of matter using physics education technology (PhET). Again, three major research questions guided the collection of the data and its analysis. The research questions were: How does the use of PhET explores scientific reasoning skills in characterising the state of matter? What are the learners' scientific reasoning skills of state of matter when using PhET? Why do learners exhibit these particular scientific reasoning skills?

Furthermore, the results obtained were analysed thematically. The data were collected through the use of two written tasks, observations and semi-structured interviews after the usage of physics education technology. Axial coding was used as type of coding. Five (5) themes emerged, namely: 1) appropriate connections between kinetic energy and temperature; 2) ability to analyse and interpret graphs in processes of state of matter; 3) making the correct predictions in state of matter; 4) developing scientific reasoning skills and understanding of the change in states of matter; and 5) inappropriate use of scientific reasoning skills, such as prediction, analysis, interpretation, evaluation and making inferences. Themes were interpreted using a theoretical framework and the literature in chapter 2 to obtain the findings of the study. Task one and task two answered this question: What are the learners' scientific reasoning skills of state of matter when using PhET? The interview transcript answered this research question: Why do learners exhibit these particular scientific reasoning skills?

4.2 Data analysis, first written task

Written task 1 is categorised into sections A and B. The following bar graph is to show that learners' scientific reasoning skills have improved with PhET intervention when writing task 1 section A. As you can see, the "appropriate use of scientific reasoning skills such as prediction, analysis, interpretation, evaluation and making inferences" improved a lot when PhET was used. The themes that were developed when PhET was used are as follows: 1) an appropriate connection between kinetic energy and temperature; 2) ability to analyse and interpret graphs in processes of state of matter; 3) making the correct prediction in state of matter; 4) developing scientific reasoning skills and understanding of the change in states of matter; and 5) inappropriate use of scientific reasoning skills, such as prediction, analysis, interpretation, evaluation and making inferences.

From the bar graph on Figure 4.1 illustrate, there were many learners who developed scientific reasoning skills. Interestingly, they were able to visualise the behaviour of the particles when writing task 1. In questions 1.1.1 to 1.1.5, learners were able to execute scientific reasoning skills since their reasoning showed that they understand the topic, even if some still lacked those scientific reasoning skills after the use of PhET simulation. Learners managed to execute scientific reasoning skills for written task 1. In this way, through the use of PhET, most of them answered question 1.1.1 correctly. Subsequently, from visualisation, I tried to show them the process of states of matter. The particles were closed to each other. When I applied the temperature, the particles started to break and increase kinetic energy of the particles. Furthermore, the states of matter changed from solid to liquid. Now, learners were able to define the melting point as the "temperature at which solid states change to liquid states". Only few learners did not manage to define melting point. They defined it as "solid change to liquid". The definition was not well articulated since they missed that temperature was applied through the breaking of molecules. By the correct definition of melting point, learners were able to execute the skill prediction. This is the reason in the bar graph, the theme making the correct prediction was high in question 1.1.1. The learners answered questions 1.1.2 and 1.1.3 correctly. The question assessed their scientific reasoning skills such as analysis and interpretation. They indicated that the answer for question 1.1.4 is “gas”, which was correct. This showed that they grasped the skill analysis and interpretation in the graph given. Additionally, they managed to interpret that when the temperature increases, the kinetic energy of the particles also increases. This is the reason why they observed that the particles are far away from each other in gas states. Learners managed to answer question 1.1.5 correctly. The question assessed the relationship between the temperature and kinetic energy of the particles. Indeed, they were able to provide the answer as melting for the question. Only few were unable to get the correct answer as it appears in the following graph. Hence, they wrote ‘gas’ as the answer, meaning they are still unable to analyse and interpret the graph. Question 1.1.6 tested if learners can evaluate and make inferences through visualisation from PhET simulation. In fact, they were aware that the temperature was constant and can make the final conclusion from the observation of the behaviour of the particles. The majority of the learners choose unchanged because the temperature was not changing. This is illustrated in the bar graph. All in all, question 1.1.7 tested the arrangement of the particles in different states. To be able to answer the question correctly, they need to develop analysis, interpretation, evaluation and make inferences. Interestingly, in this study most learners understood that an increase in temperature increases the spaces in-between the particles.

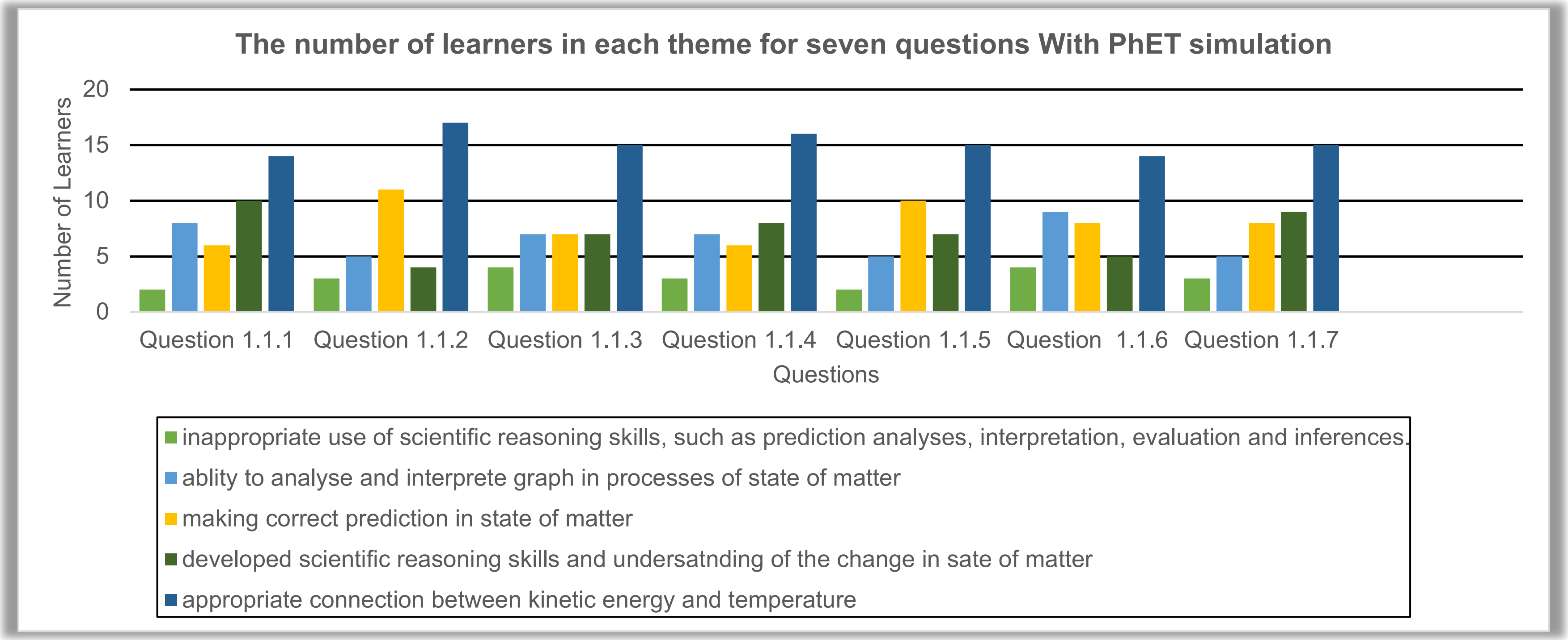


Figure 4.1: A bar graph summarising how learners exhibited scientific reasoning skills in each theme with PhET intervention

Figure 4.2 illustrates the performance of learners in bar graph to show that their scientific reasoning skills have improved with PhET intervention when writing task 1, section B. As you can see, the “appropriate use of scientific reasoning skills such as prediction, analysis, interpretation, evaluation and making inferences” is high. Still, many of them did not leave blank spaces, were able to make predictions and able to analyse when PhET was used. This is because by using PhET simulation, they were visualising the behaviour of the particles when writing all the questions in written task 1, section B. Before the use of PhET, learners were not able to analyse and interpret the graph given. With the use of PhET, they were able to analyse and interpret the graph. For example, from written task 1 section B one of the learners responded in this way:

Justice : Why was question 1.1.5 in written task 1 section A and question 1.2.4 in written task 1 section B were easy for you to answer?

Learner B : Yes the questions were easy for me to answer.

Justice : Why?

Learner B : Now, I can see the effect of temperature on the behaviour of the particles.

Justice : How is the behaviour of the particles?

Learner B : When the temperature increases, the kinetic energy of the particles also increases.

From the transcript above, I wanted to get a bigger picture if learners can execute scientific reasoning skills such as analysis and interpretation when learning through PhET simulation. Indeed, through PhET simulation, they were able to analyse that if the temperature increases, the kinetic energy of the particles also increases. This is the reason many of them in question 1.1.4 from written task section A and 1.2.4 from written task 1 section B got the answers correct respectively as “gas” in both questions 1.1.4 and 1.2.4. The use of PhET helped learners to analyse and interpret the graph. The purpose of the transcript was to evaluate if PhET can help learners to learn and develop analysis and interpretation of the particles when the temperature is applied. Indeed, through the answers received from learners, the use of PhET was useful. Furthermore, questions 1.2.1 to 1.2.8 assess scientific reasoning skills such as prediction, analysis, interpretation, evaluation and making inferences. The graph was given in written task 1 section B to allow learners to apply how particles behave through PhET simulation.

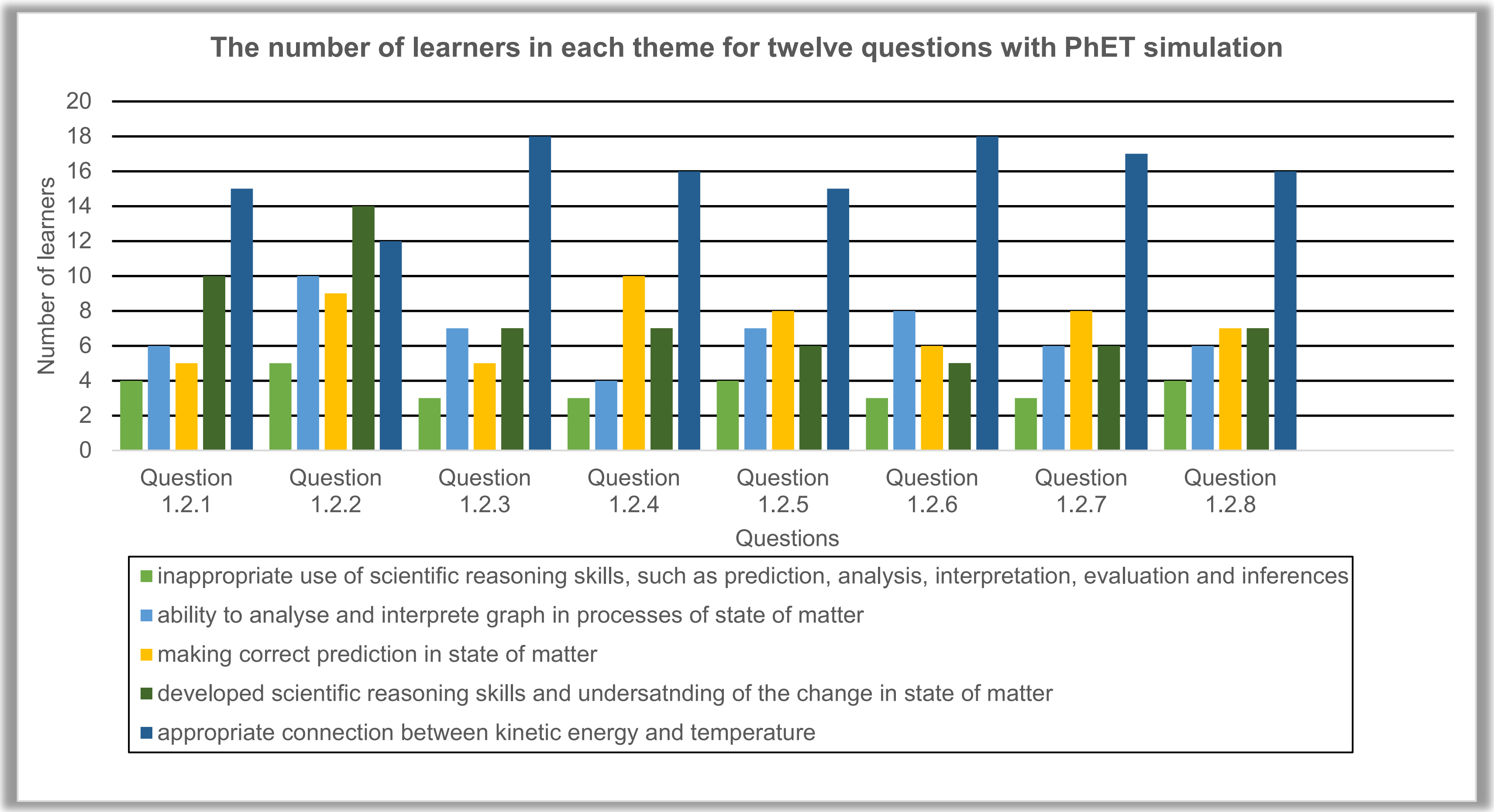
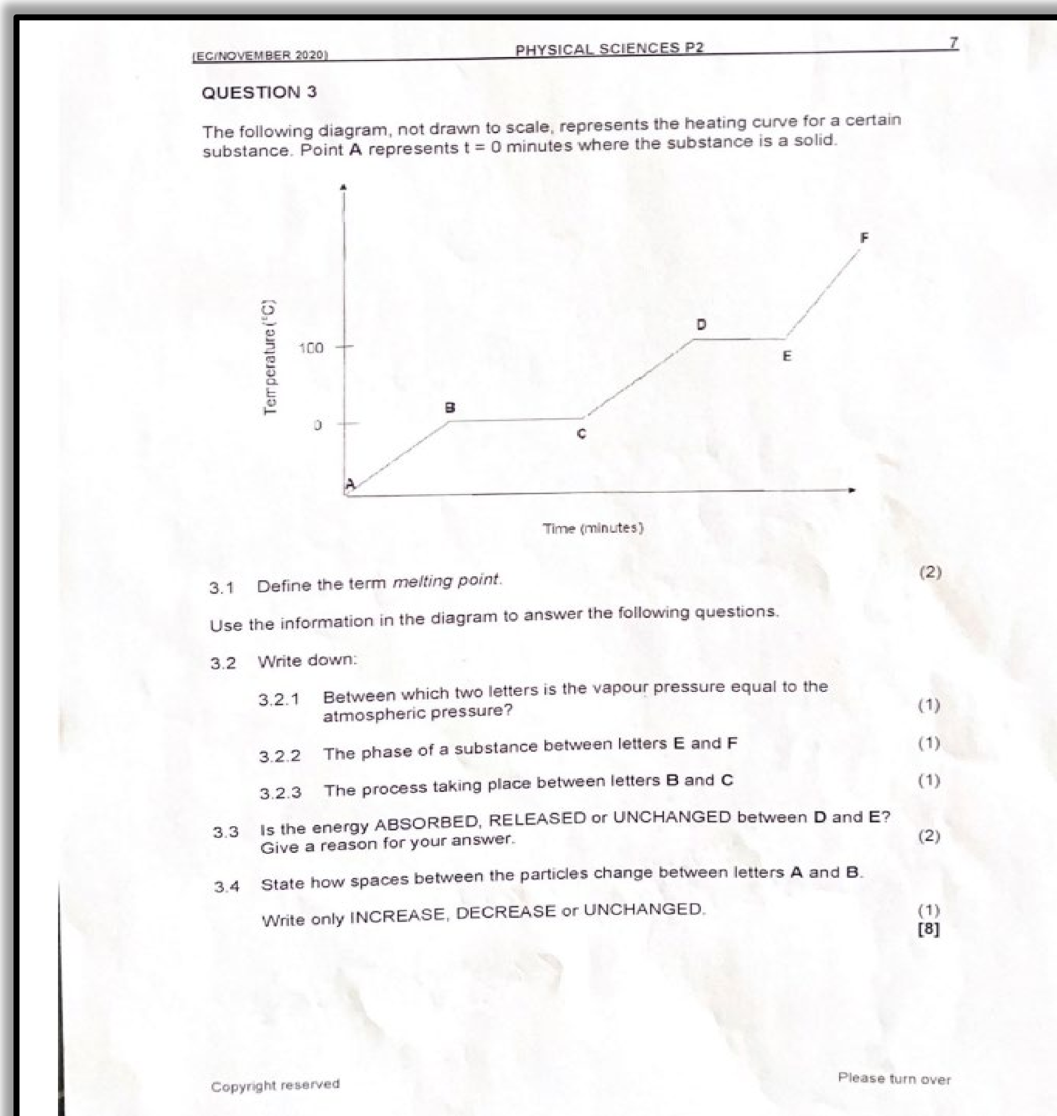


Figure 4.2: A bar graph summarising how learners exhibited scientific reasoning skills in each theme with PhET intervention

The first written task in Figure 4.3 had seven questions. Question 1.1.1 indicated that learners should define the term “melting point”. The purpose of the question was to check if they can understand what is happening when the temperature is increasing on the substance. Subsequently, they should understand that the molecules of the substance break when the temperature is applied. Hence, the arrangement of the particles is loosely packed when the temperature is applied. This should enable learners to explain the melting point as the temperature at which solid states change to liquid states. In questions 1.1.3, 1.1.4 and 1.1.5, learners were supposed to analyse and interpret the graph given to be able to answer the question. Furthermore, they visualised the behaviour of the particles when the temperature was applied on the substance. The question tested if they can apply what have been observed (the behaviour of the particles) using PhET. Hence, learners can be able to analyse and interpret the graph given. The graph shows when the temperature is applied and the states of change from one form to another. Questions 1.1.6. and 1.1.7 of written tasks 1 tested the following scientific reasoning skills: prediction, analysis, interpretation, evaluation and making inferences through the use of PhET simulation. Learners should answer question 1.1.6 as unchanged. Why? They should check the graph to analyse and interpret that the temperature is at constant (not changing) while reasoning scientifically. In question 1.1.7, they should understand the arrangement of the particles in solid, liquid and gas. Through PhET, the arrangement was visualised by learners, and in solid state, the particles were packed together; in liquid the particles were loosely packed, while in gas they were far away from each other. All in all, most learners managed to get the answers correct while few of them did not.

The following was written task 1 section A



(EC/NOVEMBER 2020) PHYSICAL SCIENCES P2 7

QUESTION 3

The following diagram, not drawn to scale, represents the heating curve for a certain substance. Point **A** represents t = 0 minutes where the substance is a solid.

3.1 Define the term *melting point*. (2)

Use the information in the diagram to answer the following questions.

3.2 Write down:

3.2.1 Between which two letters is the vapour pressure equal to the atmospheric pressure? (1)

3.2.2 The phase of a substance between letters **E** and **F** (1)

3.2.3 The process taking place between letters **B** and **C** (1)

3.3 Is the energy ABSORBED, RELEASED or UNCHANGED between **D** and **E**? Give a reason for your answer. (2)

3.4 State how spaces between the particles change between letters **A** and **B**.

Write only INCREASE, DECREASE or UNCHANGED. (1)
[8]

Copyright reserved Please turn over

Figure 4.3: Written task 1, section A with PhET intervention (DBE, 2020)

Table 4.1 illustrates the codes from the data collected through written task 1 sections A and B, semi-structured interviews and observations with PhET intervention. Consequently, from the codes below, most learners were able to execute scientific reasoning skills. Few of them did not execute scientific reasoning skills such as prediction, analysis, interpretation, evaluation and making inferences. The use of PhET helped them to understand the change in states of matter. From the following codes, five themes emerged as: 1) an appropriate connection between kinetic energy and temperature; 2) ability to analyse and interpret graphs in processes of state of matter; 3) making correct predictions in state of matter; 4) developing scientific reasoning skills and understanding of the change in states of matter; and 5) inappropriate use of scientific reasoning skills, such as prediction, analysis, interpretation, evaluation and making inferences. Furthermore, the data was analysed and informed by the themes emerging from the coded data. The tables of codes sequentially follow each other from written task 1 sections A and B, semi-structured interviews and observations.

The coding scheme below was done in this way; learners wrote the written task and the scripts were collected for marking purposes. The scripts were categorised and classified into groups according to the scientific reasoning skills exhibited by learners. After the coding, themes emerged from the data. The coding was done per each question in the written task. The first category and classification of learners' script and interview transcripts were grouped as learners who did not leave any space while writing the written task and coded as FFM in each question in written task 1. Furthermore, the theme that emerged out of the code was developing scientific reasoning skills and understanding of the change in states of matter. The second category and classification of learners' scripts and interview transcripts were grouped as learners who found the correct relationship between temperature and the behaviour of the particles. It was coded as GGM per each question in written task 1. The theme that emerged made the correct prediction in state of matter. The third category and classification were coded as TTM and the theme developed on the code was able to analyse and interpret graphs in processes of state of matter. Hence, the theme was developed because many learners were able to analyse and interpret the graph as cooling and heating curve, and the arrangement of the particles when temperature is applied. In the fourth category and classification, learners were coded as HHM. For this code, they were able to articulate all scientific reasoning skills of this study. For example, in written task one in question 1.1.6, "Is the energy absorbed, released or unchanged between D and E?" Give a reason for your answer. Many learners classified in HHM were able to get the correct answer by just checking the temperature vs time graph. When the temperature increases, the kinetic energy of the particles also increases. Through the use of PhET simulation, learners were able to execute scientific reasoning skills when writing written task 1. Lastly, the category was coded as IIM per each question. In this category, learners were unable to execute scientific reasoning skills. Even if PhET was used, it was difficult for them to get the correct answers. From the definition of melting and arrangement of the particles, learners did not understand the concept. This formed the theme of inappropriate use of scientific reasoning skills such as prediction, analysis, interpretation, evaluation and making inferences.

Table 4.1: Written task 1, codes from learners' responses in question number 1.1.1, 1.1.2, 1.1.3, 1.1.4 and 1.1.5

Questions	***Coding learners' responses, first written task**, observation and semi- **structured interview***				
Themes emerged from the data	**Theme 1: Appropriate connection between kinetic energy and temperature**	**Theme 2: Ability to analyse and interpret a graph in processes of state of matter**	**Theme 3: Making correct predictio n in state of matter**	**Theme 4: Developing scientific reasoning skills and Understanding of the change in states of matter**	**Theme 5: Inappropriate use of scientific reasoning skills such as prediction, analysis, interpretation, evaluation and making inferences.**
1.1 Write **1.1.1 Between which two letters is the vapour pressure equal to the atmospheric pressure** **1.1.2 The phase of a substance between letter E and F**	**FFM312:** Able to master the concept, paying attention, clue (having an idea) of what to do), willing to think.	**GGM312:** Correct relationship between the temperature applied and the behaviour of the particles, ability to infer and evaluate.	**TTM312:** Ability to interpret the given graph in states of matter.	**HHM312:** Appropriate to provide reasons for the answers chosen, and Able to analyse the given graph and to tell the process taking place on the given graph.	**IIM312:** Inappropriate to find the relationship between the temperature applied and the behaviour of the particles also the process taking place on the given graph.
1.1.3 The process taking place between letters B and C	**FFM323**: Able to define Process taking place, able to analyse the graph, recalling process of states of matter.	**GGM323:** Correctly, to check if the graph is cooling curve or heating curve, correctly interpreting the graph given.	**TTM323:** Ability to reason scientifically, due to visualisation.	**HHM323:** Appropriately, to analyse the given graph, and to tell the process taking place on the given graph and able to prediction.	**IIM323:** Inappropriate to analysis, interpretation, and evaluation to be able to draw the conclusion.

1.1.4 Is the energy ABSORBED, RELEASED OR UNCHANGED BETWEEN D and E? Give a reason for your answer	**FFM33:** Able to find relationship between temperature applied and kinetic energy of the particles.	**GGM33:** Correct implementation of scientific reasoning skills such as prediction, analysis, interpretation and evaluation.	**TTM33:** Ability to provide reasons due to the observing of the movement of the particles.	**HHM33** Appropriate to articulate scientific reasoning skills, and to characterise states of matter as solid, liquid and gas.	**IIM33:** Inappropriate, to articulate scientific reasoning skills and to characterise three states of matter.
1.1.5 State how spaces between the particles change between letters A and B. Write increase, decrease or unchanged	**FFM34:** Able to understand the behaviour of particles.	**GGM34:** Correct, use of scientific reasoning skills, randomly choosing the answer due to lack of visualisation.	**TTM34:** Ability to answer, inability to recall, what is the heating curve.	**HHM34:** Appropriate to perform experiment related to the written task given, and lack of analyses	**IIM34:** Inappropriate to improvise (using experiments) related to the written task given

Figure 4.4 illustrate written task 1 section B. The purpose of the task was to check if learners can execute scientific reasoning skills. In question 1.2.1, they were expected to define “sublimation” as a way of preparing them to answer the rest of the question in written task 2. They were expected to answer question 1.2.1 as the change in which the solid states change to gas states. In question 1.2.2, they were expected to use the knowledge relating to when the temperature increases, it breaks the molecule of the substance. Question 3.3 tested if they can analyse and interpret the graph by just checking on it to see that the temperature in the graph is decreasing. But the graph ended up being a cooling curve. In question 1.2.4, they were supposed to check the temperature at substance X, and thereafter decide on the phase of the substance. In that way, they will be analysing and interpreting the graph of the change in states of matter. In question 1.2.4.1, they were supposed to check that the temperature is very low then the states can be solid. In question 1.2.5 they were supposed to recall what condensation is. Furthermore, in question 1.2.6, they were supposed to make inferences; after observing the behaviour of the particles, they should draw conclusions about the arrangement of the particles. In question 1.2.7, they were supposed to recall the temperature of water at room temperature while comparing it with the temperature in the graph. In question 1.2.8, skills such as analysis, interpretation and evaluation need to be exhibited since this is a high cognitive question.

The following was written task 1 section B

Physical Sciences P2 6 September 2019 Common Test

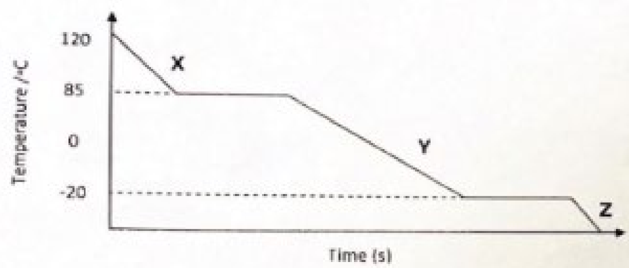
Grade 10

QUESTION 3

3.1 Define ***sublimation***. (2)

3.2 When you take a block of margarine out of the fridge, it is hard. However, after 30 minutes at room temperature it is soft enough to spread. Use kinetic molecular theory to explain this observation? (2)

The diagram below, not drawn to scale, shows the physical changes of a substance at atmospheric pressure.



3.3 Is the diagram above showing a COOLING or HEATING curve? (1)

3.4 Name phase(s) of the substance at:

3.4.1 Point **X** (1)

3.4.2 -20 °C. (2)

3.5 Write down the stage of this substance at 85 °C. (1)

3.6 Write down the particle arrangement of this substance at:

3.6.1 Point **Z** (2)

3.6.2 Point **Y** (2)

3.7 The above substance is not water. By referring to the diagram, explain why this curve does not represent water? (2)

3.8 What happens to the temperature of the substance during a PHASE CHANGE? Write down only INCREASES, DECREASES or REMAINS THE SAME. Give a REASON for the answer. (2)

[17]

Figure 4.4: Written task 2, section B with PhET intervention (DBE, 2019)

Table 4.2 illustrates the coding scheme for written task 1, section B. Vignettes were categorised and classified into groups according to the scientific reasoning skills exhibited by learners. After the coding, themes emerged from the data. The coding was done per each question in written task 1, section B. The first category and classification of the learners' scripts and interview transcripts were grouped in terms of similar characteristics. Subsequently, the themes that emerged from the coded emerged. Learners were able to find the effect of temperature on the change in states of matter. This is the reason why when the graph is given, it was easy for them to analyse and interpret referring to the decrease and increase in the temperature due to the visualisation from PhET simulation. The classification of scripts, interview transcripts and observations were coded as OOM per each question of written task 1 section B. The theme that emerged in this coded data had to do with making the correct prediction in state of matter. Thirdly, the data was coded as TTM, and the theme that emerged out of the code is: ability to analyse and interpret graphs in processes of state of matter. The fourth code was coded as PPM, and the theme that emerged was as follows: an appropriate connection between kinetic energy and temperature.

Furthermore, the fifth code in this written task was coded as UUM, and the emergent theme from the code was as followed: inappropriate use of scientific reasoning skills such as prediction, analysis, interpretation, evaluation and making inferences. The scripts were collected, transcript interviews and observation schedules were categorised and analysed in order to come with the theme. In terms of undocumented reasoning in the change of states of matter, some of the learners were not able to write the answer due some reasons. Through interview, I found that some learners did not give enough time to think related to the question posed. Others failed to execute scientific reasoning skills such as prediction, analysis, interpretation, evaluation and making inferences. Others were unable to visualise the behaviour of the particles, and there were those who indicated that the topic was too abstract.

In responses in the written task section B, learners were unable to connect kinetic energy of the particles with the temperature applied. In question 1.2.2 in the block of margarine was directed to the sun, learners were supposed to connect temperature with kinetic energy of the particles. Few learners failed to understand that the increase in temperature is proportional to the increase in the kinetic energy of the particles. In short, they were only imagining the process without putting it in to practice because they cannot see the particles with the naked eye. They know that the block of margarine will melt but related to the particles and molecules, they did not have the idea. The cause of the misunderstanding to connect the temperature applied with the kinetic energy of particles is the lack of scientific reasoning skills.

Table 4.2: Written task 1 section B, codes from learners' responses in question number 1.2.1, 1.2.2, 1.2.3, 1.2.4, 1.2.5, 1.2.6, 1.2.7, and 1.2.8

Questions	***Codes from learners' response of second written task****, observation* ***and semi- structured interview.***				
Themes emerged from the data when PhET was used	**Theme 1: Appropriate connection between kinetic energy and temperature**	**Theme 2: Ability to analyse and interpret a graph in processes of state of matter**	**Theme 3: Making correct prediction in state of matter**	**Theme 4: Developing scientific reasoning skills and Understanding of the change in states of matter**	**Theme 5: Inappropriate use of scientific reasoning skills such as prediction, analysis, interpretation, evaluation and making inferences.**
1.2.1 Define Sublimation	**ZZM31:** Able to think, grasping concept, paying attention, having an idea of what to do, willing to think and able to reason scientifically.	**OOM31:** Correct relationship between the temperature applied and the behaviour of the particles, Able to infer and evaluate.	**TTM31:** Ability to interpret the given graph in states of matter.	**PPM31:** Appropriately to provide reasons for the answers chosen, and able to analyse the given graph (Able to tell the process taking place on the given graph).	**UUM31:** Inappropriate to find the relationship between the temperature applied and the behaviour of the particles also the process taking place on the given graph.
1.2.2 When you take a block of margarine out of the fridge, it is hard. However, after 30 minutes at room temperature it is soft to spread. Use kinetic molecular theory to explain this observation	**ZZM32:** Able to analyse the graph, recalling process of states of matter.	**OOM32:** Correctly, to check if the graph is cooling curve or heating curve, correctly interpreting the graph given.	**TTM32:** Ability to reason scientifically, due to availability of observation and visualisation.	**PPM32:** Appropriate to analyse the given graph (able to tell the process taking place on the given graph and ability of prediction.	**UUM32:** Inappropriately, analysis, interpretation, and evaluation to be able to draw the conclusion.

1.2.3 Is the diagram above showing a cooling or heating curve	**ZZM33:** Able to relationship between temperature applied and kinetic energy of the particles.	**OOM33:** Correct implementation of scientific reasoning skills such as prediction, analysis, interpretation and evaluation.	**TTM33:** Ability to provide reasons due to the availability of observing the movement of the particles.	**PPM33:** Appropriate to articulate scientific reasoning skills, and inability to characterise states of matter as solid, liquid and gas.	**UUM33:** Inappropriately to articulate scientific reasoning skills and to characterise three states of matter.
1.2.4 Name phases of the substance at: **1.2.4.1 Point X** **1.2.4.2 -20 °c**	**ZZM34:** Able to understand the behaviour of particles.	**OOM34:** Correct use of scientific reasoning skills, choosing correct answer due to visualisation.	**TTM34:** Ability to recall, what is the heating curve.	**PPM34:** Appropriate to perform experiment related to the written task given, and lack of analyses.	**UUM34:** Inappropriate to improvise (using experiments) related to the written task given.
1.2.5 Write down the stage of this substance at 85 °c	**ZZM35:** Able to develop scientific reasoning skills or having enough knowledge.	**OOM35** correct answer, comprehensible, correct answer.	**TTM35:** Ability to perform experiment related to the written task given, and able analyses.	**PPM35**: Appropriate use of scientific reasoning skills.	**UUM35:** Inappropriate use of scientific reasoning skills
1.2.6 Write down the particle arrangement of this substance at: **1.2.6.1 Point Z** **1.2.6.2 Point Y**		**OOM36:** Correctly to analyse graph, due to visualisation.	**TTM36:** Ability to interpret the change in states of matter, clearly differentiating three states of matter without guessing.	**PPM36:** Appropriate response, with the idea of arrangement of the particles in three different states of matter.	**UUM36:** Inappropriately exhibited scientific reasoning skills accordingly.
1.2.7 The above substance is not water. By referring to the diagram, explain why this curve does not represent water?	**ZZM37**: .	**OOM37:**	**TTM37:** Ability to Interpret of the change in states of matter, without confusing three different states of matter.	**PPM37:**	**UUM37:**

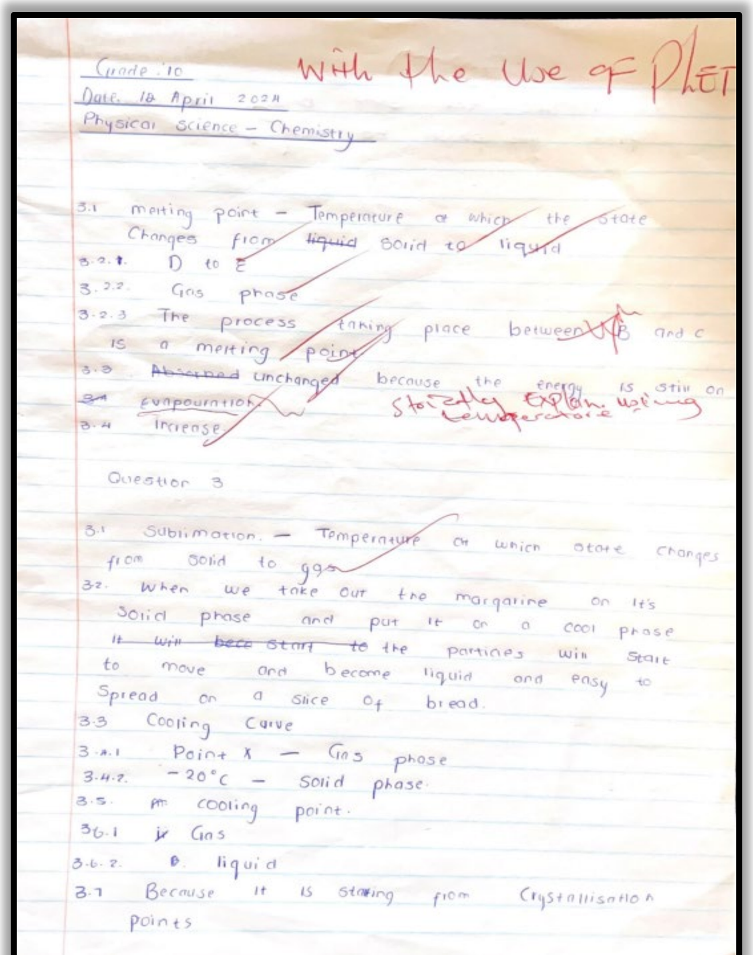
1.2.8 What happens to the temperature of the substance during a phase change? Write down only increase, decrease or remains the same. Give a reason for the answer	**ZZM38:** Able to write, even if the question is in high cognitive level, thinking clearly, no Blank spaces for various reasons.	**OOM38:** Correctly to find the relationship between temperature and the behaviour of the substance.	**TTM38:**	**PPM38:**	**UUM38:** Inappropriate to find the relationship between temperature and the behaviour of the substance.

The following themes are for written task 1 sections A and B, semi- structured interview and observation after the use of PhET simulation

4.2.1 Theme 1: Appropriate connection between kinetic energy and temperature

Learners were able to observe the behaviour of particles. From learners' scripts, they answered question 1.2.6 from written 1 section B correctly. For example, they managed to get the arrangement of the particles while the temperature was decreasing. They indicated that when the temperature decreases, even the behaviour of the particles decreases. Subsequently, they provided that the states of matter change from gas to liquid and liquid to solid when the temperature decreases. Furthermore, in written task 1, they were able to observe that when the temperature increases, the kinetic energy of the particles also increases. Hence, they were able to indicate that when the temperature increases, the states change from solid to liquid and liquid to gas. They end up providing the answer for question 1.1.5 from written task 1 section A as gas which was correct. More importantly, learners provided that the reason for the temperature is directly proportional to kinetic energy of the particles. Interestingly, the temperature affected the arrangement of the particles to change the states of matter from one form to another. For example, solid to liquid. Thus, by using PhET simulation, learners were able to find the relationship between the behaviour of the particles when the temperature is applied. Now, the particles are in motion when the temperature is applied. They were able to conclude by checking the arrangement of the particles. By using PhET, they develop scientific reasoning skills such as analysis and interpretation. Their reasoning was based on what was observed. By so doing, the change in states of matter was easy to learn.

The following vignettes from written tasks 1 sections A and B show the improvement of learners on the relationship between the behaviour of the particles and the temperature applied.

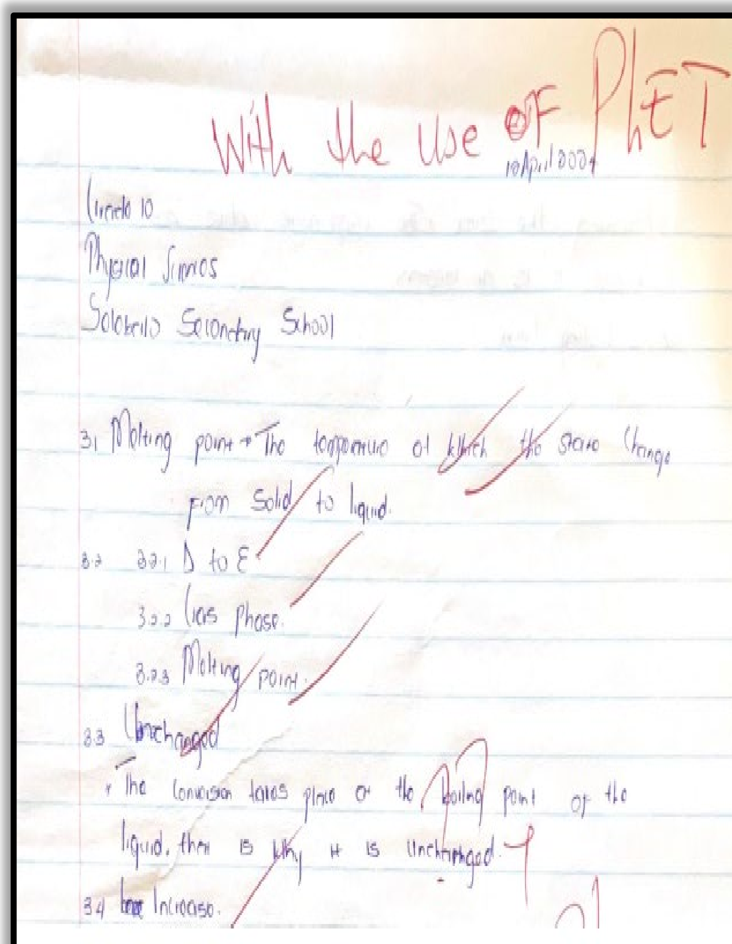

Grade : 10
Date. 18 April 2024
Physical Science – Chemistry

3.1 melting point – Temperature at which the state Changes from ~~liquid~~ Solid to liquid
3.2.1. D to E
3.2.2. Gas phase
3.2.3 The process taking place between B and C is a melting point
3.3 ~~Absorbed~~ unchanged because the energy is still on
~~3.4~~ evapouration
3.4 increase

Question 3

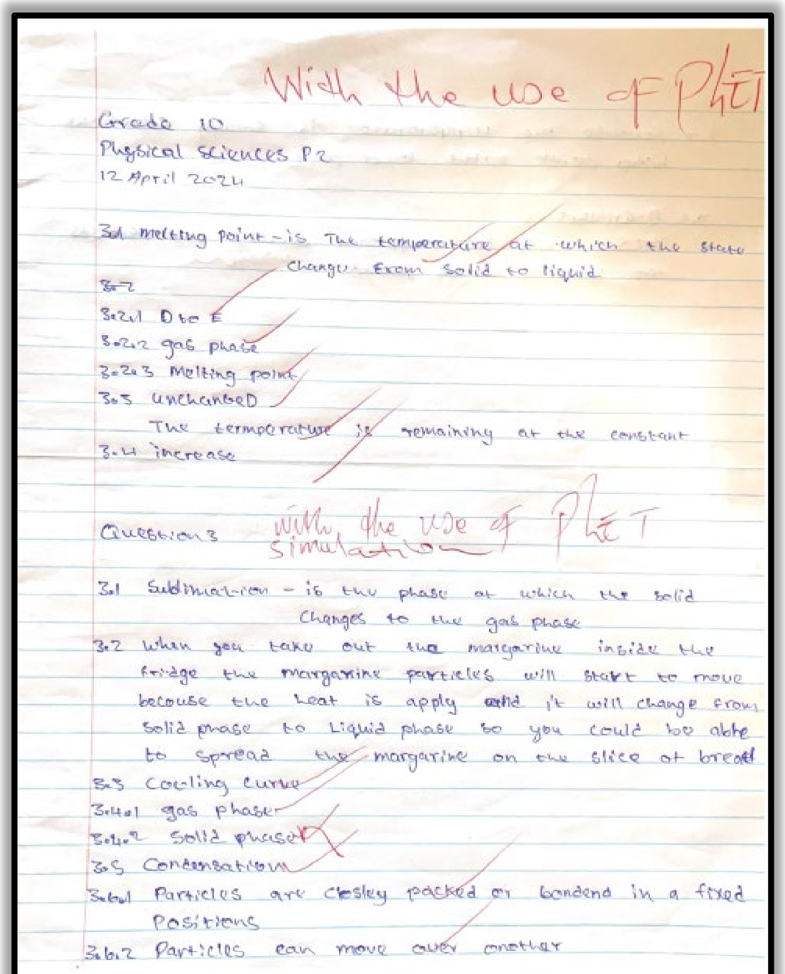
3.1 Sublimation – Temperature at which state changes from Solid to gas
3.2. When we take out the margarine on it's Solid phase and put it on a cool phase ~~it will beco start to~~ the particles will start to move and become liquid and easy to Spread on a slice of bread.
3.3 Cooling Curve
3.4.1 Point X – Gas phase
3.4.2. –20°C – Solid phase.
3.5. ~~m~~ cooling point.
3.6.1 ~~V~~ Gas
3.6.2. ~~B~~ liquid
3.7 Because it is starting from Crystallisation points

Figure 4.5a: Learner D section A and B response


With the use of PhET
18 April 2024
Grade 10
Physical Sciences
Solobelilo Secondary School

3.1 Melting point – The temperature at which the state change from Solid to liquid.
3.2 3.2.1 D to E
3.2.2 Gas phase.
3.2.3 Melting point.
3.3 Unchanged
– The conversion takes place at the boiling point of the liquid, that is why it is unchanged.
3.4 ~~too~~ Increase.

Figure 4.5b: Learner B section A response



With the use of PhET

Grade 10
Physical sciences P2
12 April 2024

3.1 melting point - is The temperature at which the state change from solid to liquid
3.2
3.2.1 D to E
3.2.2 gas phase
3.2.3 Melting point
3.3 unchanged
The temperature is remaining at the constant
3.4 increase

Question 3 With the use of PhET simulation

3.1 Sublimation - is the phase at which the solid changes to the gas phase
3.2 when you take out the margarine inside the fridge the margarine particles will start to move becouse the heat is apply and it will change from solid phase to Liquid phase so you could be able to spread the margarine on the slice of bread
3.3 Cooling curve
3.4.1 gas phase
3.4.2 Solid phase
3.5 Condensation
3.6.1 Particles are closley packed or bondend in a fixed positions
3.6.2 Particles can move over another

Figure 4.5c: Learner W section A and B response

Figure 4.6 shows how learners used PhET to find the relationship between the behaviour of the particles and the temperature applied. They adjusted the temperature by increasing and decreasing it. Below it shows the decrease in temperature. Now, the particles are closely packed and are clear in the graph given. When learners increased the temperature, the particles started to be loosely packed to form liquid states. Again, when they kept on increasing the temperature, the state changed to gas states. PhET simulation helped them to learn better since the change of states of matter is too abstract in nature. Additionally, the pressure is directly proportional to the applied. Learners were to visualise this with the naked eye.

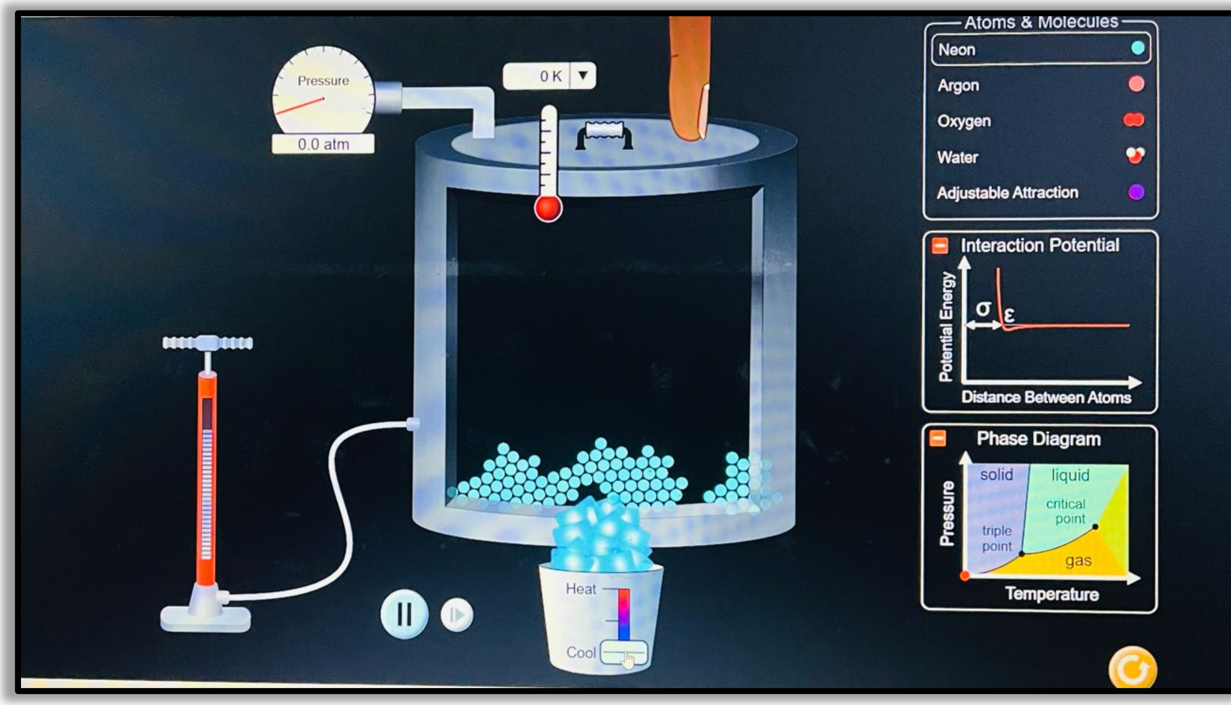


Figure 4.6: PhET simulation, the relationship between the behaviour of the particles and temperature (decreased)

Justice : Can you please explain the effect of temperature on the kinetic energy of the particles?

Learner W : When the temperature was decrease, the kinetic energy of the particles also decreased.

Justice : Good, how did you know the arrangements of the particles?

Learner W : Through PhET simulation, it was easy to observe the behaviour of the particles in solid, liquid and gas.

Justice : Do you mean PhET was useful in learning the change of states of matter?

Learner W : Yes PhET made the topic and the questions from written task 1, section A and B simple.

Justice : Why do you say that?

Learner W : I was able to see the particles with my naked eye.

Justice W : Okay, I get it.

From the interview transcript, I can tell that PhET simulation helped learners to learn the change in states of matter. Similarly, from learners' vignette, it was easy for them to execute scientific reasoning skills such as analysis and interpretation. Hence, their skills developed because they can now observe the kinetic energy of the particles and relate it with temperature. Also, when the temperature decreases, they can make a final judgement on the states of matter by observing the behaviour of the particles. The reason for them to execute analysis and interpretation as a skill when the temperature is increasing is because they do it practically while observing the behaviour of the particles.

Animation Figure 4.7 shows that when the temperature increases, the behaviour of the particles gains kinetic energy. This is the reason the behaviour of the particles in Figure 4.6 is not the same as the particles in Figure 4.7. In Figure 4.6, the temperature decreases and the particles take the states of solid. While in Figure 4.7, the temperature is increased and the particles take the liquid states. From the vignette below, learners were able to observe that when the temperature is high, the kinetic energy of the particles is also high. If you can check in Figure 4.6 and Figure 4.7, the temperature in Figure 4.6 was 0K and in Figure 4.7, it was 53K. Additionally, learners were taught how to change the temperature from kelvins to degrees Celsius (1K=-272.15). Because PhET uses kelvins to avoid confusion to the learners. All in all, learning through PhET simulation helped them to get the correct relationship between kinetic energy of the particles and the temperature.

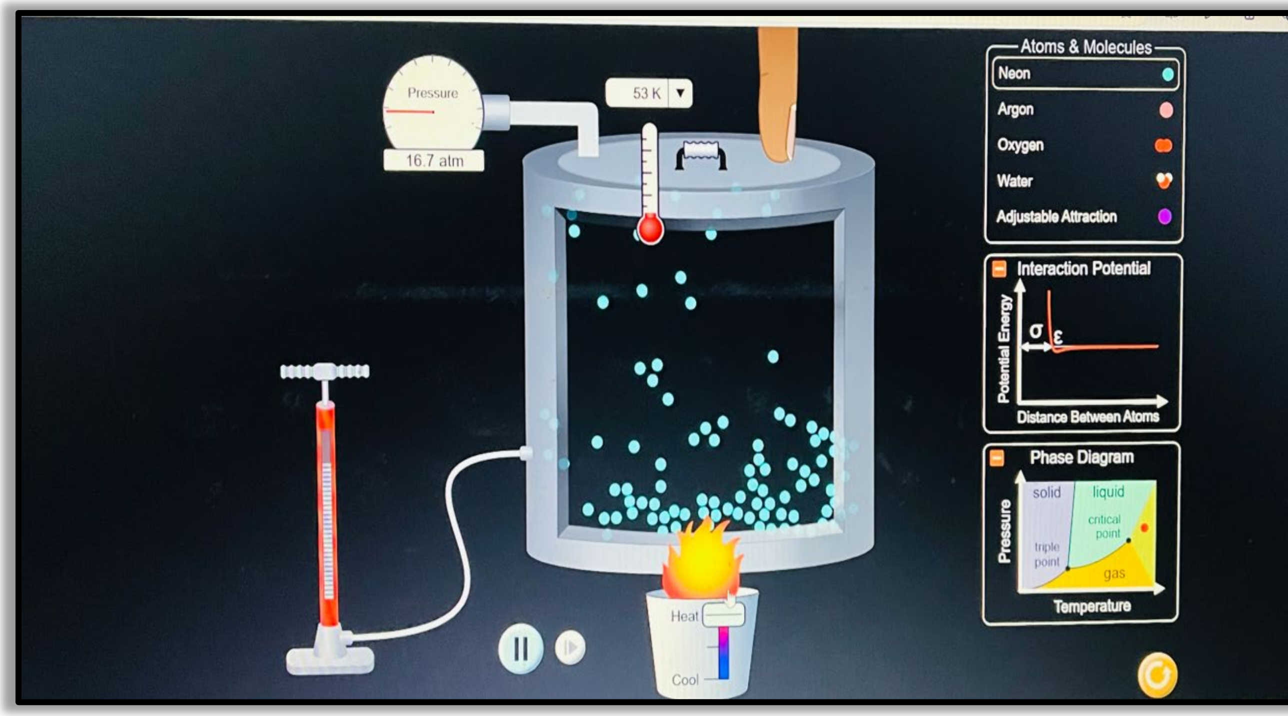
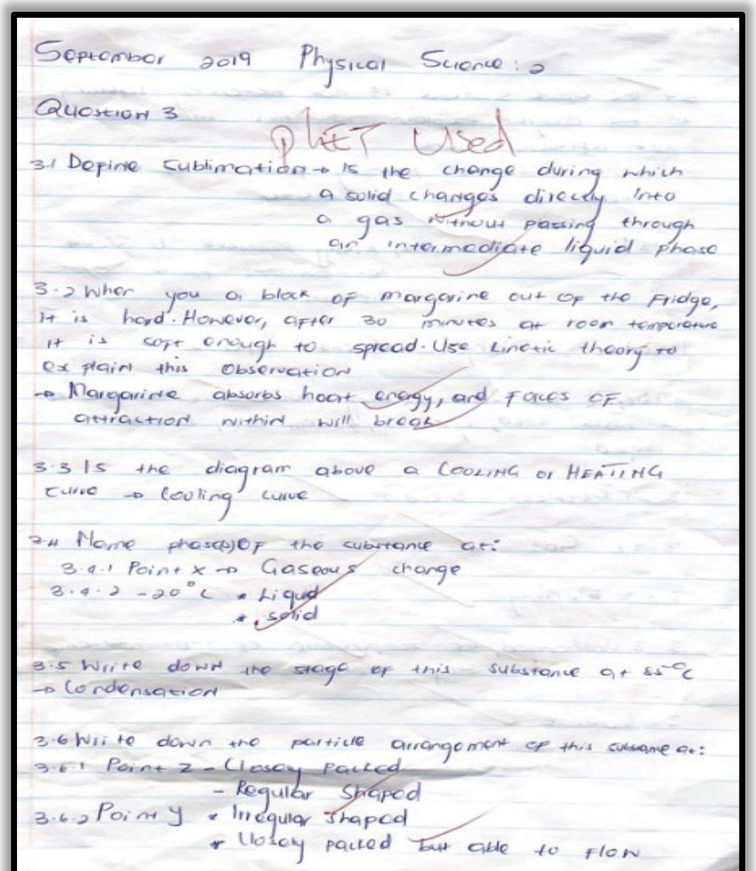


Figure 4.7: PhET simulation, the relationship between the behaviour of the particles and the temperature (Increased)

4.2.2 Theme 2: Ability to analyse and interpret a graph in processes of states of matter



September 2019 Physical Science: 2

Question 3

3.1 Define sublimation → is the change during which a solid changes directly into a gas without passing through an intermediate liquid phase

3.2 When you a block of margarine out of the fridge, it is hard. However, after 30 minutes at room temperature it is soft enough to spread. Use kinetic theory to explain this observation

→ Margarine absorbs heat energy, and forces of attraction within will break

3.3 Is the diagram above a COOLING or HEATING curve → cooling curve

3.4 Name phase(s) of the substance at:

3.4.1 Point x → Gaseous change

3.4.2 -20°C • Liquid • solid

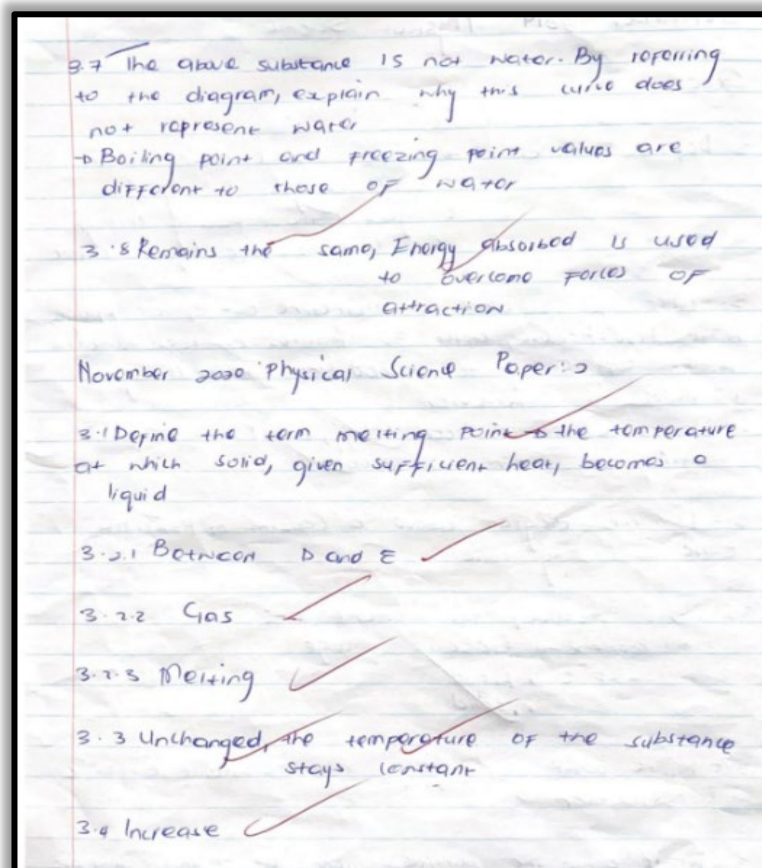
3.5 Write down the stage of this substance at 55°C → Condensation

3.6 Write down the particle arrangement of this substance at:

3.6.1 Point z – Closely packed – Regular shaped

3.6.2 Point y • Irregular shaped • Closely packed but able to flow

Figure 4.8a: Learner H Section A response



3.7 The above substance is not water. By referring to the diagram, explain why this curve does not represent water

→ Boiling point and freezing point values are different to those of water

3.8 Remains the same, Energy absorbed is used to overcome forces of attraction

November 2020 Physical Science Paper: 2

3.1 Define the term melting point → the temperature at which solid, given sufficient heat, becomes a liquid

3.2.1 Between D and E

3.2.2 Gas

3.2.3 Melting

3.3 Unchanged, the temperature of the substance stays constant

3.4 Increase

Figure 4.8b: Learner J section A response

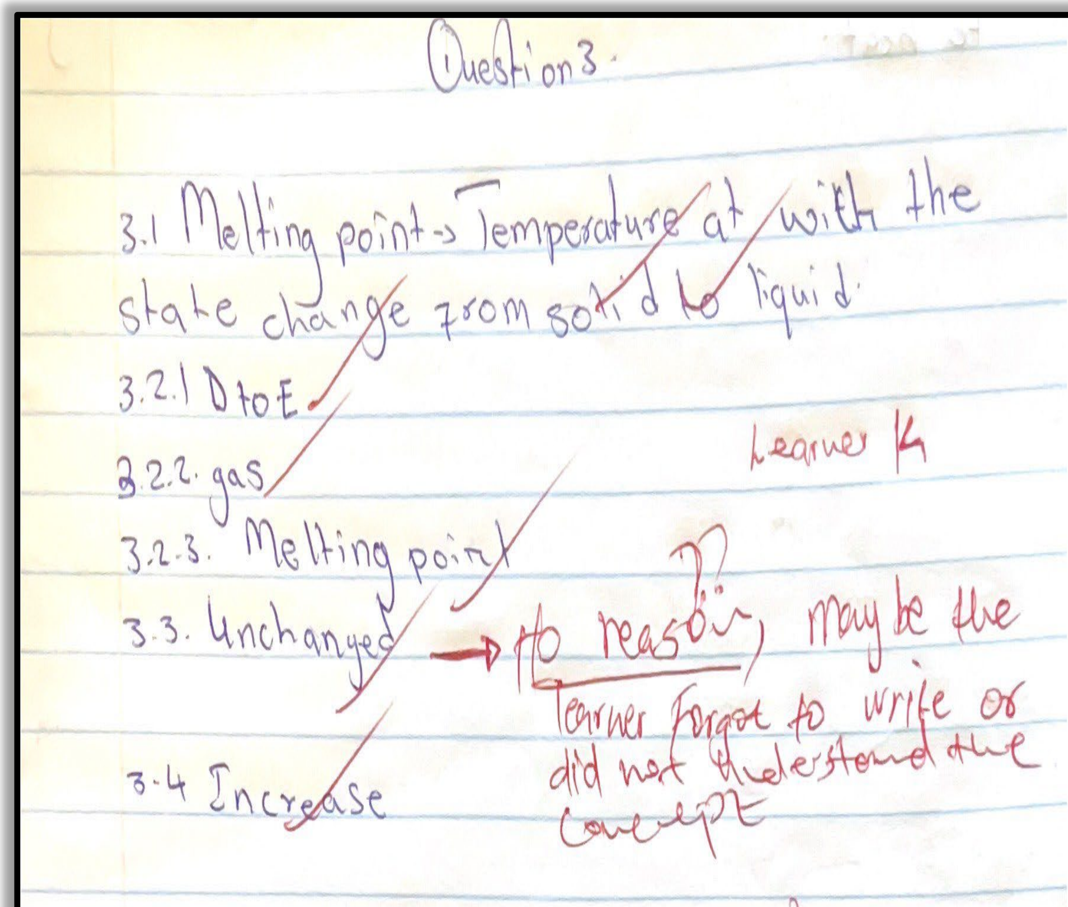


Figure 4.8c: Learner K Section A response

With the use of PhET simulation, learners were able to analyse and interpret the graph in processes of states of matter. They were able to spot if the graph is cooling curve or heating curve. On the one hand, they were able to define the sublimation and melting point by just analysing the graph. On the other hand, they were able to interpret the graph by indicating when the phase changes from one form to another. For example; "solid to gas". From the use of PhET, the following vignette helped them to develop scientific reasoning skills such as analysis and interpretation, because they were able to reason out by noticing that the graph is for cooling and heating curve. As you can see, there is speed, temperature and kinetic energy, the behaviour of the particles and pressure. Learners were able to observe how the variables are related. This is the reason they were able to apply the knowledge acquired from this visualisation in written task 1 sections A and B. Through the visualisation, the behaviour on the particles is not the same as the one on the vignette below. The reason is that when you increase the temperature, learners were able to see that the behaviour of the particles or kinetic energy also increases. The same thing, when the temperature decreases, the behaviour of the particles or kinetic energy also decreases. Furthermore, many learners were able to notice that the temperature affected the behaviour of the particles. This is the reason it was easy for them to understand different states of matter from the graph in written tasks 1 and 2. Hence, learners developed scientific reasoning skills such as analysis and interpretation because of the visualisation of the particles when the temperature is increased or decreased.

Justice : Through observation, how can you explain the behaviour of particles?

Learner J : When the experiments started, the particles were packed together.

Justice : What do we call that states?

Learner J : Solid.

Justice : Why?

Learner J: At the beginning, I did not apply the temperature, the ice was formed.

Justice : What did you observe when I started increasing the temperature?

Learner J : The particles started to move….

Justice : Good, when the particles started to move it means the phase changes from solid to liquid.

Learner J : OOHHHH, with the peers in the class started to understand the topic "change in states of matter".

Justice : Asking group of learners, what happens when I keep increasing the temperature?

Learner J with his classmates: The phase will change to gas now, the particles are far away from each other.

Justice : Good.

From the transcript above, learners were able to interpret the question for written task 1 sections A and B because they applied what was seen with the naked eye. They indicated that from both graphs in written task 1 sections A and B, they were able to interpret when the temperature increases and decreases. Furthermore, they indicated that when the temperature increases or decreases, it affected the change in states of matter. This is the reason they were able to answer the questions correctly with the intervention of PhET simulation. To analyse and interpret the graph of processes of states of matter was easy in written task 1 sections A and B. Briefly, PhET made the learning of change in states of matter less abstract. Thus, the theme that emerged from the collected data was ability to analyse and interpret a graph in processes of states of matter. Additionally, it was coded as TTM for written task 1, sections A and B.

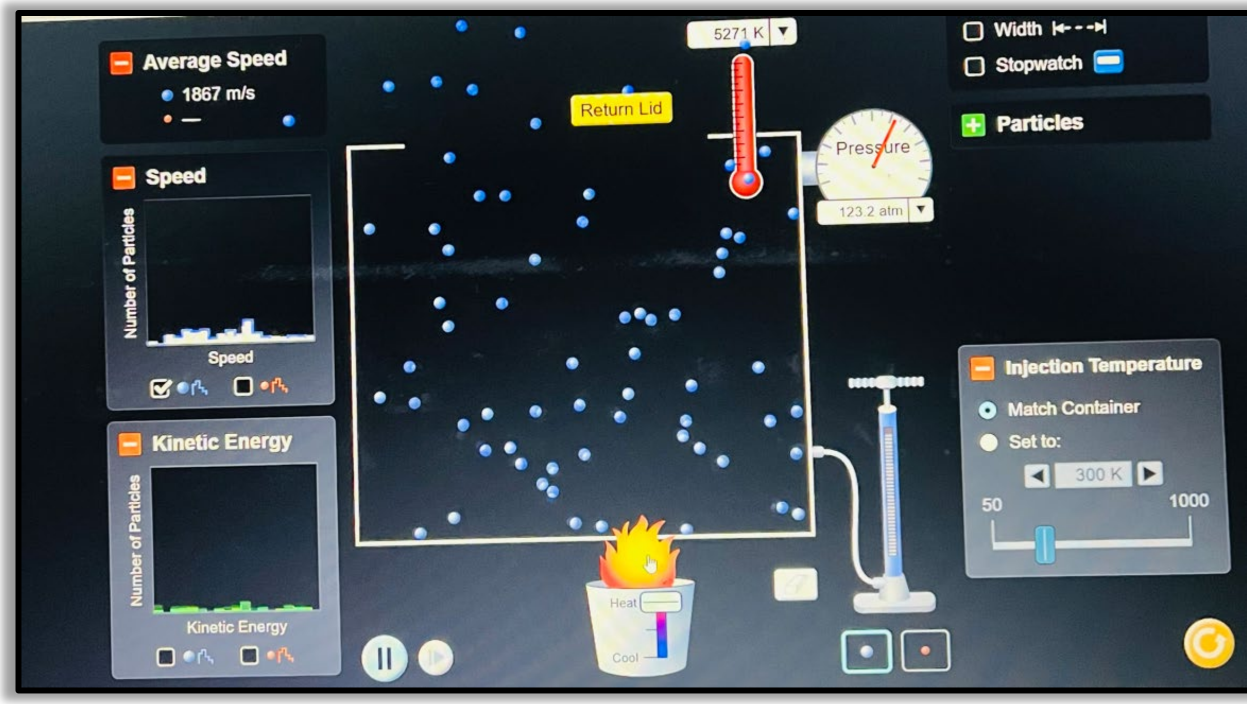
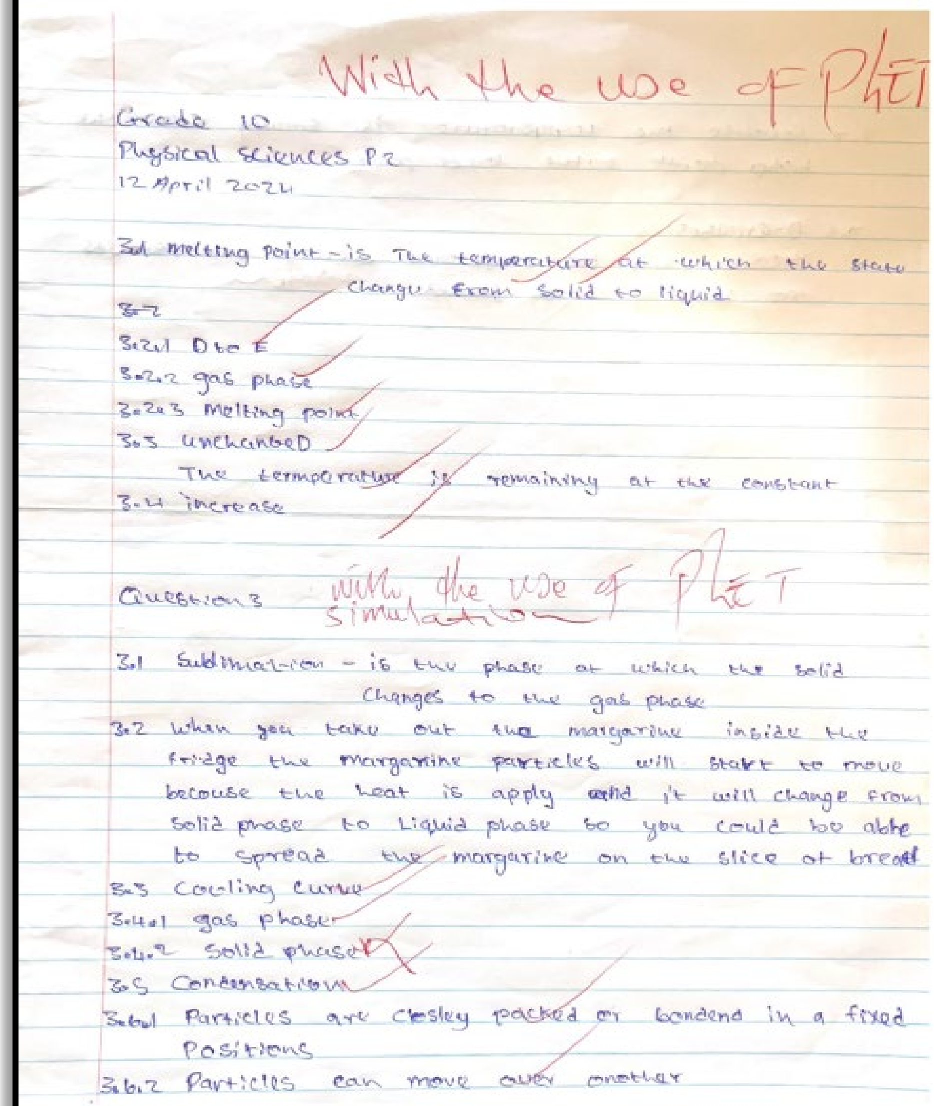


Figure 4.9: The relationship between temperature, pressure, speed of the particles, kinetic energy

Figure 4.9 is an animation that helped learners to reason scientifically. Concerning when you keep increasing the temperature, the states of matter can change from solid to liquid and liquid to gas. From written task 1, sections A and B, learners were allowed to give the states of matter when the temperature was increasing in the graph. Indeed, through PhET simulation, they were able to notice that the temperature affects the behaviour of the particles. More importantly, from the animation above, the behaviour of the particles represents the gas states. At the same time, learners observed the behaviour of the particles from solid to gas states. From Figure 4.9, the temperature starts from 0K to 527K and even the speed of the particles started at 0 m/s to 1867 m/s. Hence, this is to illustrate that temperature is directly proportional to the behaviour of the particles. All in all, from the observation of the particles in relation to temperature, learners were able to interpret and analyse the graph in written task 1, sections A and B.

4.2.3 Theme 3: Making correct prediction in state of matter



With the use of PhET

Grade 10
Physical sciences P2
12 April 2024

3.1 melting point – is The temperature at which the state change from solid to liquid
3.2
3.2.1 D to E
3.2.2 gas phase
3.2.3 melting point
3.3 unchanged
The temperature is remaining at the constant
3.4 increase

Question 3 with the use of PhET simulation

3.1 Sublimation – is the phase at which the solid changes to the gas phase
3.2 when you take out the margarine inside the fridge the margarine particles will start to move becouse the heat is apply and it will change from solid phase to Liquid phase so you could be able to spread the margarine on the slice of bread
3.3 Cooling curve
3.4.1 gas phase
3.4.2 Solid phase
3.5 Condensation
3.6.1 Particles are closley packed or bondend in a fixed positions
3.6.2 Particles can move over onother

Figure 4.10a: Learner E section B response

Predicting the state of matter of a substance often involves considering factors like temperature and pressure, as well as the intermolecular forces within the substance. Here is a basic guide for predicting the state of matter. Learners were able to adapt the aspect temperature. As a general rule, increasing the temperature tends to promote transitions from solid to liquid to gas. Conversely, decreasing temperature favours transitions in the opposite direction. At very low temperatures, some substances were able to change the states from gas to liquid and to solid. Pressure in the written tasks was also an aspect. Increasing pressure can cause substances to transition to a denser state. For example, at higher pressures, gases may liquefy or solidify. Conversely, decreasing pressure can cause liquids to vaporise or solids to sublimate. By using PhET simulation, it was easy for learners to understand the topic. Additionally, they were observing the behaviour of the particles. The strength of intermolecular forces within a substance greatly influences its state of matter. Substances with strong intermolecular forces such as hydrogen bonding or ion-ion interactions tend to exist as solids or liquids at room temperature, while those with weaker forces often exist as gases. Learners were able to visualise the attraction by using PhET simulation as a tool. PhET simulation made learners to understand the topic better. By just checking on the states of matter graph, they were able to predict if it is a melting point, boiling point or sublimation. The states can change from one form to another. For example, solid to liquid and liquid to solid. The following shows different states of matter as solid, liquid and gas.

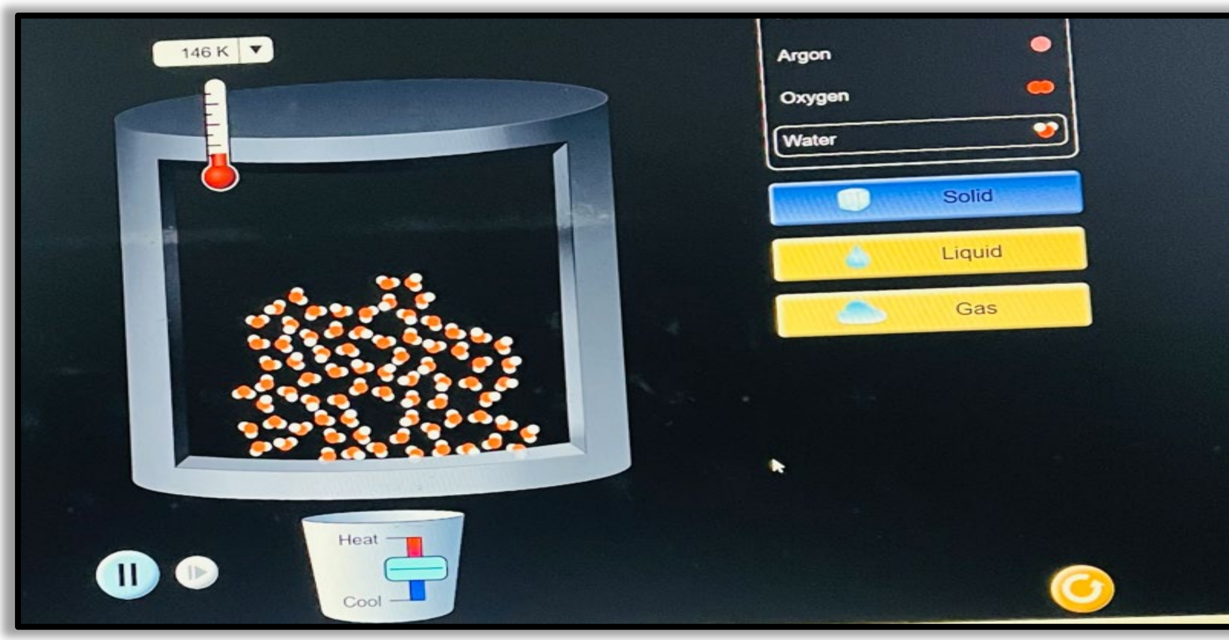


Figure 4.11: Liquid state through PhET simulation

Figure 4.11 illustrated the hypothesis: when the tempearature is applied, the process of the states is melting point. The above vignette helped learners to come up the correct definiton of melting point. Many learners in written task 1 section A indicated that melting point is the temperature at which solid changes to gas. Indeed, from the above, learners were able to observe that the bonds of the substance are breaking. Futhermore, the states of matter changed from solid to liquid while the tempearture was applied.

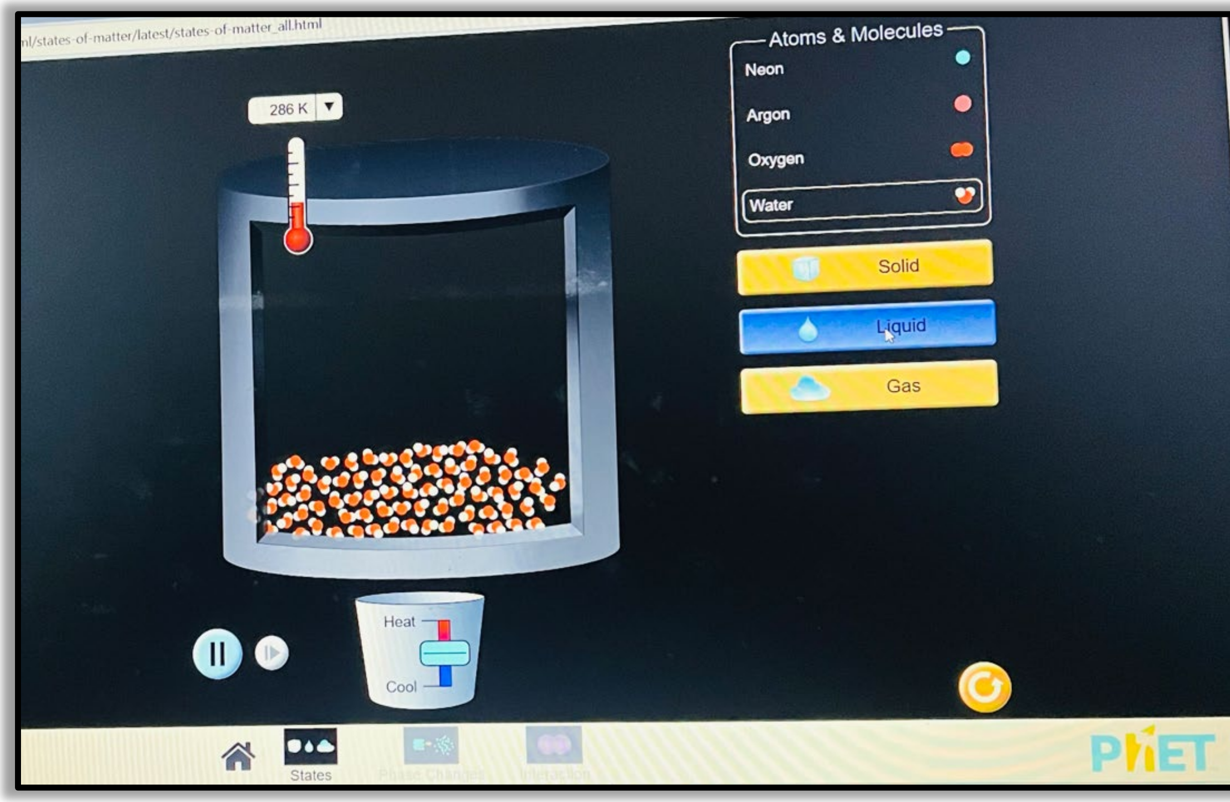


Figure 4.12: Solid states through PhET simulation

Vignette in Figure 4.12, I showed the learners the behaviour of the particles in solid states. The vignette helped them to apply what was seen on the video in the written task 1, sections A and B. The particles are closely packed together. From written task 2, learners were asked to write down the particle arrangement of particles at point Z and point Y. They managed to get the correct answers because they can observe that the decrease in temperature decreases the behaviour of the particles. Indeed, they managed to interpret the graph by indicating that the graph is for the cooling curve. This means that for Point Y, learners indicated that the particles are loosely packed, while in Point Z, the particles are closely packed. In conclusion, they were able to predict and define the melting point.

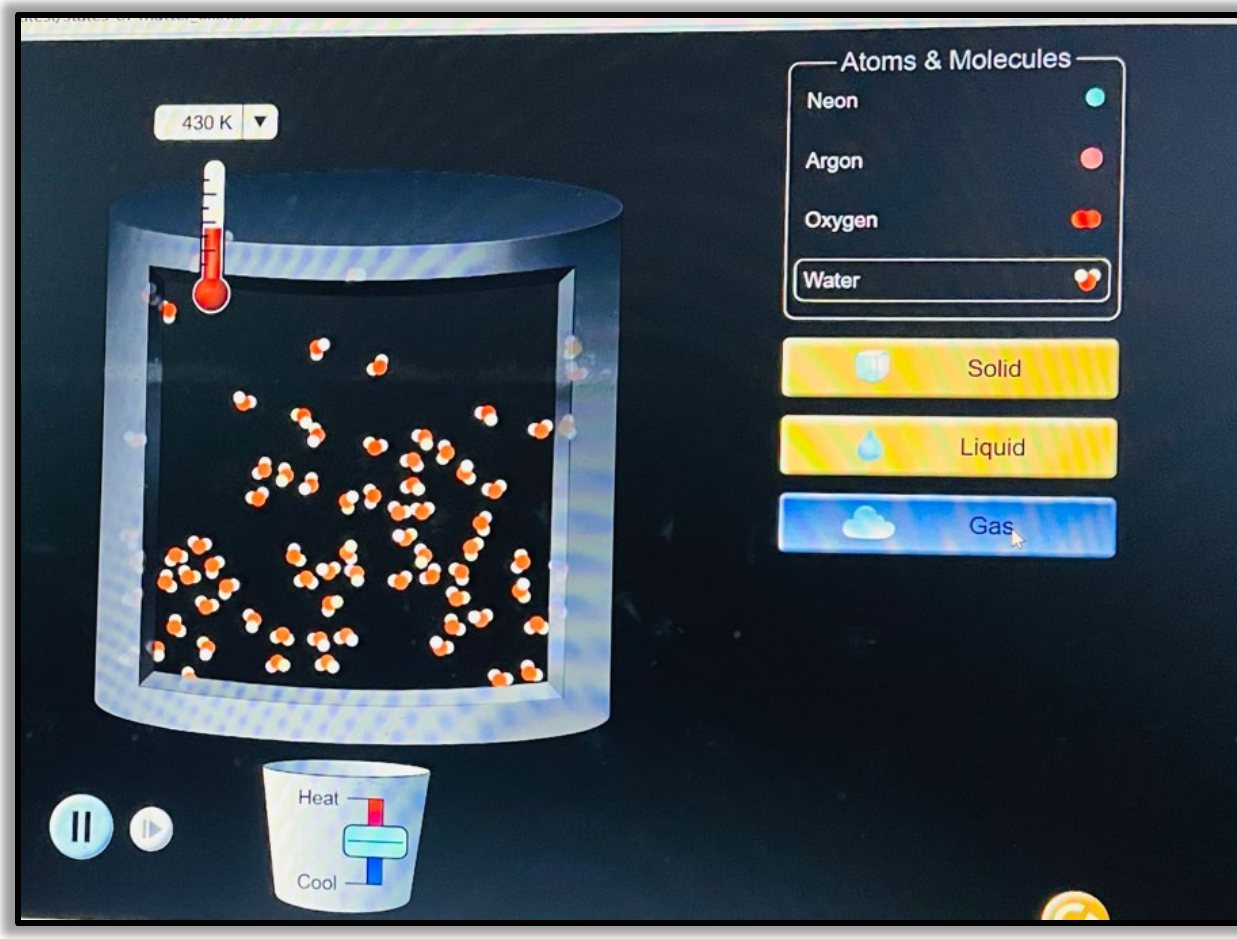
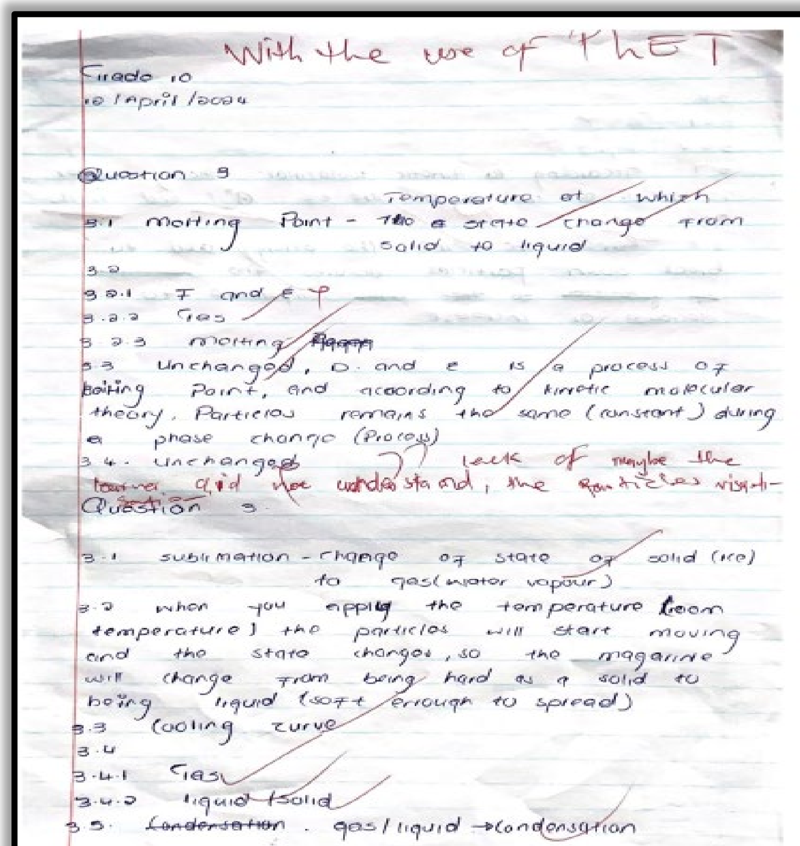


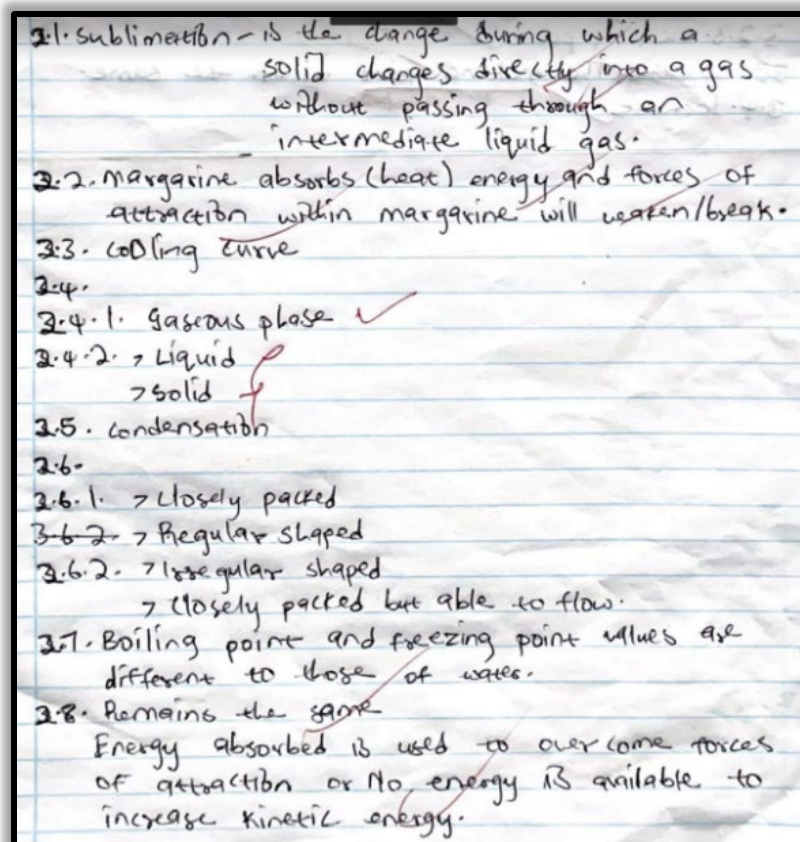
Figure 4.13: Gas state through PhET simulation

Figure 4.13 above illustrates phase diagrams, which graphically represent the relationships between temperature, pressure, and the states of matter of a substance. With the use of PhET, learners were able to help to predict the state of a substance under specific conditions. They predicted in this way from written tasks 1 and 2 respectively. In written task 1, they indicated that the graph is for heating curve, the reason being that when the temperature increases, the behaviour of the particles will also increase. Furthermore, the states of matter will change from solid to liquid. Finally, they indicated that the graph takes the melting process. This is the reason they managed to define melting point as the temperature at which solid changes into liquid. Similarly, in section B, learners indicated that the graph is for cooling curve. Finally, the process of states of matter ends up freezing because the temperature decreased to form solid states. Again, the arrangement of a chemical structure when PhET was used implies that the molecular structure of a substance can also play a role in determining its state of matter. For example, linear molecules might be more likely to form solids, while spherical molecules might favour gases. Furthermore, phase transitions in understanding the specific conditions under which phase transitions occur (e.g., melting, freezing, boiling, condensation) were helpful in predicting the behaviour of a substance as it changes state. By considering these factors, you can make informed predictions about the state of matter of a substance under different conditions. However, it is important to note that predictions may not always be accurate due to the complexity of interactions involved. Hence, I indicated what learners responded from written task 1, sections A and B. The following scripts show the improvement of learners when PhET was used.



With the use of KMT
Grade 10
10 April 2024
Question 3
3.1 Melting Point - The state change from solid to liquid
Temperature at which
3.2
3.2.1 F and E
3.2.2 Gas
3.2.3 Melting
3.3 Unchanged, D and E is a process of boiling point, and according to kinetic molecular theory, Particles remains the same (constant) during a phase change (Process)
3.4 Unchanged
lack of maybe the learner did not understand, the particles
Question 3
3.1 Sublimation - change of state of solid (ice) to gas (water vapour)
3.2 when you apply the temperature (room temperature) the particles will start moving and the state changes, so the magarine will change from being hard as a solid to being liquid (soft enough to spread)
3.3 Cooling curve
3.4
3.4.1 Gas
3.4.2 liquid / solid
3.5 ~~Condensation~~ gas / liquid → condensation

Figure 4.14a: Learner B section B response



3.1 Sublimation - is the change during which a solid changes directly into a gas without passing through an intermediate liquid gas.
3.2 Margarine absorbs (heat) energy and forces of attraction within margarine will weaken/break.
3.3 Cooling curve
3.4
3.4.1 Gaseous phase
3.4.2 > Liquid
> Solid
3.5 Condensation
3.6
3.6.1 > Closely packed
~~3.6.2~~ > Regular shaped
3.6.2 > Irregular shaped
> Closely packed but able to flow.
3.7 Boiling point and freezing point values are different to those of water.
3.8 Remains the same
Energy absorbed is used to overcome forces of attraction or no energy is available to increase kinetic energy.

Figure 4.14b: Learner Y section B response

Justice : Why was question 1.1.4 in written task 1, section A and question 1.2.4 in written task 1 section B were easy for you to answer?

Learner B : Yes the questions were easy for me to answer.

Justice : Why?

Learner B : Now, I can see the effect of temperature on the behaviour of the particles.

Justice : How is the behaviour of the particles?

Learner B : When the temperature increases, the kinetic energy of the particles also Increases.

Justice : Now, you got the relationship correct.

Justice : How did you get question 1.13, 1.1.4 and 1.1.5 correct?

Learner Y : It was easy for me to get the answer correct.

Justice : Why?

Learner Y : Through visualisation from PhET simulation, I was able to analyse and interpret the graph by checking the effect of temperature on the behaviour of the particles.

Justice : This is the reason you were able to answer the questions?

Learner Y : Yes sir.

Justice : But on the PhET, you were not given a graph, how did you comprehend the Questions?

Learner Y : Those questions were the application of what I observed.

Justice : Why was question 1.1.4 in written task 1 and question 1.2.4 on section B were easy for you to answer?

Learner D : Yes, I observed the particles moving with my naked eye.

Justice : Okay….. add more related to the observation.

Learner D : The change in states of matter was too abstract to learn without visualisation in 3 dimensions.

Justice : Good

From the transcript above, learners needed a tool to visualise the behaviour of the particles when the temperature is applied. At the same time, they were able to visualise the change in states of matter. Moreover, due to high kinetic energy of the particles of the behaviour and low kinetic energy of the particles, they were able to acquire scientific reasoning skills such as interpretation and analysis. Two written tasks 1 and 2 illustrate that learners were supposed to analyse and interpret the graph related to the change in state of matter. Indeed, they were able to analyse and interpret the graph. Additionally, this is the reason Learner B from the transcript showed that he understands the relationship between the temperature and kinetic energy of the particles. All in all, the use of PhET simulation was fruitful in learning the change in states of matter.

4.2.4 Theme 4: Developing scientific reasoning skills on the change of states of matter and understanding of the change in states of matter

Through the use PhET simulation, learners were able to develop scientific reasoning skills such as prediction, analysis, interpretation, evaluation and making inferences. Through the use of PhET simulations, many of them were able to define melting point and sublimation. They defined melting point as the temperature at which solid states change to liquid states, sublimation as the change of solid to gas. Frome the two definitions, I concluded that learners mastered the prediction skill. Furthermore, from the two graphs in written task 1 sections A and B, they were able to recognise that the increase in temperature increases the kinetic energy of the particles. Similarly, the decrease in temperature decreases the kinetic energy of the particles. Interestingly, the relationship of temperature with kinetic energy helped learners to develop the skills of analysis, interpretation and evaluation. Hence, after the mastery of the skills, they need to observe the behaviour of the particles for them to develop inferences. In this study, they used PhET to observe the behaviour of the particles. For learners to reason scientifically, they need to observe. In this study, they were observing the change in states of matter. They used what they observed to write the two written tasks 1, sections A and B.

Justice : Why was written task 1, sections A and B was easy for you to get the questions correct?

Learner S : Because, we were able to utilise scientific reasoning skills, such as prediction, analysis, interpretation, evaluation and making inferences.

Justice : This is because of using PhET simulation as tool for you to display scientific reasoning skills accordingly.

Learner S : Yes.

Justice : Why was written task 1, sections A and B easy for you to get the questions correct?

Learner M : Sir, I have the same reason with learner S.

Understanding the change in states of matter was crucial in comprehending the behaviour of substances under different conditions in written task 1, sections A and B. Matter can exist in three primary states: solid, liquid and gas. The transition between these states occurs due to changes in temperature and pressure. In the solid state, particles are closely packed together and have fixed positions. They vibrate around these positions, but they do not move freely past one another. Solids have definite shapes and volumes. Liquids have particles that are still closely packed together, but they are free to move past one another. This allows liquids to flow and take the shape of their container. Liquids have a definite volume but not a definite shape. Hence, the use of PhET made the learning simple, by recognising the effect of temperature and pressure on behaviour of particles. The following transcript interviews are about learners' understanding of the concept with the intervention of PhET simulation.

Learner R: Gases have particles that are far apart and move freely. They have neither a definite shape nor a definite volume and will expand to fill the entire volume of their container.

These state changes occur through processes known as phase transitions:

Learners R, T, Y, I and N : Explain the following process to show how their scientific reasoning has improved.

Melting: the transition from solid to liquid, where a solid substance gains enough thermal energy to overcome the forces holding its particles in a fixed position.

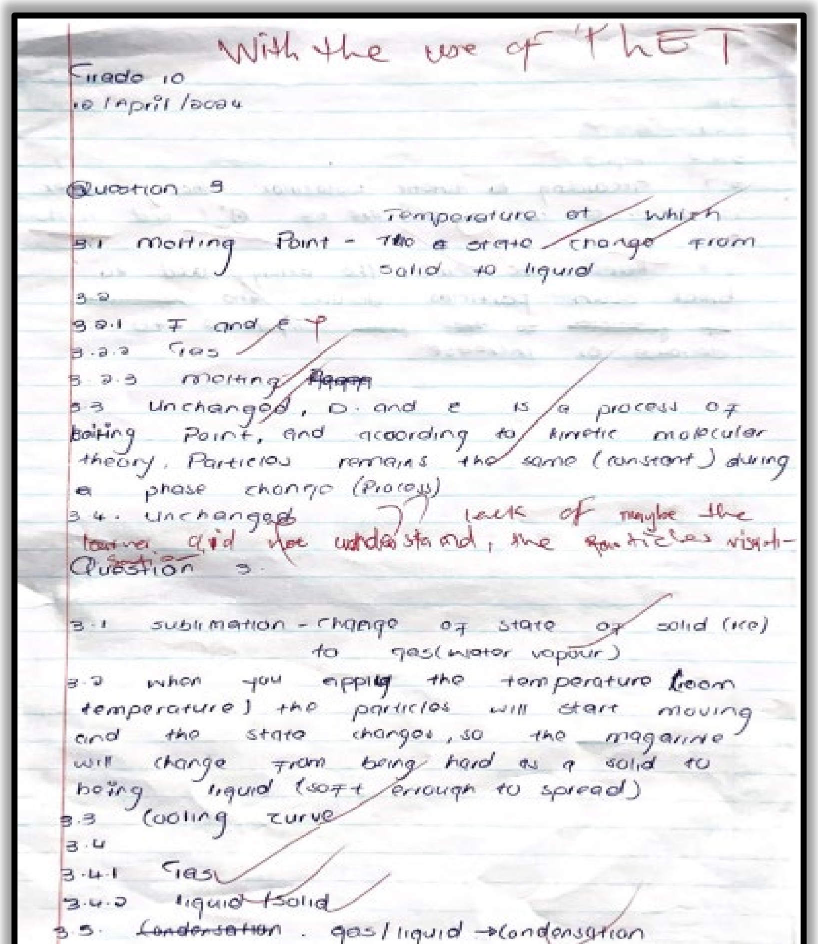
Freezing: the transition from liquid to solid, where a liquid loses thermal energy, causing its particles to slow down and eventually form a solid structure.

Vaporisation: the transition from liquid to gas, which can occur either gradually through evaporation or rapidly through boiling. In both cases, the liquid gains enough energy to overcome intermolecular forces and escape into the gas phase.

Condensation: the reverse of vaporisation, where a gas loses enough energy to transition into the liquid phase.

Sublimation: the transition directly from solid to gas, bypassing the liquid phase, or from gas to solid without going through the liquid phase. This occurs under specific conditions of temperature and pressure.

Thus, understanding these changes in states of matter is fundamental in various fields, including chemistry, physics and engineering, as they underpin many natural phenomena and industrial processes.



With the use of PhET

Grade 10
10 /April /2024

Question 3

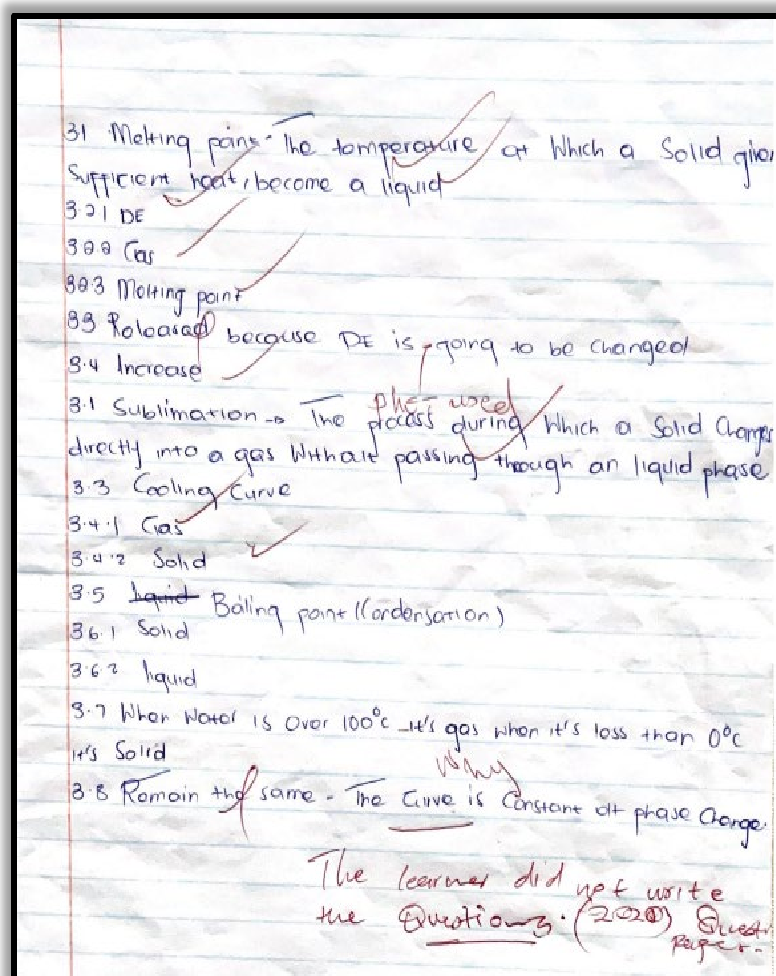
3.1 Melting Point - The temperature at which the state change from solid to liquid
3.2
3.2.1 F and E
3.2.2 Gas
3.2.3 Melting
3.3 Unchanged, D and E is a process of boiling point, and according to kinetic molecular theory, Particles remains the same (constant) during a phase change (Process)
3.4 Unchanged

lack of maybe the learner did not understand, the particles vibrat-

Question 3

3.1 sublimation - change of state of solid (ice) to gas (water vapour)
3.2 when you apply the temperature (room temperature) the particles will start moving and the state changes, so the magarine will change from being hard as a solid to being liquid (soft enough to spread)
3.3 Cooling curve
3.4
3.4.1 Gas
3.4.2 liquid /Solid
3.5 ~~Condensation~~ . gas / liquid → condensation

Figure 4.15a: Learner S section A and B response



3.1 Melting point - The temperature at which a Solid given Sufficient heat, become a liquid
3.2.1 DE
3.2.2 Gas
3.2.3 Melting point
3.3 Released because DE is going to be changed
3.4 Increase
3.1 Sublimation → The process during which a Solid changes directly into a gas without passing through an liquid phase
3.3 Cooling Curve
3.4.1 Gas
3.4.2 Solid
3.5 ~~liquid~~ Boiling point (Condensation)
3.6.1 Solid
3.6.2 liquid
3.7 When water is over 100°c it's gas when it's less than 0°c it's Solid
3.8 Remain the same - The Curve is Constant at phase change. Why

The learner did not write the Question 3 (2020) Question Paper.

Figure 4.15b: Learner M section A and B response

4.2.5 Theme 5: Inappropriate use of scientific reasoning skills such as prediction, analysis, interpretation, evaluation and making inferences.

Some of the learners still lack scientific reasoning skills even after the intervention of PhET. They did not show that they were visualising the behaviour of the particles through PhET. The following is a transcript interview to show how learners were still struggling to execute scientific reasoning skills. Additionally, the transcript interview showed that few of them were still confused after PhET intervention.

Justice : Why did you not get the correct answers? Even when you were visualising the behaviour of the particles through PhET simulation?

Learner W : Truly speaking, the topic is too difficult for me to comprehend.

Justice : When the temperature is applied, how is the behaviour of the particles?

Learner W : The problem with these questions is that they want us to analyse and interpret the graph. I don't know the answer.

Justice : Okay….

Justice : According to you what is particle?

Learner A : Truly speaking sir, I don't know what to say.

Justice : For you to understand this written task, first you must understand what particle is.

Justice : Again, what is the behaviour of particles in solid, liquid and gas?

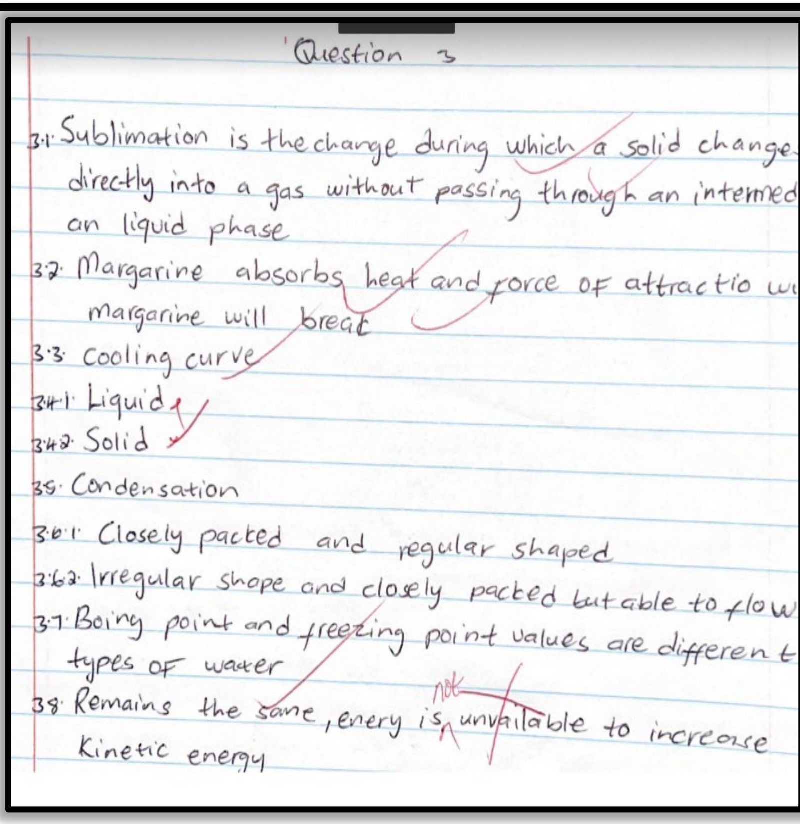
Learner A : In solid the particles are closed to each other, for liquid and gas I don't know how to differentiate in terms of the particles.

Justice : To differentiate liquid and gas, according to the behaviour of particles, you must apply the temperature. The more the temperature, the more kinetic energy of the particles.

Justice : Why did you write boiling in question 1.1.4 because the phase of the substance is the one that is needed?

Learner A : I thought the question wants process not the phase.

The transcript above showed that the behaviour of particles in state of matter is too difficult to visualise with the naked eye. For learners to get questions 1.1.3 and 1.1.4, they need to acquire scientific reasoning skills such as prediction. Furthermore, before answering written task 1, they need to predict. For example, using my own example, they might start by saying the graph is for cooling or heating curve. Thereafter, they should come up with the correct relationship between the temperature applied and the behaviour of the particles. Moreover, according to the transcript above, learners in Grade 10 find it difficult to analyse the relationship between temperature and the particles. Learner A in the transcript indicated that “I don’t even understand what is particles”. This shows that to say a particle is a small portion of matter is not enough for learners to understand since particles are macroscopic in nature. Interestingly, as a teacher, I tried to draw three boxes on the board to show them the behaviour of particles using three boxes; but still, some of the learners find it difficult since the particles are not moving. They only visualise them.



Question 3

3.1 Sublimation is the change during which a solid change directly into a gas without passing through an intermed an liquid phase

3.2 Margarine absorbs heat and force of attractio w margarine will break

3.3 Cooling curve

3.4.1 Liquid

3.4.2 Solid

3.5 Condensation

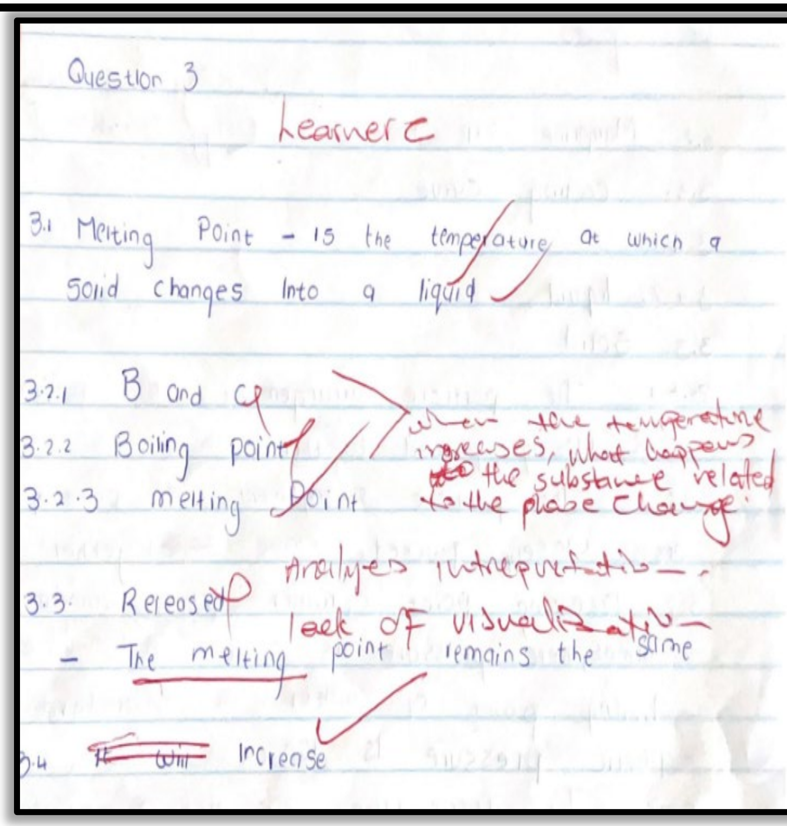
3.6.1 Closely packed and regular shaped

3.6.2 Irregular shape and closely packed but able to flow

3.7 Boiing point and freezing point values are different types of water

3.8 Remains the same, enery is not unvailable to increase Kinetic energy

Figure 4.16a: Learner A section A response



Question 3

Learner C

3.1 Melting Point - is the temperature at which a solid changes into a liquid

3.2.1 B and C

3.2.2 Boiling point

3.2.3 melting point

when the temperature increases, what happens to the substance related to the phase change?

Analyses interpretation

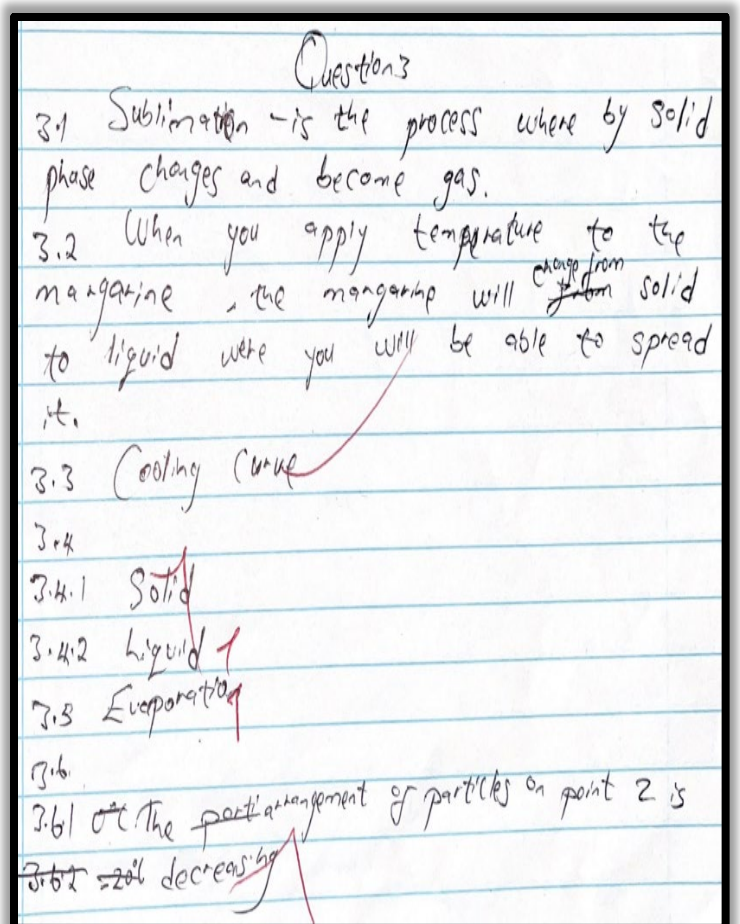
3.3 Released

lack of visualization

- The melting point remains the same

3.4 ~~It will~~ Increase

Figure 4.16b: Learner B section B response



Question 3

3.1 Sublimation - is the process where by solid phase changes and become gas.

3.2 When you apply temperature to the margarine, the margarine will change from solid to liquid were you will be able to spread it.

3.3 Cooling Curve

3.4

3.4.1 Solid

3.4.2 Liquid

3.3 Evaporation

3.6

3.6.1 ~~ot~~ The ~~parti~~ arrangement of particles on point 2 is

~~3.6.2 =20~~ decreasing

Figure 4.16c: Learner U section B response

Learners used to learn states of matter to visualise the particles on the chalkboard. For example, the illustration of the behaviour of the particles on the chalkboard was in this way:

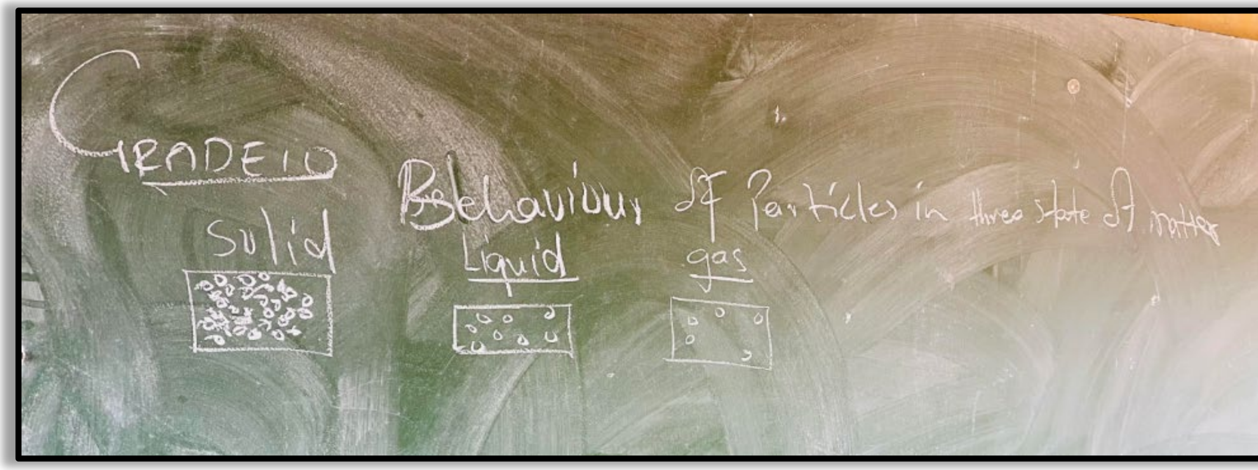


Figure 4.17: Behaviour of the particles on the chalkboard

All in all, learners failed to connect the temperature applied and the kinetic energy of the particles. They learn chemistry better through observation, since chemistry is a mind-on and hands-on subject. Subsequently, in this study, for learners to understand the change in states of matter, they need to observe the behaviour of particles in three different states of matter. Presently, from learners' scripts, you can tell that they need to visualise the change in states of matter. Over more, the written task in section A in question 1.1.6 showed that learners chose the answer. However, they did not have a valid reason to substantiate that answer, and thus left the space.

4.3 Written task 2 on state of matter, temperature and kinetic energy

Figure 4.18 illustrates that learners' scientific reasoning skills have improved with PhET intervention when writing task 2. As you can see, the "appropriate use of scientific reasoning skills such as prediction, analysis, interpretation, evaluation and making inferences". Hence, learners were clearly executed scientific reasoning skills. In this written task, the use of PhET simulation was to test if learners can adapt scientific reasoning skills. Indeed, many of them were able to get the answers correct in this written task. In question 2.2, it was very difficult to imagine how the temperature and kinetic energy of the particles are related. Furthermore, through PhET, learners were able to get the answers correct because it was easy to visualise how the temperature affects the kinetic energy of the particles. On the PhET simulation, they were able to decrease and increase the temperature while observing the behaviour of the particles. In this way, they were able to adapt prediction, analysis, interpretation, evaluation and inference in this written task. Question 2.3 was about the arrangement of the particles. It was easy for learners to choose the answer as the gas expands and occupies the whole space since it was a multiple-choice question. As you can see in the graph, scientific reasoning skills such as prediction, analysis, interpretation, evaluation and making inferences are well articulated. Thus, the scientific reasoning skills of learners has improved according to the bar graph. Similarly, question 2.5 allowed them to provide the properties of solid, liquid and gas. The question was too abstract in nature, but through PhET, learners can observe the properties in terms of particles, size, shape and density. Through PhET simulation, the properties of solid, liquid and gas were not the same. For example, particles in solid are packed together, in liquid they are loosely packed, and in gas, they occupy the whole space.

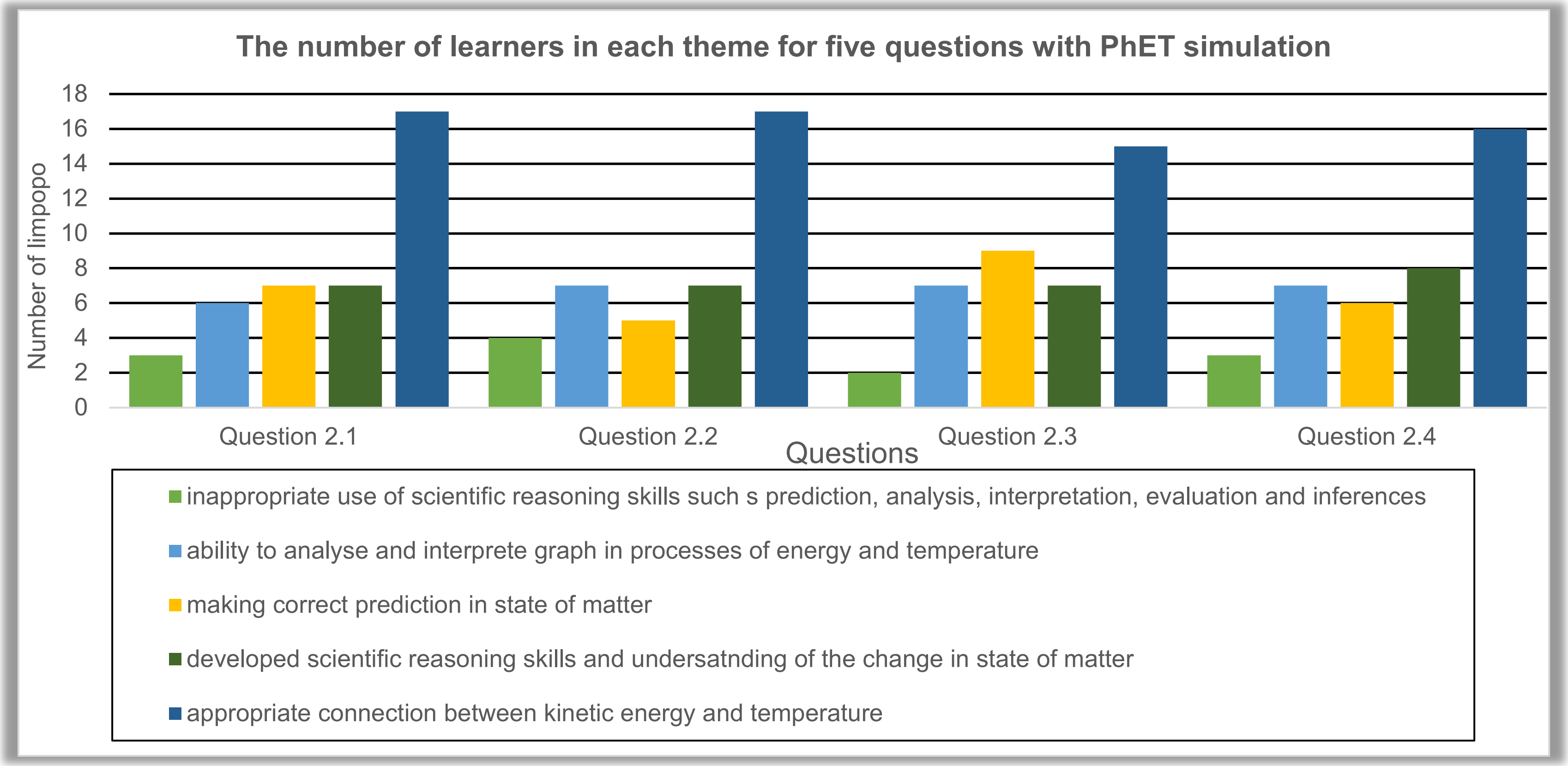
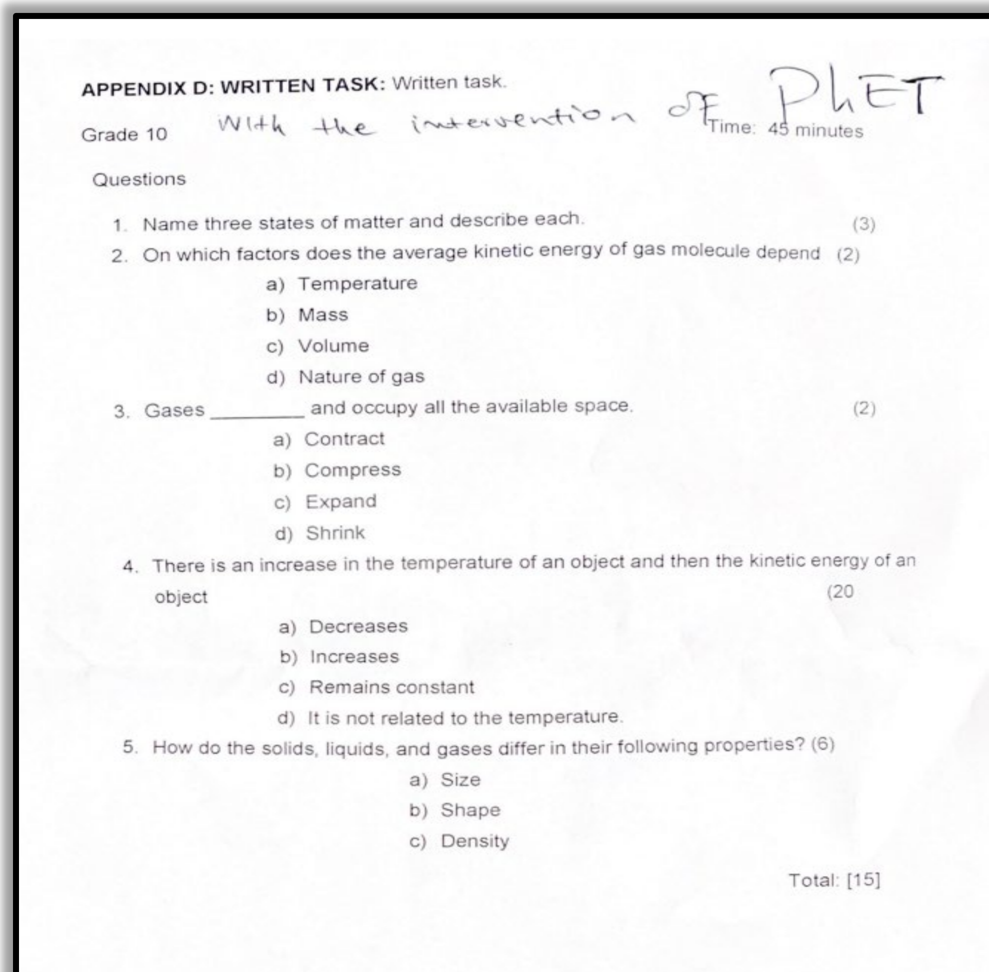


Figure 4.18: A bar graph summarising how learners exhibited scientific reasoning skills in each theme with PhET intervention

The task in Figure 4.19 was given to the learners as written task 2, which consists of five questions. Question 2.1 was for learners to recall three states of matter and to describe each. Questions 2.2, 2.3 and 2.4 are multiple choice questions but the cognitive level of the questions is high in terms of Bloom's taxonomy. Learners observed the behaviour of the particles for them to answer the three questions. In question 2.2, the answer was "temperature", in question 2.3, the answer was "expanded", lastly in question 2.4, the answer was "increase". Many learners were able to get the answers correct through PhET simulation. Question 2.5 was to differentiate three states of matter in terms of the behaviour of the particles. The question was a low cognitive level. Learners were able to recall and answer the question correctly.



APPENDIX D: WRITTEN TASK: Written task.

Grade 10 With the intervention of PhET Time: 45 minutes

Questions

1. Name three states of matter and describe each. (3)
2. On which factors does the average kinetic energy of gas molecule depend (2)
   a) Temperature
   b) Mass
   c) Volume
   d) Nature of gas
3. Gases _________ and occupy all the available space. (2)
   a) Contract
   b) Compress
   c) Expand
   d) Shrink
4. There is an increase in the temperature of an object and then the kinetic energy of an object (20
   a) Decreases
   b) Increases
   c) Remains constant
   d) It is not related to the temperature.
5. How do the solids, liquids, and gases differ in their following properties? (6)
   a) Size
   b) Shape
   c) Density

Total: [15]

Figure 4.19: Written task 2 with PhET intervention

Table 4.3 illustrates the coding scheme for written task 2. Learners wrote written task 2 and the vignettes were collected for marking purposes, and were categorised and classified into groups according to the scientific reasoning skills exhibited by learners. After the coding, themes emerged from the data. The coding was done per each question in the written task. The first category and classification of learners' scripts and interview transcripts were grouped as learners did not leave any space while writing the written task and coded as FFFM per each question in written task 2. The theme that emerged from the code was, developing scientific reasoning skills and understanding of the change in states of matter. The learners did not leave spaces because PhET helped them to learn the change in states of matter. They were able to find the effect of temperature on the change in states of matter. This is the reason why when the graph is given, it was easy for them to analyse and interpret it by referring to the decrease and increase of the temperature due to the visualisation from PhET simulation. The classification of scripts, interview transcripts and observations were coded as GGGM per each question in written task 2. The theme that emerged in this coded data was as follows, making the correct prediction in state of matter. Thirdly, the data was coded as TTTM and the theme that emerged out of the code is: ability to analyse and interpret graphs in processes of state of matter. The fourth code was coded as HHHM and the theme that emerged was as follows: an appropriate connection between kinetic energy and temperature.

Furthermore, the fifth code in this written task was coded as IIIM, and the theme that emerged from the code was as follows: inappropriate use of scientific reasoning skills such as prediction, analysis, interpretation, evaluation and making inferences. Learners failed to connect the kinetic energy of the particles with the temperature applied when interpreting and analysing the graph. Subsequently, they failed to get questions 2.2 and 2.3 incorrect because they needed to connect the temperature and kinetic energy of the particles. Additionally, they needed to understand the effect of temperature on the kinetic energy of the particles. At the same time, the lack of visualisation of the temperature applied on the substance and kinetic energy of the particles might be the cause of learners' failure to get the correct answers for question 2.4 in written task 2. All in all, few learners in written task 2 failed to get the correct answers.

How does the use of PhET explore scientific reasoning skills in characterising the state of matter?

What are the learners' scientific reasoning skills of state of matter when using PhET?

Why do learners exhibit these particular scientific reasoning skills?

The three research questions above were answered when the data was collected under the usage of PhET simulation. When analysing the transcripts, learners answered this question: "why do learners exhibit these particular scientific reasoning skills is answered"? Furthermore, the vignettes answered this question, "what are the learners' scientific reasoning skills of state of matter when using PhET"? Data was collected using PhET simulation to check if scientific reasoning skills were developed by learners. In these two written tasks, learners were able to visualise the behaviour of particles in 3 dimensions when the temperature is applied. They grasped the relationship between the temperature applied and the behaviour of the particles when PhET was used. Through the usage of PhET simulation, learners were able to acquire scientific reasoning skills such as prediction, analysis, interpretation, evaluation and making inferences. When the data was collected using PhET simulations, five (5) themes were developed namely: 1) an appropriate connection between kinetic energy and temperature; 2) ability to analyse and interpret a graph in processes of state of matter; 3) making the correct predictions in state of matter; 4) developing scientific reasoning skills and understanding of the change in states of matter; and 5) inappropriate use of scientific reasoning skills such as prediction, analysis, interpretation, evaluation and making inferences.

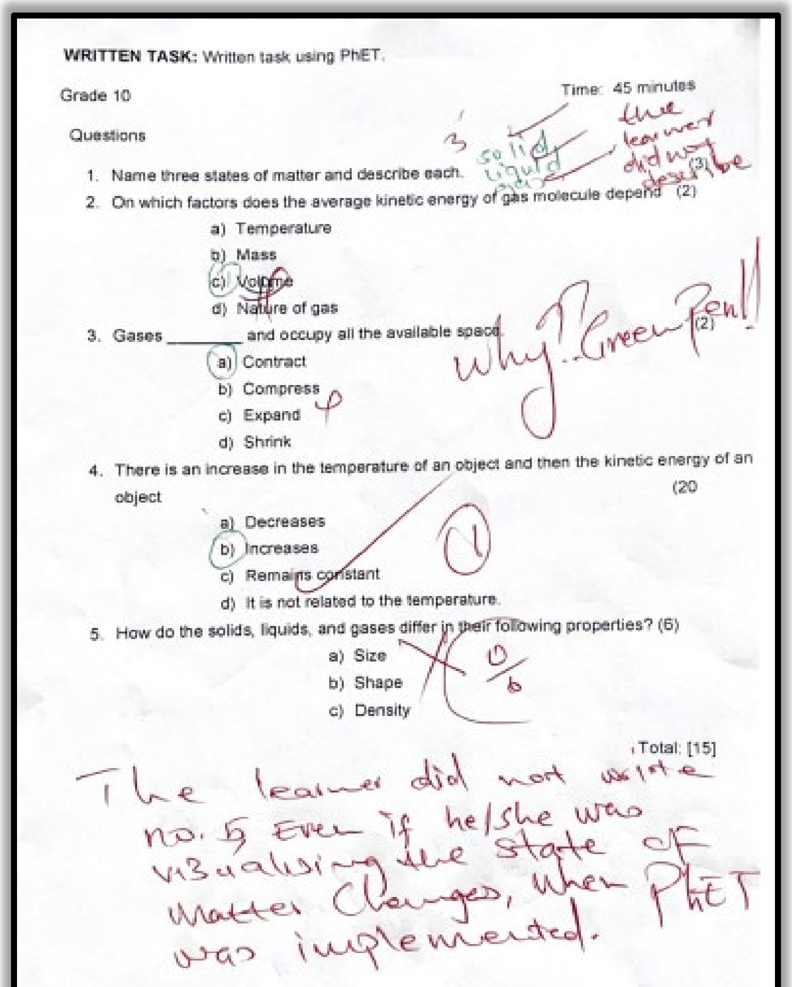
Table 4.3: Written task 2, codes from learners' responses in question number 2.1, 2.2, 2.3 and 2.4

Questions	***Codes from learners' response of*** *third* ***written task****, observation and semi****- structured interview.***				
Themes emerged from the data	**Theme 1: Appropriate connection between kinetic energy and temperature**	**Theme 2: Ability to analyse and interpret a graph in processes of state of matter**	**Theme 3: Making correct prediction in state of matter**	**Theme 4: Developing scientific reasoning skills and Understanding of the change in states of matter**	**Theme 5: Inappropriate use of scientific reasoning skills such as prediction, analysis, interpretation, evaluation and making inferences.**
1.1 Name three states of matter and describe each	**FFFM1:** Able to master the concept, paying attention, clue (having an idea of what to do), willing to think.	**GGGM1:** Correct relationship between the temperature applied and the behaviour of the particles, ability to infer and evaluate.	**TTTM1:** Ability to interpret the given graph in states of matter.	**HHHM1:** Appropriate to provide reasons for the answers chosen, and able to analyse the given graph and to tell the process taking place on the given graph.	**IIIM1:** Inappropriate to find the relationship between the temperature applied and the behaviour of the particles also the process taking place on the given graph.
2.2 On which factors do the average kinetic energy of gas molecule depend	**FFFM2:** Able to define process taking place, able to analyse the graph, recalling process of states of matter.	**GGGM2:** Correctly, to check if the graph is cooling curve or heating curve, correctly interpreting the graph given.	**TTTM2:** Ability to reason scientifically, due to visualisation.	**HHHM2:** Appropriately, to analyse the given graph, and to tell the process taking place on the given graph and able to prediction.	**IIIM2:** Inappropriate to analysis, interpretation, and evaluation to be able to draw the conclusion.

2.3 Gases ________ and occupy all the available space.	**FFFM3:** Able to find relationship between temperature applied and kinetic energy of the particles.	**GGGM3:** Correct implementation of scientific reasoning skills such as prediction, analysis, interpretation and evaluation.	**TTTM3:** Ability to provide reasons due to the observing of the movement of the particles.	**HHHM3** Appropriate to articulate scientific reasoning skills, and to characterise states of matter as solid, liquid and gas.	**IIIM3:** Inappropriate, to articulate scientific reasoning skills and to characterise three states of matter.
2.4 There is an increase in the temperature of an object and then the kinetic energy of an object	**FFFM4n5:** Able to understand the behaviour of particles.	**GGGM4n5:** Correct, use of scientific reasoning skills, randomly choosing the answer due to lack of visualisation.	**TTTM4n5:** Ability to answer, inability to recall, what is the heating curve.	**HHHM4n5:** Appropriate to perform experiment related to the written task given, and lack of analyses	**IIIM4n5:** Inappropriate to improvise (using experiments) related to the written task given

4.3.1 Theme 1: Appropriate connection between kinetic energy and temperature

Learners were able to get the correct answers from written task 2. Firstly, they were able to get the correct relationship between kinetic energy of the particles and the temperature applied. Consequently, it helped them define solid, liquid and gas in terms of the particles, even if some of the learners listed did not describe the three states of matter. The three multiple choices in written task 2 showed that learners got the relationship between temperature and kinetic energy of the particles. For example, learners in my class indicated that the particles take more space in gas states. While particles in solid states take less space, in liquid they are loosely packed. Hence, the temperature affected the arrangement of the particles in three different states of matter. Scripts were categorised and classified for coding, coded as HHHM. A theme emerged from collected data as “appropriate connection between kinetic energy and temperature”, since many learners were able to come up with the correct relationship between the two factors.



WRITTEN TASK: Written task using PhET.

Grade 10 Time: 45 minutes

Questions

1. Name three states of matter and describe each. (3)
2. On which factors does the average kinetic energy of gas molecule depend (2)
   - a) Temperature
   - b) Mass
   - c) Volume
   - d) Nature of gas
3. Gases ________ and occupy all the available space. (2)
   - a) Contract
   - b) Compress
   - c) Expand
   - d) Shrink
4. There is an increase in the temperature of an object and then the kinetic energy of an object (20
   - a) Decreases
   - b) Increases
   - c) Remains constant
   - d) It is not related to the temperature.
5. How do the solids, liquids, and gases differ in their following properties? (6)
   - a) Size
   - b) Shape
   - c) Density

Total: [15]

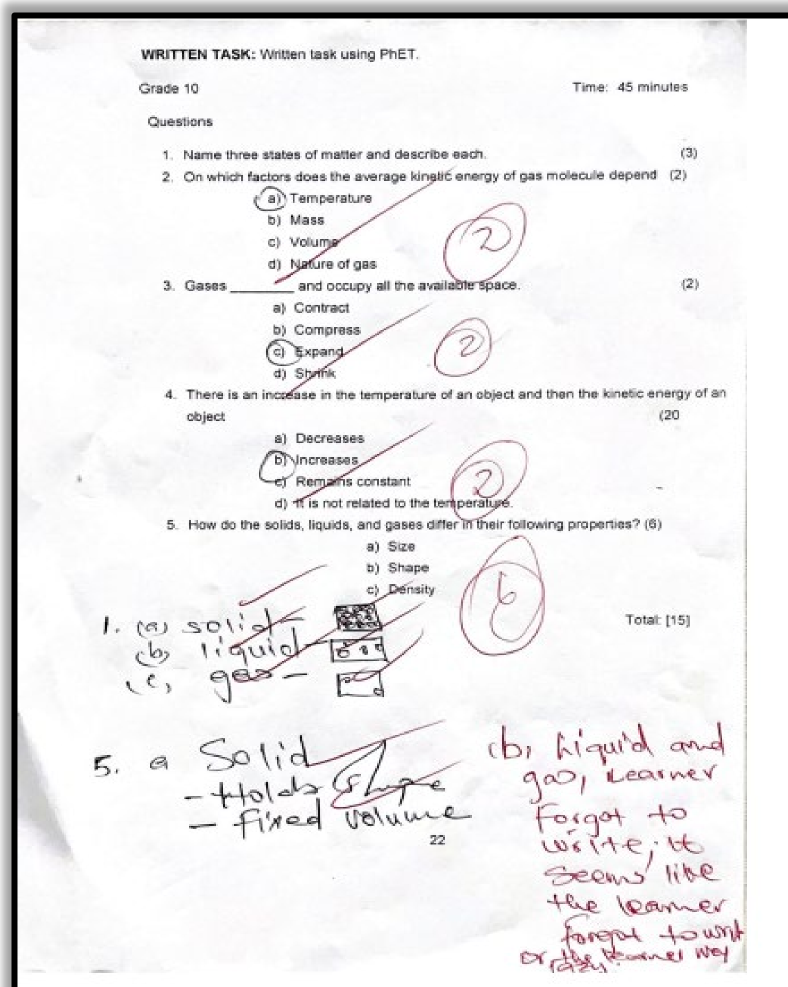
solid liquid gas

the learner did not describe

why? Green Pen!!

The learner did not write no. 5 Even if he/she was visualising the state of matter changes, when PhET was implemented.

Figure 100a: Learner N task 2 response



WRITTEN TASK: Written task using PhET.

Grade 10 Time: 45 minutes

Questions

1. Name three states of matter and describe each. (3)
2. On which factors does the average kinetic energy of gas molecule depend (2)
   - a) Temperature
   - b) Mass
   - c) Volume
   - d) Nature of gas
3. Gases ________ and occupy all the available space. (2)
   - a) Contract
   - b) Compress
   - c) Expand
   - d) Shrink
4. There is an increase in the temperature of an object and then the kinetic energy of an object (20
   - a) Decreases
   - b) Increases
   - c) Remains constant
   - d) It is not related to the temperature.
5. How do the solids, liquids, and gases differ in their following properties? (6)
   - a) Size
   - b) Shape
   - c) Density

Total: [15]

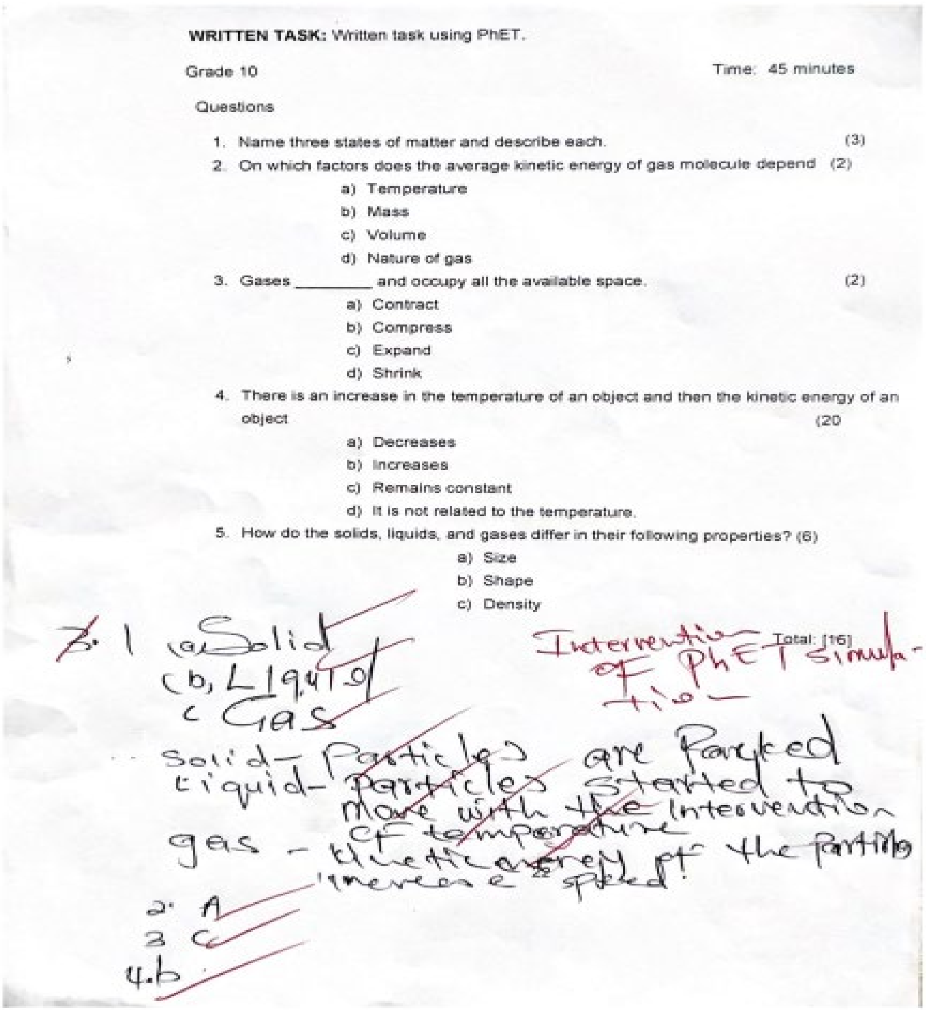
1. (a) solid
   (b) liquid
   (c) gas

5. a Solid
   - Holds Shape
   - fixed volume

(b) liquid and gas, Learner forgot to write, it seems like the learner forgot to write or the learner was lazy.

22

Figure 4.20b: Learner I task 2 response


WRITTEN TASK: Written task using PhET.

Grade 10 Time: 45 minutes

Questions

1. Name three states of matter and describe each. (3)
2. On which factors does the average kinetic energy of gas molecule depend (2)
   a) Temperature
   b) Mass
   c) Volume
   d) Nature of gas
3. Gases ________ and occupy all the available space. (2)
   a) Contract
   b) Compress
   c) Expand
   d) Shrink
4. There is an increase in the temperature of an object and then the kinetic energy of an object (20
   a) Decreases
   b) Increases
   c) Remains constant
   d) It is not related to the temperature.
5. How do the solids, liquids, and gases differ in their following properties? (6)
   a) Size
   b) Shape
   c) Density

Total: [16]

1 (a) Solid
(b) Liquid
c Gas

Solid – Particles are Packed
Liquid – Particles started to move with the intervention of temperature
gas – kinetic energy of the particles increase speed!

2. A
3 C
4. b

Intervention of PhET simulation

Figure 4.20c: Learner R task 2 response

The vignette in Figure 4.21 illustrates the behaviour of particles in solid, liquid and gas. Indeed, the particles in solid are closely packed together, and in liquid they are loosely packed. In gas, the particles occupy more space. The arrangement of the particles depends on the temperature. If the temperature is increased, the states of matter can change from solid to liquid. If the temperature keeps increasing, the states change from liquid to gas. The particles will gain kinetic energy from the temperature increased.

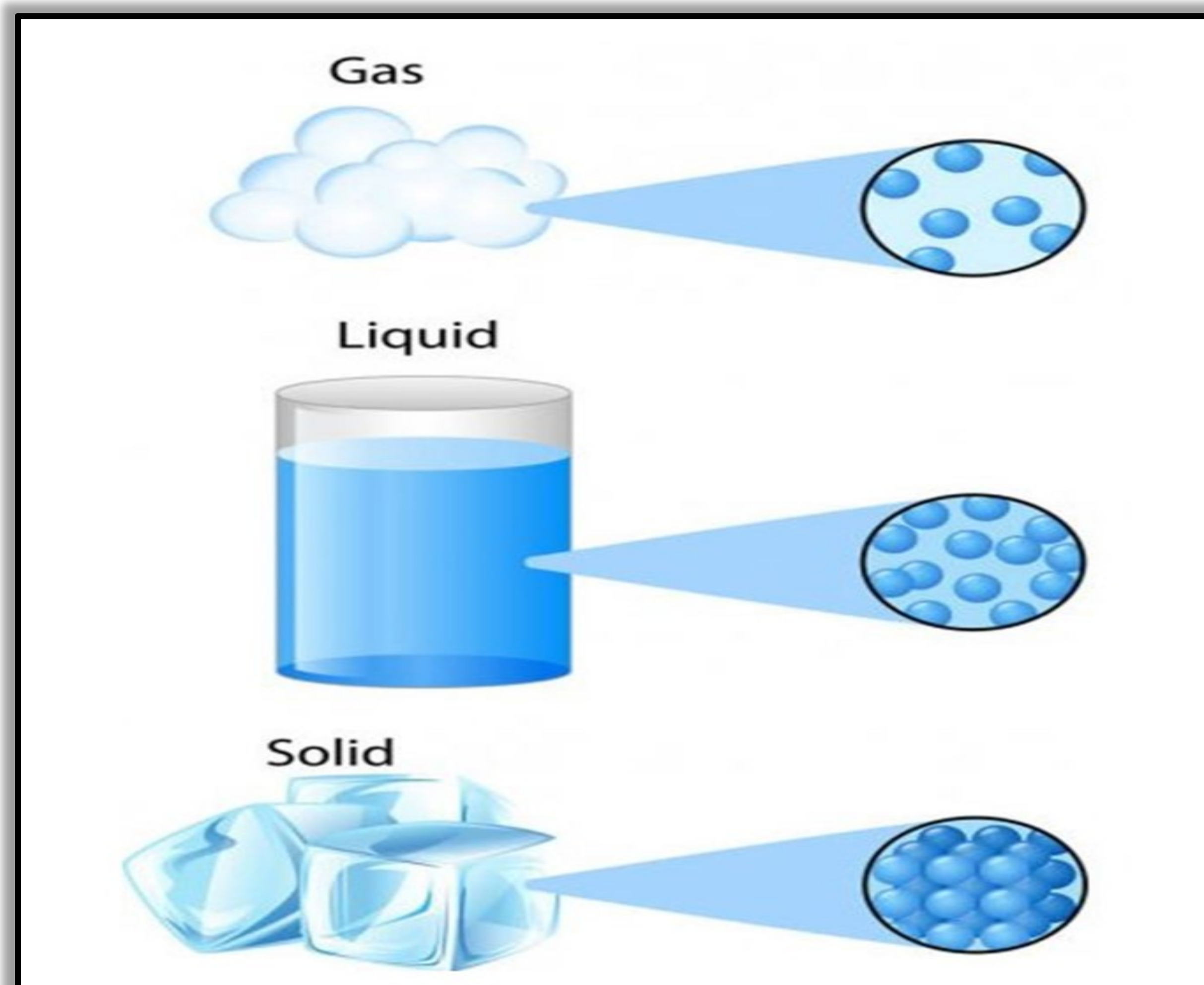


Figure 4.21: The change in states of matter in terms of the particles from PhET simulation

The transcript shows that through the use of PhET simulation, learners understood written task 2. They indicated that they were able to list and describe the three states of matter. They explained solid as particles that are close to each other. In liquid, the particles are loosely packed. In gas, they are far away from each other. Subsequently, learners were able to observe that the temperature affected the behaviour of the particles. This is the reasons they were able to answer questions 2.2, 2.3 and 2.4 in written task 2. Question 2.2 was about relationship between kinetic energy and temperature. Similarly, question 3 tested if learners understand the arrangement of the particles in gas states. Indeed, they provided the answer as particles occupy more space in gas states. Hence, by giving those answers, learners developed scientific reasoning skills such as analysis and interpretation. All in all, through the use of PhET, learners learn the change in states of matter. The following transcript is to consolidate that learning through PhET helps learners in characterising states of matter.

Justice : What is the change in states of matter through visualisation?

Learner R : When the temperature was applied, the particles were changing its velocity.

Justice : Okay, explain the behaviour in solid, liquid and gas?

Learner R : In solid the particles were packed together. When the temperature was applied, the particles start to be away from each other to be solid states. When the temperature keeps increasing, the states change from liquid to gas.

Justice : Okay.

Justice : Did the use of PhET help you in learning the change in states of matter?

Learner N : Yes.

Justice : How?

Learner N : I was able to observe the behaviour of the particles through PhET Simulation.

Learner N : This is the reason I was able to differentiate three states of matter in written task 2.

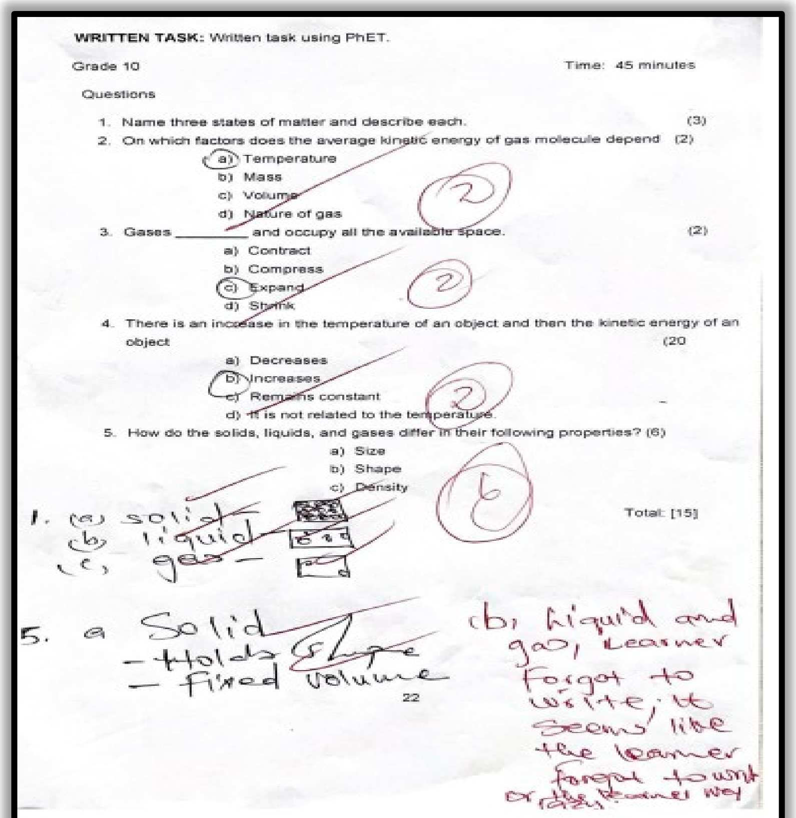
4.3.2 Theme 2: Ability to analyse and interpret a graph in processes of states of matter

Two learners were able to exhibit scientific reasoning skills when writing the second task. Through interactions, it was clear that they were able to predict, analyse, interpret and evaluate the change in states of matter. At the same time, through interviews, learners showed that through visualisation of the behaviour of particles in three different states of matter on PhET simulation, they were able to characterise three states of matter. This is the reason some of them were able to execute scientific reasoning skills. The topic 'change in states of matter' is abstract in nature because learners were not able to observe the particles moving. Furthermore, for them to understand the topic, they should first imagine and observe the movement of the particles in solid, liquid and gas. Subsequently, when the graph is given for them to analyse, interpret and evaluate, it was difficult to apply the scientific reasoning skills. In this case, learners were able to display scientific reasoning skills when answering written task 2. Through the interview, even if learners managed to get written task 2 correct, it was too difficult for them to execute, predict, analyse, interpret, infer and evaluate the change in states of matter. While I was moving around and observing, learners were able to execute scientific reasoning skills.

Through the use of PhET simulation, learners were able to execute scientific reasoning skills such as analysis and interpretation. To analyse and interpret what you see is much better than to do it through imagination since the topic is too abstract in nature. The following two questions needed learners to observe to be able to analyse and interpret. Most learners managed to get the questions correct by observing the movement of the particles through PhET simulation. "On which factors do the average kinetic energy of gas molecule depend"? and "is there an increase in the temperature of an object and then the kinetic energy of an object"?

Learners analysed and interpreted the change in states of matter and used it in written task 2. The use of PhET simulation was very useful in learning the change in states of matter. They were able to write the following question to show the understanding related to the change in states of matter through the use of PhET simulation. "How do the solids, liquids, and gases differ in their following properties"?

a) Size
b) Shape
c) Density


WRITTEN TASK: Written task using PhET.

Grade 10 Time: 45 minutes

Questions

1. Name three states of matter and describe each. (3)
2. On which factors does the average kinetic energy of gas molecule depend (2)
   a) Temperature
   b) Mass
   c) Volume
   d) Nature of gas
3. Gases ________ and occupy all the available space. (2)
   a) Contract
   b) Compress
   c) Expand
   d) Shrink
4. There is an increase in the temperature of an object and then the kinetic energy of an object (20
   a) Decreases
   b) Increases
   c) Remains constant
   d) It is not related to the temperature.
5. How do the solids, liquids, and gases differ in their following properties? (6)
   a) Size
   b) Shape
   c) Density

Total: [15]

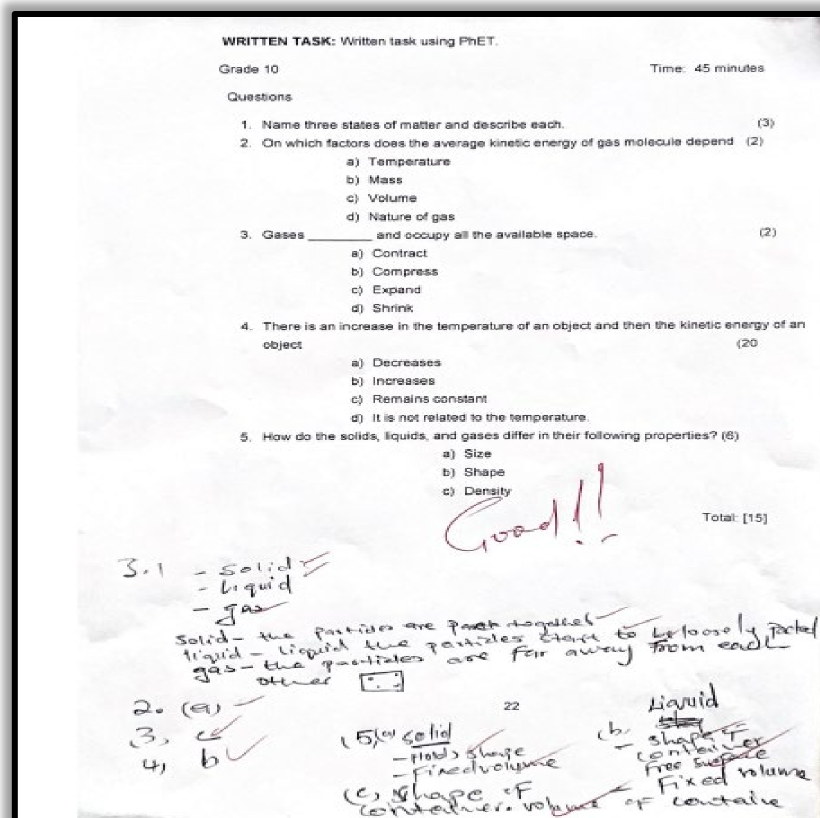
1. (a) solid
(b) liquid
(c) gas

5. a Solid
- Holds Shape
- fixed volume

(b) liquid and gas, Learner forgot to write, it seems like the learner forgot to write or the same way

22

Figure 4.22a: Learner M task 2 response


WRITTEN TASK: Written task using PhET.

Grade 10 Time: 45 minutes

Questions

1. Name three states of matter and describe each. (3)
2. On which factors does the average kinetic energy of gas molecule depend (2)
   a) Temperature
   b) Mass
   c) Volume
   d) Nature of gas
3. Gases ________ and occupy all the available space. (2)
   a) Contract
   b) Compress
   c) Expand
   d) Shrink
4. There is an increase in the temperature of an object and then the kinetic energy of an object (20
   a) Decreases
   b) Increases
   c) Remains constant
   d) It is not related to the temperature.
5. How do the solids, liquids, and gases differ in their following properties? (6)
   a) Size
   b) Shape
   c) Density

Total: [15]

Good!!

3.1 - Solid
- Liquid
- gas

Solid - the particles are packed together
liquid - liquid the particles start to be loosely packed
gas - the particles are far away from each other

2. (a)
3. c
4. b

5. (a) Solid
- Holds shape
- Fixed volume

(b) Liquid
- shape of container
- Free surface
- Fixed volume

(c) shape of container, volume of container

22

Figure 4.22b: learner Y task 2 response.

The vignette in Figure 4.23 was used to help learners to answer the question:

From the vignette in Figure 4.23, learners changed the temperature while observing the behaviour of the particles. We started with the temperature at zero. The kinetic energy of the particles was also at zero. During the learning process, we concluded that the state is solid. The reason being that the particles are closely packed. We kept increasing the temperature. The particles started to move a bit to change the solid states to liquid. Further increasing the temperature, the particles were all over the borders of the container to form a gas state. After the use of PhET simulation, learners were able to understand the arrangement of the particles in three states of matter. This is the reason they were able to get the correct answers in written task 2.

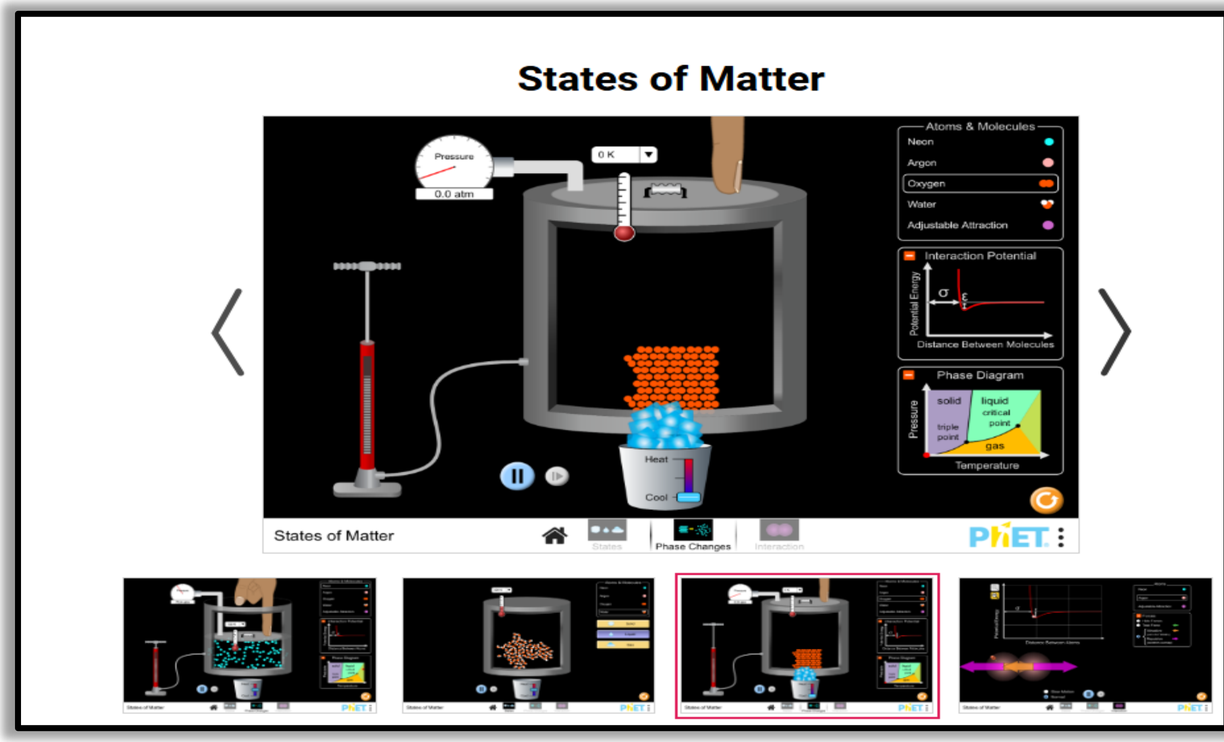
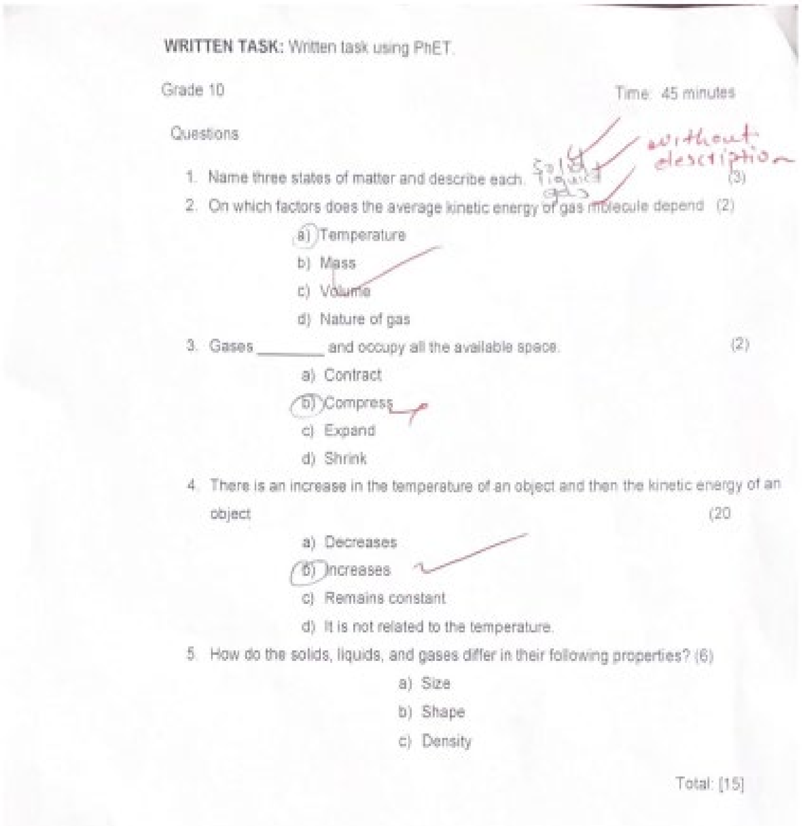


Figure 4.23: The increase and decrease of states of matter

4.3.3 Theme 3: Making correct prediction in state of matter


WRITTEN TASK: Written task using PhET.

Grade 10 Time: 45 minutes

Questions

1. Name three states of matter and describe each. (3)
2. On which factors does the average kinetic energy of gas molecule depend (2)
    a) Temperature
    b) Mass
    c) Volume
    d) Nature of gas
3. Gases _______ and occupy all the available space. (2)
    a) Contract
    b) Compress
    c) Expand
    d) Shrink
4. There is an increase in the temperature of an object and then the kinetic energy of an object (20
    a) Decreases
    b) Increases
    c) Remains constant
    d) It is not related to the temperature.
5. How do the solids, liquids, and gases differ in their following properties? (6)
    a) Size
    b) Shape
    c) Density

Total: [15]

Figure 4.24: Leaner B task 2 response

PhET simulations provided a hands-on approach in adjusting the temperature, pressure and the speed of the particles. The visual approach to learn states of matter makes it easier to understand and predict changes in the state of matter under varying conditions. Learners were able to make informed predictions on the change in states of matter, such as, if you increase the temperature, what is the behaviour of the particles? For example, if you start with solid, predict when it was melted and become liquid. Similarly, predict the transition from liquid to gas if you continue to increase the temperature.

Justice : What are the factors affecting the behaviour of the particles?

Learner O : Temperature and pressure.

Justice : Why temperature and pressure?

Learners O : Through PhET simulation, I was able to observe the behaviour of particles.

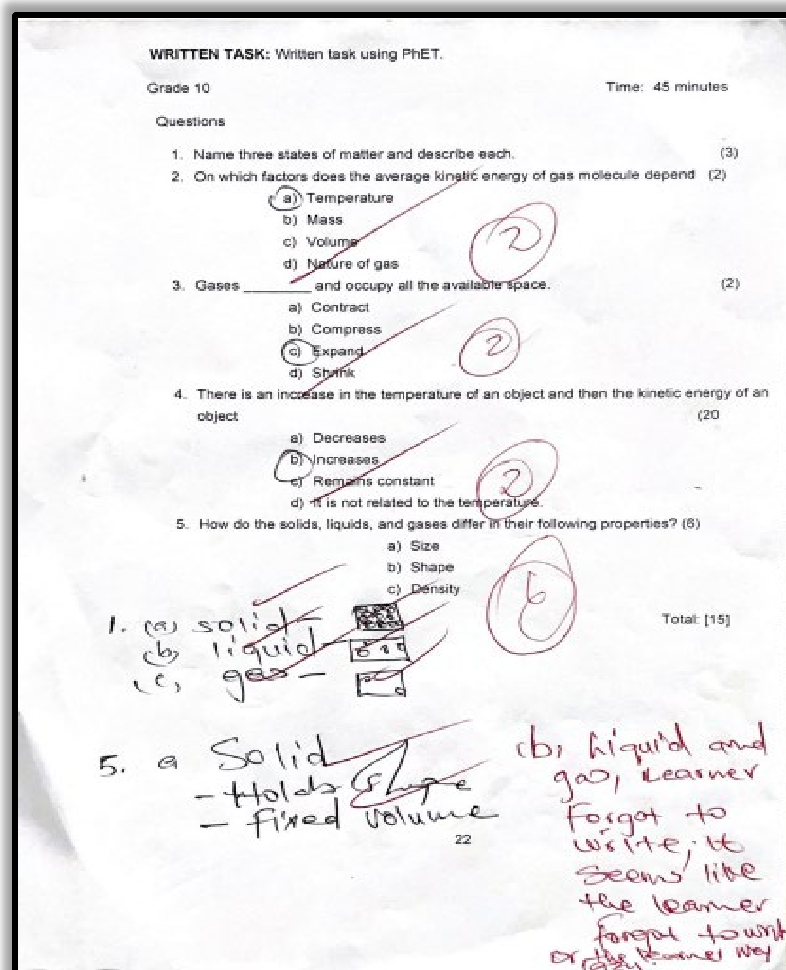
Justice : How?

Learner O : When the temperature increase also the kinetic energy of the particles increase and when the temperature decreases also the kinetic energy decrease.

The transcript above shows that observing the behaviour of the particles helped learners to make predictions. Subsequently, learners were able to visualise the behaviour of the particles when the temperature increases or decreases. Learners were able to hypothesise. For example, the hypothesis was when the temperature increases, the behaviour of the particles also increases. Through PhET simulation, most learners were able to develop scientific reasoning skills such as prediction.

4.3.4 Theme 4: Developing scientific reasoning skills on the change of states of matter and understanding of the change in states of matter

Learners were able to list and describe the questions by observing the behaviour of the particles. In question 2.2, they noted that the decrease and increase in temperature affects the behaviour of particles. Consequently, they were given four answers to choose such as temperature, mass, volume and nature of gas. From the four answers, they were able to choose temperature as the answer. Indeed, temperature was the correct answer. Because through PhET, learners were able to observe that the kinetic energy of the particles depends on temperature. Question 2.3 tested if learners understand the behaviour of particles in gas. Indeed, they were able to figure out that in gas, the particles occupy large spaces. This shows that the use of PhET led to the development of scientific reasoning skills in this study.



WRITTEN TASK: Written task using PhET.

Grade 10 Time: 45 minutes

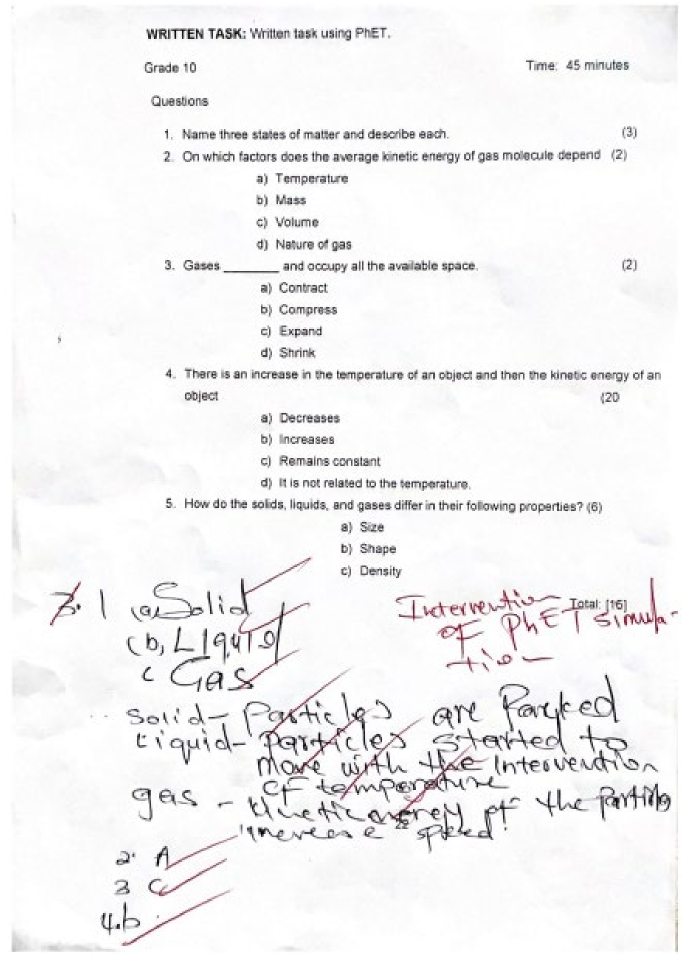
Questions

1. Name three states of matter and describe each. (3)
2. On which factors does the average kinetic energy of gas molecule depend (2)
   a) Temperature
   b) Mass
   c) Volume
   d) Nature of gas
3. Gases ________ and occupy all the available space. (2)
   a) Contract
   b) Compress
   c) Expand
   d) Shrink
4. There is an increase in the temperature of an object and then the kinetic energy of an object (20
   a) Decreases
   b) Increases
   c) Remains constant
   d) It is not related to the temperature.
5. How do the solids, liquids, and gases differ in their following properties? (6)
   a) Size
   b) Shape
   c) Density

Total: [15]

22

Figure 4.25a: Learner T task 2 response



WRITTEN TASK: Written task using PhET.

Grade 10 Time: 45 minutes

Questions

1. Name three states of matter and describe each. (3)
2. On which factors does the average kinetic energy of gas molecule depend (2)
   a) Temperature
   b) Mass
   c) Volume
   d) Nature of gas
3. Gases ________ and occupy all the available space. (2)
   a) Contract
   b) Compress
   c) Expand
   d) Shrink
4. There is an increase in the temperature of an object and then the kinetic energy of an object (20
   a) Decreases
   b) Increases
   c) Remains constant
   d) It is not related to the temperature.
5. How do the solids, liquids, and gases differ in their following properties? (6)
   a) Size
   b) Shape
   c) Density

Total: [16]

22

Figure 4.25b: Learner I task 2 response

Justice : How did you develop scientific reasoning skills such as prediction, analysis, interpretation, evaluation and inferences?

Learner T : Through the use of PhET simulation, I developed scientific reasoning skills easily.

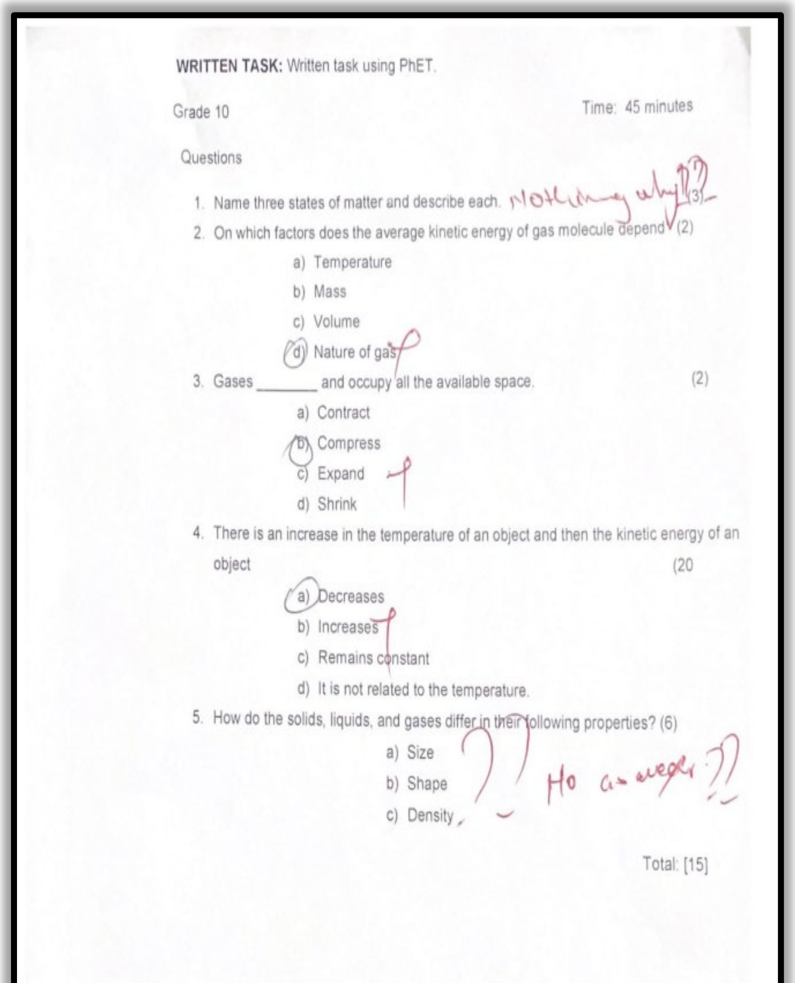
Justice : Meaning PhET is useful in learning the change in states of matter?

Learner T : Yes.

Justice : Okay, the use of PhET is useful.

From the transcripts, learners were able to reason out, and provide a clear picture of why these scientific reasoning skills are executed. At the same time, they indicated that the use of PhET simulation helped them to develop scientific reasoning skills such as prediction, analysis, interpretation, evaluation and making inferences. Hence, most of them were able to observe the kinetic energy of the particles. Moreover, they were able to analyse and interpret what was observed.

4.3.5 Theme 5: Inappropriate use of scientific reasoning skills such as prediction, analysis, interpretation, evaluation and making inferences



WRITTEN TASK: Written task using PhET.

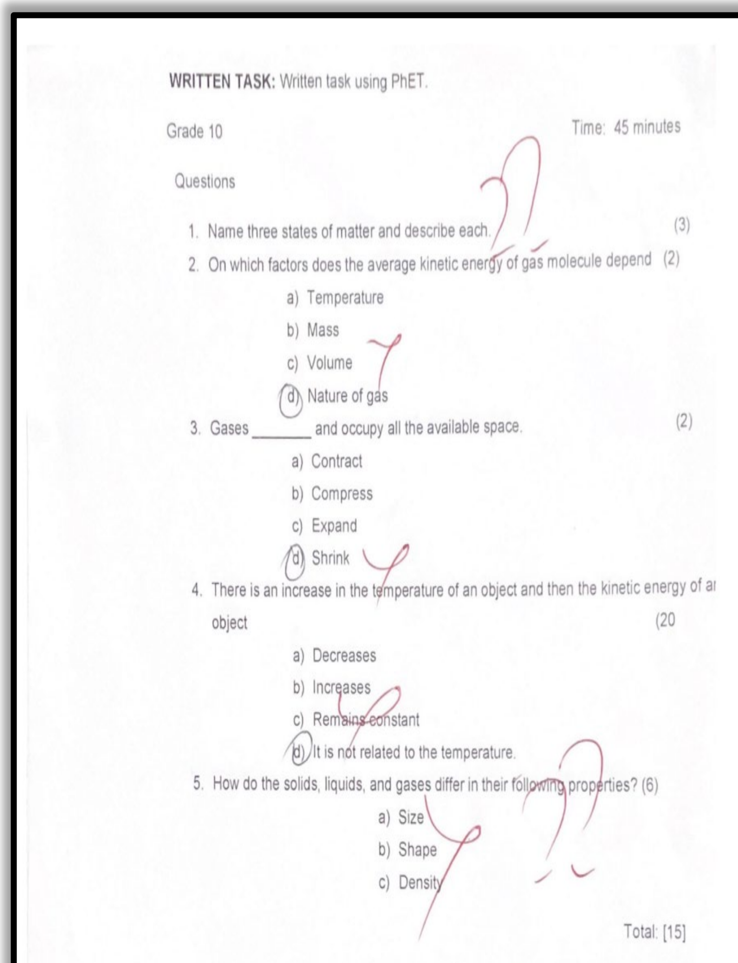
Grade 10 Time: 45 minutes

Questions

1. Name three states of matter and describe each. (3)
2. On which factors does the average kinetic energy of gas molecule depend (2)
   a) Temperature
   b) Mass
   c) Volume
   d) Nature of gas
3. Gases _______ and occupy all the available space. (2)
   a) Contract
   b) Compress
   c) Expand
   d) Shrink
4. There is an increase in the temperature of an object and then the kinetic energy of an object (20
   a) Decreases
   b) Increases
   c) Remains constant
   d) It is not related to the temperature.
5. How do the solids, liquids, and gases differ in their following properties? (6)
   a) Size
   b) Shape
   c) Density

Total: [15]

Figure 4.26a: Leaners P task 2 response



WRITTEN TASK: Written task using PhET.

Grade 10 Time: 45 minutes

Questions

1. Name three states of matter and describe each. (3)
2. On which factors does the average kinetic energy of gas molecule depend (2)
   a) Temperature
   b) Mass
   c) Volume
   d) Nature of gas
3. Gases _______ and occupy all the available space. (2)
   a) Contract
   b) Compress
   c) Expand
   d) Shrink
4. There is an increase in the temperature of an object and then the kinetic energy of ar object (20
   a) Decreases
   b) Increases
   c) Remains constant
   d) It is not related to the temperature.
5. How do the solids, liquids, and gases differ in their following properties? (6)
   a) Size
   b) Shape
   c) Density

Total: [15]

Figure 4.26b: Leaners Z task 2 response

Some of the learners still lack scientific reasoning skills even after the intervention of PhET. Learners did not show that they were visualising the behaviour of the particles through PhET. The following is a transcript interview to show how they were still struggling to execute scientific reasoning skills. Additionally, the transcript interview showed that few of them were still confused after PhET intervention. Before answering the given written task 2, you should first formulate the hypothesis. For learners to understand the questions in written task 2, they should first know if the graph of cooling curve or heating curve will able to come up with the hypothesis. Furthermore, in the written task, those who did not acquire the skills prediction did not understand the assessment. To predict is to lead you to be able to analyse, interpret, evaluate and infer. All in all, even after the use of PhET, it was too difficult for some learners to exhibit scientific reasoning skills.

Justice : It seems the topic is too abstract for you, why?

Learner Z : Yes, it becomes difficulty for me to develop the scientific reasoning skills.

Justice : Some of the scientific reasoning skills were not relevant for the topic.

Learner Z : Okay Sir.

From the transcript, through the reasoning of learners in written task 2, I can conclude that they lack scientific reasoning skills such as analysis and interpretation. To develop how to analyse and interpret graphs on processes of states of matter, learners should visualise the particles in 3-D. This showed that it was difficult for them to get question 2.2 from the written task 2 correct. Hence, during the visualisation of the particles, when the temperature decreases and increases, they were not paying the attention. Yes, in actual fact it was not going to be difficult if they were able to visualise the movement of the particles. The question was going to be less abstract. The lack of visualisation led them to fail to analyse and interpret the graph given in written task 2.

4.4 Observations from written tasks

Through observation, I facilitated the learning progress. While learners were writing the two written tasks, I was moving around and checking if they were able to execute scientific reasoning skills such as prediction, analysis, interpretation, evaluation and making inferences. During the writing of written task 1, I asked them why they understand the arrangement of the particles in solid, liquid and gas. They indicated that observing the particles of states of matter from PhET, they observed that the arrangement of the particles depends on the temperature. Through PhET simulations, when the temperature was increasing, the kinetic energy of the particles also increased the speed. Furthermore, when the temperature decreased, the kinetic energy of the particles also decreased. Hence, they were able to conclude about the arrangement of solid, liquid and gas by finding the relationship between temperature and kinetic energy of the particles. Furthermore, from the relationship between temperature and arrangement of the particles, they were able to conclude if the graph is for cooling curve or heating curve. In written task 1 section A, they indicated that the graph is for the heating curve while in written task 1 section B, they indicated that the graph is for the cooling curve. Indeed, written task 1 sections A and B were for the heating curve and cooling curve, respectively. Consequently, they were able to develop scientific reasoning skills because of using PhET simulation. They indicated that through PhET simulation, they were able to get questions correct. Furthermore, when the temperature decreased, they were able to observe that the spaces between the particles in solid decreased; in liquid the space started to increase further; and in gas the spaces are widely opened. Additionally, learners got question 1.1.5 in written task 1 section A correct as ‘increase’ because they had developed the skills of making inferences.

Through the written task 2 section B, learners indicated that the topic is no longer too abstract with PhET intervention. They learn through observing because the particles are too abstract in nature. It is very difficult to visualise the particles in 3-dimensions. Thus, PhET was able to visualise the behaviour of the particles in 3-dimension. Furthermore, while observing, they were able to recognise that the decrease in temperature makes the process of states of matter to be freezing point. Also, they indicated that the particles are packed together when observing through PhET simulation. Subsequently, learners were able to answer questions 1.2.6.1 and 1.2.6.2 of written task 1 section B. In question 1.2.8 of written task section B, they indicated that the graph is for cooling curve. This means that when the temperature decreases, the three states change from gas to liquid and to solid. Hence, this aligned with the process of states of matter. From the two written tasks, many learners were able to exhibit scientific reasoning skills such as prediction, analysis, interpretation, evaluation and making inferences. Only few of them failed to exhibit scientific reasoning skills.

Table 4.4 illustrate the observation schedule, which summarises what was observed with comments during written tasks 1 and 2. When observing through the use of PhET simulation, they were able to grasp high cognitive reasoning skills when characterising the states of matter, solid, liquid and gas. Their scientific reasoning improved when PhET was introduced. At the same time, it was easy to characterise the state of matter as solid, liquid and gas because of visualising the change in states of matter. Furthermore, through observation, most learners were able to find the relationship between temperature and the behaviour of the particles. Through observation, they were able to predict. For example, to explain what melting point and boiling point are. While observing, they were able to observe the behaviour of the particles when the temperature increased and decreased. They were able to notice the graph as cooling curve and heating curve. To be able to characterise the states of matter depends on the arrangements of the particles. All in all, it was easy to characterise the state of matter as solid, liquid and gas because of visualising the change in states of matter.

Table 4.4: Observation schedule

QUESTIONS	YES	NO	COMMENTS
1. **Learners can grasp high cognitive reasoning skills when performing the experiments**	Yes		Through the use of PhET simulation, learners were able to grasp high cognitive reasoning skills when characterising the states of matter, solid, liquid and gas, the scientific reasoning of learners has improved when PhET was introduced
2. **Learners can explain the particles using kinetic molecular theory**	Yes		Learners were able to execute, scientific reasoning skills such as prediction, analysis, interpretation, evaluation and making inferences
3. **From the experiments, learners can characterise solid, liquid and gas**	Yes		It was easy to characterise the state of matter as solid, liquid and gas because of visualising the change in states of matter
4. **Learners can explain the effect of temperature to find the difference between the three phases.**	Yes		Through observation, most learners were able to find the relationship between temperature and the behaviour of the particles

4.4 Interpretation of results

In this section, the five themes are interpreted using scientific discovery of dual search and literature. In each theme, the scientific reasoning skills were evaluated from the written responses from the two physical science tasks, observations and semi-structured interviews. The purpose of the study was to explore scientific reasoning skills of states of matter using physics education technology (PhET). The particles are microscopic in nature, and it is impossible to visualise their behaviour in the school laboratories due to the scarcity of the relevant equipment. Consequently, PhET simulation is adopted as a tool to visualise the behaviour of the particles in this study. Additionally, this chapter evaluates and interrogates the results to answer the following research questions that were mentioned in chapter one: What are the learners' scientific reasoning skills of state of matter when using PhET? And why do learners exhibit these particular scientific reasoning skills?

The chapter presents the interpretation of results from the two written tasks, observations and semi-structured interviews using scientific reasoning skills, scientific discovery as dual search and the literature. Firstly, learners wrote the first written task 1, sections A and B and written task 2. Essentially, this enables me to come up with strategies on how to assist them during the process of developing scientific reasoning skills. Secondly, to check how scientific reasoning skills are utilised when writing the written task. Lastly, to check if learners can use scientific reasoning to apply the change in states of matter, I observed three written tasks. In a way, the chapter also interpreted the results from observations and semi-structured interviews. The three tenets of the theoretical framework play a vital role in interpreting the results.

As detailed in chapter two, the theory entails three tenets: 1) searching the hypothesis space; 2) searching experiments; and 3) evaluating evidence. The three tenets support each other. Hence, the two written tasks in this chapter help to interpret the results.

The results obtained through the written tasks, observations and semi-structured interviews were coded using the axial coding and further analysed thematically. Precisely, two written tasks were categorised into five themes that developed when PhET was used as follows: 1) appropriate connections between kinetic energy and temperature; 2) ability to analyse and interpret a graph in processes of state of matter; 3) making predictions in state of matter; 4) developing scientific reasoning skills and understanding of the change in states of matter; and 5) inappropriate use of scientific reasoning skills, such as prediction, analysis, interpretation, evaluation and making inferences. Hence, the results in each theme are interpreted using the existing literature together with the three tenets of scientific discovery as dual search below:

4.4.1 Theme 1: Appropriate connection between kinetic energy and temperature

In the current study, learners were able to find the correct relationship between the kinetic energy of the particles and the temperature applied. Subsequently, they developed the scientific reasoning skills such as analysis and interpretation through PhET simulation. With the auspices of the SDDS learners were able to search the hypothesis space, and used imagination to conclude on the behaviour of the particles. More importantly, the tenet of search for the hypothesis was implemented for them to design the hypothesis of the change in states of matter (Klahr & Dunbar, 1998). Similarly, a study by Obaya et al. (2023) showed that learners were able to find the relationship between law on the conservation of matter and chemical reactions, resulting in a positive impact on all the questions given in the written task. Interestingly, a study by Obaya et al. highlighted that the use of PhET helped learners to visualise the relationship between law on the conversation of matter and its chemical reaction. Consequently, learners were able to visualise the relationship between law on the conservation of matter because of the correct adoption of search of the experiment in SDDS. Equally important, in the current study, in the interview transcripts, learners indicated that through observation of the particles, they were able to find how temperature affected the behaviour of the particles. Through using theoretical framework to evaluate the results, this shows that they were able to operate within one of the tenets of the SDDS “evaluating the evidence”. Rahmawati et al. (2022) also seem to agree with the assertion that PhET simulations were clear and easy to follow. No difference was found in a study by Farcis (2023), which indicated that PhET simulation helped learners to analyse and interpret the questions. This happened in this way: the results moved from 45% to 89%. Subsequently, PhET simulation helps learners to develop the skills to analyse and interpret the questions given from task 1, sections A and B. In a similar manner, PhET simulation makes learning easy because learners were able to analyse sub-microscopic representations of various acid and base solutions having the same concentration (Nuraida et al., 2021). In this way, they were also able to develop the skills analysis and interpretation. With the PhET simulations, they were able to visualise the behaviour of the particles in solid, liquid and gas. For example, they were able to experience the increase and decrease in temperature while observing the behaviour of the particles. Presently, they were able to observe, characterise, visualise and explore the hidden properties of the three states of matter, solid, liquid and gas. Most importantly, they were able to develop analysis, prediction, interpretation and evaluation when the states change from one form to another. Firstly, for example, in sequential order, learners developed how to analyse by finding the appropriate relationship between the behaviour of the particles and temperature applied through the use of PhET simulation. Secondly, they came up with the hypothesis, as when the temperature increases, the behaviour of the particles also increases, and when the temperature increases, the behaviour of the particles decreases. By observing the behaviour of the particles when the temperature increases and decreases from PhET simulation, learners were able to predict the processes of states of matter as melting point, and came up with the correct definition. Lastly, when the graph of cooling and heating was given, they were able to interpret and evaluate the following properties: temperature applied on the particles, kinetic energy of the particles, arrangements of the particles, and the change in states of matter and pressure.

Three tenets of the theoretical framework that guides the current study: “search hypothesis”, “search experiment” and “evaluate the evidence” evaluate if learners were able to come up with the hypothesis, search the experiments and evaluate evidence (Adri, 2023). Through the use of PhET simulation, they were able to come up with the “hypothesis”, perform the “experiments” and “evaluate the evidence” from the visualisation of the behaviour of the particles (Lobato & Zimmerman, 2018). Firstly, learners formulated the “hypothesis” as, when the temperature increases, the behaviour of the particles will also increase. Similarly, a study by Najib et al. (2022) indicated that to formulate the hypothesis helped learners in the analysis and interpretation of connections between the concepts. The results of this current study and a study by Najib et al. showed that to come with the hypothesis helped learners to make connections between the concepts. In contrast with a study by Najib et al., a study by Mashaqbeh (2014) showed that after the hypothesis, learners should perform the experiment and check if it was correct or wrong. Ultimately, Mashaqbeh's (2014), study used PhET to visualise chemistry concepts to achieve good results. Similarly, in the current study, PhET was used to visualise the behaviour of the particles as speedy or less speedy to be able to conclude on the final states of matter. Secondly, they used PhET simulation to perform the experiment. Concurrently, they observed the relationship between temperature and the behaviour of the particles. At the same time, learners evaluated evidence from observing, exploring and visualising the behaviour of the particles through PhET simulation (Liu et al., 2022). In a similar manner, PhET helps the learning of quadratic functions in mathematics and explores simulations in a visual and interactive way (de Sousa & Alves, 2022). During interview transcripts, learner Z indicated that from the diagram of cooling and heating curve, they can tell if the substance is water or not. This shows that learners were able to operate under the tenet of "evaluating the evidence" sufficiently. No difference was found in a study by Byrne (2020). PhET was also used for learners to understand the physics concepts related to motion. Learners are spending far more time in front of screens. In contrast with a study by de Sousa and Alves (2022), the difference was that PhET helps learners in visualising quadratic functions in mathematics, while in a study by Byrne (2020), PhET was capable of visualising the concepts related to motions. In the study by Byrne, learners were unable to adopt the tenet of the SDDS such as search for the hypothesis. For example, they did not design the hypothesis for the experiments of motions, they were just visualising the motions. However, the were able to achieve the "search for the experiments" according to SDDS. Both studies by de Sousa and Alves (2022) and Byrne (2020), differ with the current study because PhET was capable of visualising the behaviour of particles in different states of matter. A study by Dallaire and Gosselin (2016) is not in line with the current results of the study. It was still difficult to grasp the concept of state of matter such as the change in states of matter because learners were not able to engage themselves in the observation process. Subsequently, PhET was not used in the study by Dallaire and Gosselin (2016), where learners were visualising the behaviour of the particles on the board, whereas in the current study, visualisation was in a 3-Dimension. Hence, the above study by Dallaire and Gosselin (2016) was not aligned with the current study, and the study by Byrne (2020) because learners did not observe the behaviour of the particles through PhET simulation. Over and above, in the current study, learners were able to make conclusions related to the arrangements of the particles, states of matter, temperature and process of states of matter through PhET simulation. For example, from the current study, when the temperature increases, the behaviour of the particles also increases. Consequently, the arrangements of the particles changed, resulting in learners observing when the states change from solid to liquid and liquid to gas. Formerly, from the hypothesis, learners showed that their scientific reasoning skills such as prediction improved when PhET was used. In contrast, the majority of the subjects do not seem to be able to approach the issue of change in the state of matter (Rodriguez & Castro, 2014). Briefly, in the current study, learners were able to develop scientific reasoning skills such as analysis and interpretation by observing the relationship between temperature and behaviour of the particles and if the graph is for cooling curve and heating curve.

In the current study, learner M showed that PhET helped in visualising the behaviour of the particles when the temperature increases and decreases. Indeed, when the temperature increases, the kinetic energy of the particles also increases, and the relationship was directly proportional. In the same way, when the temperature decreased, the kinetic energy of the particles also decreased, and the relationship was inversely proportional. The results are the same as a study by Ndihokubwayo et al. (2020), which interpreted the results to show how PhET improved the conceptual understanding of geometric optics. Ultimately, the PhET was the tool that visualised the behaviour of the particles in this study. Furthermore, PhET simulations are powerful tools for helping learners visualise electrons, photons, atoms, wave interferences and other quantum phenomena that cannot be observed directly (McKagan et al., 2008).

In the same way, in this study, PhET was capable of visualising the behaviour of the particles in solid, liquid and gas to help learners to explore scientific reasoning skills such as prediction, analysis, interpretation, inferences and evaluation. For example, learners executed the scientific reasoning skills, and stated the hypothesis results. They developed scientific reasoning skill of prediction. Subsequently, after performing the experiment using PhET simulation, they were able to conclude if the prediction was correctly stated or not. To illustrate that learners were able to predict, if the temperature increases, the behaviour of the particles also increases. In fact, the prediction was correctly stated. In this way, the prediction as a skill is developed by learners in the current study when the PhET is used (Doloksaribu & Triwiyono, 2021). On the other hand, through PhET simulation, they were able to visualise the arrangements of the particles, the states change, temperature increases and decreases and the process of states of matter. To support the study above, similar results from a study by Dantic et al. (2022) indicated that by visualising, they were able to analyse and interpret using PhET simulation.

More importantly, McKagan et al. indicated that learners can conduct experiments about topics such as the photoelectric effect and double slit interference in many physics' labs. There is much going on inside these experiments that they cannot observe. Findings from Saudelli et al. (2021) describe the PhET, their usage in teaching practice, and how PhET helped learners to develop analysis and interpretation, and to provide a visual representation and mental model of the physics concepts that can be discovered, sensed, and manipulated by learners who construct learning based on the PhET response to their use of the tool. Additionally, PhET allows learners to connect real-life phenomena and the underlying science, making those that do not appear to be visible (Masruroh et al., 2020). Similarly, from a study by Masruroh et al., which is the same as the current study, learners were able to observe the behaviour of the particles when the temperature increased and decreased, resulting in learners to "search the experiments" through PhET simulation (Klahr, 1989). In short, learners started to "evaluate the evidence" because after observing and visualising the behaviour of the particles, they were able to conclude on the change of states of matter. For example, at the beginning of the experiment through PhET simulation, the particles were packed together (solid state), and when learners applied the temperature through PhET simulation, the particles started to be loosely packed (liquid state). Hence, learners started to "evaluate the evidence" to find the effect of temperature on the behaviour of the particles. Another study by Masruroh et al. highlighted that in designing the electrical circuit, PhET simulated an image of the movement of the current in a circuit, where the current cannot be seen by the naked eye on the actual electronic components. They knew that in the electrical circuit of the series, if one of the lights is disconnected, then the other lamp is extinguished. Because the cables are arranged in parallel, so that if one of the lights is disconnected then the current stopped flowing. Hence, PhET-assisted learners in learning wave material. It can be concluded that the PhET simulation-assisted problem-based learning model has an effect on student learning outcomes in wave material (Imaniah et al., 2023).

A study by Imaniah et al. which was aligned with the current study, support the fact that PhET improve scientific reasoning skills. Subsequently, learner C indicated that they found the arrangements particles in solid, liquid and gas through PhET simulation. On the one hand, learners used PhET to analyse the concept of saturation as it pertains to the point at which salt can no longer dissolve effectively in water (Rayan et al., 2023). For example, in Rayan et al. (2023), PhET was useful because it helps learners in this way: they added salt gradually into the water, witnessing its dissolution. On the other hand, Arabacioglu and Unver (2016) have proven that the integration of virtual simulation PhET makes the learning process simple in gas properties. Learners were able to visualise the behaviour of the particles through PhET simulation, and they improved their scientific reasoning skills like in the current literature. Similarly, to blend PhET simulation in learning energy and change it enables them to be interested in learning, and further stimulate their thinking potential (Maghan, 2017). More importantly, in the current study, learners found it interesting to learn through PhET simulation because they developed scientific reasoning skills to written tasks 1 and 2. Fencl's (2013) study supported the argument that learners developed interpretation as a skill, and comprehended how to raise or lower the total energy level. This shows that they developed interpretation as a skill when using PhET simulation. In the same way, in this current study through visualisation learners were able to develop interpretation as a scientific reason skill because now they comprehend the behaviour of the particles in solid, liquid and gas using PhET simulation. In summary, they were able to find the relationship between the behaviour of the particles and the temperature applied when PhET was used. In short, when the temperature increases, the kinetic energy of the particles also increases. Also, when the temperature decreases, the kinetic energy of the particles also decreases.

4.4.2 Theme 2: Ability to analyse and interpret a graph in processes of state of matter

Through the use of PhET simulation, learners were able to analyse and interpret the question and the graph given (Sarwoto et al., 2020). At the same time, no difference was found. Through the use of PhET, they were able to observe the processes of states of matter from melting to freezing sublimation. This emanated from visualising the three states of matter when the temperature is applied in terms of the behaviour of the particles. This question was given to the learners in this current study in written task 1 section B: 1.2.2 "When you take a block of margarine out of the fridge, it is hard. However, after 30 minutes at room temperature it is soft to spread. Use kinetic molecular theory to explain this observation". Before the use of PhET, learners were unable to analyse and interpret the question above after the use of PhET. The question was easy for them to analyse and interpret (Jenkins & Howard, 2019). In this way, they developed scientific reasoning skills such as analysis and interpretation through "searching the experiment" (Klahr & Dunbars, 1998). Interestingly, learners were able to relate on the breaking of the molecules when the temperature is applied from the sun. Through the use of PhET, they observed the behaviour of the particles. Furthermore, to evaluating evidence space, they should be able to analyse and interpret data, make informed inferences and draw conclusions (Lobato & Zimmerman, 2018). This is the reason they were able to relate on the breaking of molecules when the margarine was directed to the sun (evaluating the evidence). Hence, it was coded as ZZM32, OOM32, TTM32, PPM32 and UUM32 in written task 1, section A after the use of PhET simulation.

In this current study, through the use of PhET, they were able to spot if the graph is cooling curve or heating curve. At first, they were able to define sublimation and melting point by just analysing the graph. They were also able to execute the analysis and interpretation as the scientific reasoning skills throughout the written task 1, sections A and B. Similarly, learners who applied the scientific approach always started the problem-solving process by analysing the problems qualitatively (Yuliati et al., 2018). No difference was found. In this current study, when the PhET was introduced, they started to develop scientific reasoning skills such as analysis and interpretation.

Using PhET, learners were able to analyse if salt can dissolve into water (Rayan et al., 2023). As supported by the findings of this study, PhET was able to help learners to analyse the change in states of matter. Similarly, another study showed that the use of PhET was helpful in learning how to construct simple, series, parallel and series-parallel circuits (Potane & Bayeta, 2018). In the interview transcripts, learner R showed that through the use of PhET, they were able to spot if the graph is cooling curve or heating curve by checking the increase and decrease of the temperature applied. This also accords with our earlier observations that PhET helped learners to visualise the atomic structure, leading to an increase in the performance from 50.6% to 85.7%. In the current findings, the bar graph on data presentation showed that appropriate scientific reasoning skills such as prediction, analysis, interpretation, evaluation and making inferences have increased. This supports the assertion that the use of PhET simulation improved the scientific reasoning skills on learners such as prediction, analysis, interpretation, evaluation and inference when observing the behaviour of the particles. Through observing the behaviour of the particle's learners were able to conclude on the arrangements of the particle when using PhET simulation.

4.4.3 Theme 3: Making correct predictions in state of matter

Prediction in the scientific way is a fundamental part of the scientific method, serving as a means to test hypotheses and theories, validate models, and advance scientific knowledge through systematic observation and experimentation (Karpatne et al., 2017). In this current study, learners were able to predict what can happen when the temperature is applied on the substance. Through the use of PhET, learners were able to predict that if the temperature increases, the kinetic energy of the particles also increases. Hardyadi and Pujiastuti (2020) conducted a study to determine effects of using PhET simulation in systems of living organisms. The study found that the use of PhET simulation is significant in improving learners how to make predictions, analyse, interpret and evaluate the change in states of matter. These findings concurred with the findings I got with the PhET intervention. Interestingly, the two tenets of SDDS "search hypothesis" and "search experiment" indicate that learners were able to formulate the hypothesis relating to the change in states of matter. Results from Piyatissa et al. (2018) indicated that learning forces in physics using PhET worked well to support the textual and verbal explanations of the scientific principles. Similarly, Beichumila et al. (2022) found that simulations improved learners' basic skills of observation, prediction, pattern analysis, and reasoning science process skills.

The results of this study indicated that by using PhET simulation, it was easy for learners to understand the change in states of matter. Additionally, they observed the behaviour of the particles and intermolecular forces. The strength of intermolecular forces within a substance greatly influences its state of matter (Merchant, 2019). Substances with strong intermolecular forces such as hydrogen bonding or ion-ion interactions tend to exist as solids or liquids at room temperature, while those with weaker forces often exist as gases. Learners were able to visualise the attraction by using PhET simulation as a tool. Similarly, Bandoy et al. (2015) found that 28% mentioned that using PhET is very effective, and 72% said that it is effective. Contrary to the current study, Yunzal and Casinillo (2020) found that learning electrodynamics using PhET simulations did not significantly improve learning, although learners showed interest in playing with the simulations. All in all, learners were able to predict when PhET was used. Through the PhET, some modes of motion displayed in the simulation are more visualised and even more interesting than the real conditions in a real laboratory (Verawati et al., 2022). This shows that PhET software creates abstract physics animation such as atom, electrons, protons and magnetic field, which cannot be seen with the naked eye (Susilawati et al., 2023). Similarly, Bandoy et al. (2015) found that 28% mentioned that using PhET is very effective, and 72% said that it is effective. In the same way, the current study showed that the learning of the change in states of matter through PhET was fruitful. Hence, learners were able to define melting and sublimation. Additionally, they indicated that the simulations are very helpful, attractive and appealing. Over more, the use of PhET simulation improved the critical thinking and creative skills of learners (Hasyim & Prastowo, 2020). In contrast, Yunzal and Casinillo (2020) highlighted that PhET simulation has revealed a low improvement in students' performance in the conceptual assessment in electrodynamics. All in all, the visualisation of the particles through PhET in different states of matter enabled learners to analyse and interpret the graph of states of matter of cooling and heating, resulting in them providing the reasoning on the answer.

For example, the graph showed that the temperature is decreasing, and it was easy for them to characterise the transition of state of matter from liquid to solid.

4.4.4 Theme 4: Developing scientific reasoning skills and understanding of the change in states of matter

Through the use PhET simulation, learners were able to develop scientific reasoning skills such as prediction, analysis, interpretation, evaluation and making inferences. Learners managed to execute scientific reasoning skills accordingly when PhET was used. This resulted in better understanding of the topic ‘change in states of matter’. Learners wrote written tasks 1 and 2 before PhET intervention and after PhET intervention. Through analysis, they were able to predict, analyse, interpret, evaluate and infer the use of PhET. Hence, the above results in this study were supported by the following studies. According to Klahr and Dunbar, exhibiting the scientific reasoning skills means that learners need to evaluate the evidence. Visualisation in chemistry can help to make the chemistry at a particular level less abstract because the students can see these particles moving using PhET (Suits & Sanger, 2013). Furthermore, learner N was able to describe solids, liquids and gas using kinetic molecular theory to describe the behaviour of particles through PhET simulation. Hardyadi and Pujiastuti (2020) conducted research intending to determine the presence or absence of a significant effect of the use of PhET simulation media on the learning achievements of the basic energy material in the life system. Through PhET simulation, gas molecules collide and move without fixed structural boundaries creating the dispersion and compressibility properties of gaseous matter (Gunawan et al., 2023). At the same time, Rohmah and Hidayan (2022) indicated that the use of PhET improved learning outcomes in online learning of molecular geometry material. For example, before using PhET, learners obtained 36%, and after the use of PhET the performance was 90%. Similarly, both studies were the same because with the use of PhET, learning has improved. Impressively, both studies above showed that PhET simulation was a powerful tool to make what is unseen with the naked eye to be visible. Even in this study, PhET was capable of visualising the behaviour of the particles because they are microscopic in nature.

Additionally, results of the current study from interview transcript of learner A showed that learners were able to characterise the three states of matter as solid, liquid and gas by visualising the behaviour of the particles through PhET simulation. Consequently, to perform the experiment helped learners to develop deep understanding. In this case, the experiment was performed using PhET simulation for learners to visualise the states of matter. Furthermore, observing the behaviour of the particles when temperature is applied helped learners to evaluate the evidence. Hence, through evaluating, learners were able to find the relationship between the temperature and kinetic energy of the particles. For example, when the temperature increases, the kinetic energy of the particles also increases. This results in them characterising the states of matter accordingly as solid, liquid and gas. Interactive PhET simulation have been showed to engage learners in active learning to enhance their conceptual understanding and promote critical thinking (Mashami et al., 2023). In short, they were able to define the process of states of matter such as melting point, sublimation and condensation. For example, they defined melting point as the temperature at which the solid-state changes to liquid state. To add on the conclusion, learners were able to come up with the trend that the decrease in temperature results in decrease in kinetic energy of the particles. Thus, they were unable to characterise the states of matter when the temperature is increasing.

4.4.5 Theme 5: Inappropriate use of scientific reasoning skills such as prediction, analysis, interpretation, evaluation and making inferences

Few learners still lack to execute scientific reasoning skills after the intervention of PhET simulation. Subsequently, in this study, they observe the behaviour of the particles through PhET simulation still the written tasks were difficult for them. Similarly, a study by Yunzal and Casinillo (2020) reported that learners were playing with the software PhET simulation than learning electrodynamics. To substantiate this, they were interested in how the PhET is used not focusing on the behaviour of the change in states of matter. This ends up with learners with inappropriate use of scientific reasoning skills. Furthermore, they fail to exhibit scientific reasoning skills to categorise three states of matter. Some of the learners are hands on, and need to touch experiments for them to have better understanding. Theme 5, the inappropriate use of scientific reasoning skills such as prediction, analysis, interpretation, evaluation and making inferences is categorised into five subtopics such as: (1) inappropriate connections between kinetic energy and temperature; (2) inability to analyse and interpret a graph in processes of state of matter; (3) failure to make correct predictions in state of matter; (4) undocumented reasoning in the change of states of matter, i) not know what to write, (ii) particles are too abstract to see with the naked eye, (iii) inability to think in a short period of time; and (5) appropriate use of scientific reasoning skills such as prediction, analysis, interpretation, evaluation and making inferences.

Inappropriate connection between kinetic energy and temperature

In this study, learners were unable to find the appropriate relationship between the behaviour of the particles and temperature applied. When they were given the graph to analyse, interpret and evaluate, it was too difficult for them to write written tasks one and two. The results of the current study are consistent with a study by Ozdemir (2021), who indicated that learners started to confuse the change in states of matter solid to liquid and liquid to gas when the temperature is applied. Similarly, in this study, it was too difficult to characterise the three states of matter solid, liquid and gas. To substantiate the difficulty of characterising the three states of matter, Borghini et al. (2022) showed that learners are unable to make connections between kinetic energy of the particles and the temperature applied on the different state of matter. This is due to their failure to implement one of the tenets of scientific discovery as dual search (SDDS), which is searching the hypothesis space. Firstly, learners were supposed to search for the hypothesis related to the change in states of matter. For example, when the temperature increases, the behaviour of the particle’s changes. Secondly, through the hypothesis, learners were able to search the experiments and visualise the behaviour of the particles when the temperature is applied. Thirdly, they were supposed to evaluate the evidence through visualising. From the results of this study, some learners were unable to show how the behaviour of the particles and the temperature affect each other with PhET intervention in written task 1, section A.

The current study shows that learners are unable to visualise the behaviour of the particles in solid, liquid and gas. At the same time, the lack of visualisation of the temperature applied on the substance and kinetic energy of the particles might be the cause of learners' failure to get the correct answers in the questions 1.1.3 and 1.1.4 in written task 1 section A before PhET intervention. These results are consistent with those of other studies, and suggest that learners found it difficult to characterise the three states of matter due to failure to connect concepts such as kinetic energy and temperature applied (Guiselin et al., 2022). Surprisingly, some of the learners were able to find the relationship between the behaviour of the particles and the temperature applied. Hence, they were able to visualise the behaviour of the particles drawn on the chalkboard and to comprehend the behaviour of particles in solid, liquid and gas in written task 1. In contrast to these current results in chapter 4, there were not many learners who got the correct answer in questions 1.1.3 and 1.1.4 in this study. This showed that learners need to visualise the behaviour of the particles moving when the temperature is applied. Similarly, Jasien (2018) found that learners were unable to infer from the behaviour of the particles when the temperature keeps increasing. To substantiate, from Jasien's study, even in this study, learners are unable to make inferences to come up with the correct relationship between the behaviour of the particles and the temperature applied. Thus, from the interview transcripts in written task 1 section A, learner A showed the confusion as "in solid the particles are closed to each other, for liquid and gas I don't know how to differentiate in terms of the particles". This showed that Learner A was unable to make inferences, resulting in him failing to comprehend the relationship between the behaviour of the particles and the temperature applied.

Inability to analyse and interpret a graph in processes of states of matter

Learners were unable to analyse and interpret the graph given in chapter four written tasks 1 and 2 before the use of PhET simulation. Analysis and interpretation are the scientific reasoning skills learners should acquire when writing task 1, sections A and B. In the current study, Learner W seemed confused, "Sir! I randomly choose the answer" when answering question 1.1.5 in written task 1 section A. In short, the learner was unable to analyse and interpret the graph given in the change of processes of states of matter. Furthermore, the inability to analyse and interpret is due to insufficient visualisation of the movement of the particles of three different states of matter (Jenkins & Howard, 2019). Equally important, the scientific discovery as dual search (SDDS) highlighted one of the tenets as learners should be able to search the experiments. Learners were supposed to visualise the behaviour of particles when performing experiments related to the change in states of matter. Afterwards, when they perform the experiments, they could be able to evaluate the evidence. For example, they can be able to observe the behaviour of the particles when the temperature is applied. Additionally, they can conclude on the states of matter as solid, liquid and gas according to the behaviour of the particles. In the current findings, learners visualised the behaviour of the particles in solid, liquid and gas on the chalkboard. Most of them were unable to analyse and interpret the graph given on the change in states of matter. This finding corroborates the ideas by Borghini et al. (2022), who suggested that learners had difficulty to analyse when the particles were not moving. They only visualised the drawn dots inside the box on the chalkboard when states change from one state to another. This is the reason they were unable to get the correct answers in written task 1 sections A and B due to their inability to execute scientific reasoning skills such as analysis. All in all, the lack of visualisation in 3-D results in learners lacking scientific reasoning skills.

In this current study, in the interview transcripts, Learner U indicated that “Sir! You drew 3 boxes to show us the behaviour of particles in three states of matter but it’s not helping”. This showed that learners are unable to visualise the three states of matter to be able to analyse the written tasks. A study by Vieira and Morais (2021) indicated that learners experience challenges to characterise three states of matter. They were given three boxes with different dots inside to represent the behaviour of the particles when temperature is applied. 5 out of 40 learners were able to comprehend the dots as the behaviour of the particles. Still in the same study, three (3) learners showed that it was difficult to get question 1.1.5 from the written task 1 section A correct due to the lack of analysis and scientific reasoning skills. To illustrate this from written task 1, learners were supposed to analyse and interpret the graph given by checking the effects of temperature on the behaviour of the particles.

From the answers, you can conclude that they are unable to analyse and interpret the graph given as written tasks. Similarly, another study by Chomanee et al. (2022) indicated that learners had difficulty in state of matter, specifically when the phase change due to the abstract nature of atoms and molecules. Hence, the findings concurred with the findings of this study because the responses of the learners showed that the topic is too abstract in nature. For example, from the interview, learner U indicated that “I don’t know the answer for question 3.4.1”. Briefly, learners lack scientific reasoning skills such as analysis and interpretation, which emanated from the visualisation of the particles in 3-D, dimensions.

Failure to make the correct prediction in state of matter

Learners do not perform experiments with the formulated hypothesis (Löffelsender et al., 2021). Most of them were unable to define melting point and sublimation. Consequently, learners failed to formulate the hypothesis due to lack of scientific reasoning skills of prediction. Similarly, in studies by Jasien (2018) and Löffelsender et al. (2021), learners failed to analyse the graph in this way. When the temperature increases, the kinetic energy of the particles also increases. The difficulty of interactions between particles and temperature results in learners failing to predict the change in state of matter. Furthermore, they were unable to formulate the hypothesis and to make predictions. For example, they were unable to explain what melting point and sublimation are. They indicated that in melting point, they do not see the behaviour of the particles starting to move or the breaking of the molecules. They were unable to visualise the behaviour of the particles to be able to predict.

Learners were unable to define “sublimation”. This is because they did not even observe when the states change from solid to straight to gas. At the same time, they were supposed to visualise the change of states for them to be able to define “sublimation” correctly. Again, for learners to acquire the scientific reasoning skill “prediction”, they need to observe the states of change from one form to another. Learner J answered question 1.1.1 as follows: “the phase at which liquid changes to gas” shows that the learner does not know how to make a prediction to be able to come up with the correct definition. To make a prediction helps learners to get all the questions correctly. To substantiate the idea, learner A got question 2.1 wrong. The questions that followed were also wrong. One of the issues that emerges from these findings is that learners are unable to observe, evaluate and infer the behaviour of the particles. Consequently, they struggle in learning state of matter because of lack of good resources to demonstrate the behaviour of the particles (Healy et al., 2021). Similarly, in this study, learners were supposed to observe when the temperature increases and when it decreases. In this way, they can be able to evaluate and make inferences.

Undocumented reasoning in the change of states of matter

Most learners left spaces open because they did not know what to write while others did not understand the topic at all. Few of the learners did not write the answers because they did not give themselves enough time to think. Undocumented reasoning is when learners leave open spaces without giving the answer on the question asked (Li et al., 2020). They did not know what to write since the change in states of matter is too abstract. In other words, they did not understand the topic at all. For them to understand the change in states of matter, they should find the relationship between temperature and the behaviour of the particles, arrangement of the particles, difference between the diagram of cooling and heating curve, and characterise three states of matter in the diagram of the change in states of matter. Similarly, a study by Baydere (2021) highlighted those learners found it challenging to interpret graphs given on the change of states when the temperature is applied. Hence, some of them left spaces open without writing answers. Learners learn better through observation. Other findings support the assertion that learners need to acquire skills of interpretation because graphs need to be interpreted before answering the question that follows (Inaltekin & Akcay, 2021).

During the interviews, Learner K indicated that it was difficult for him to find the relationship between temperature and kinetic energy of the particles. Indeed, to learn without visualisation in 3-D made learning difficulty. Another study by Lopez and Pinto (2017) indicated that the learning of three states of matter was very difficult without visualising the behaviour of the particles. Few learners failed to find the relationship between temperature and kinetic energy because the changes in states of matter often involve abstract concepts such as molecular movement, energy transfer and phase transitions that are not directly observable. This made it challenging for learners to visualise and understand what is happening on a microscopic level. In a similar manner, they were unable to reason scientifically when the temperature decreased on the water liquid states (Renati, 2022). This emanated from the issue of their inability to explain what freezing point is. This stresses the point that learners lack the skill of prediction. Hence, the challenges are due to the lack of visualisation. Another reason for learners to lack scientific reasoning skills or to leave spaces open were inadequate instructional methods. Traditional instructional methods that rely heavily on rote memorisation and passive learning may not be effective in teaching scientific reasoning. Active learning strategies such as hands-on experiments, simulations and inquiry-based learning are often more effective but may not always be used. Contrarily, the PhET simulation was used in this study to improve scientific reasoning in learning the change in states of matter. Future studies on the current topic are therefore advised to address these challenges in learning the change in states of matter. Learners can use a variety of strategies, including inquiry-based learning, hands-on experiments, visual aids, analogies and formative assessments to support and enhance learners' scientific reasoning skills.

4.5 Synthesis

The interpretation of the results has led to the realisation of principal findings of the study. First, learners were able to find the relationship between the temperature and behaviour of the particles in different states of matter such as solid, liquid and gas. Accordingly, the justification that was given by learners during the interviews highlighted that through the use of PhET, they could visually see the animations that clarify the microscopic increase and decrease of the temperature, resulting in increased kinetic energy of the particles. This results in the particles to behave differently in solid, liquid and gas. In solid, the particles pack together as tightly as possible in a neat and ordered arrangement; in liquid particles are quite close together and move with random motion throughout the container; and in gas they move rapidly in all directions, colliding with each other. Consequently, learners were able to achieve scientific reasoning skills of prediction and analysis because they were able to come up with the hypothesis such as "when the temperature increases, the kinetic energy of the particles also increases". According to the SDDS, this indicates that they were comfortably operating within the tenet, 'search for hypotheses.' Second, by observing the behaviour of the particles in terms of arrangements using PhET simulation, learners were able to conclude on the final states of matter. They concluded the states of matter in this way, they are closed and organised in solids, closed but irregular in liquids and far apart and irregular in gases. Also, during the interviews, they provided a reason that the simulations clearly displayed the various arrangement and behaviour of the particles. For example, in a solid state, they were packed together and with vibrations; in a liquid state, the particles were loosely packed; and in a gas state, the particles were far apart and in motion. As a result, the scientific reasoning skills of analysis and interpretation were achieved. Hence, in the auspices of the SDDS, the learners were collecting data related to the change in states of matter, exhibiting scientific reasoning skills within the tenet, ‘search for experiment’.

Third, learners were able to generate the trend of the decrease in temperature results with a decrease in kinetic energy of the particles. During the interview, they provided justifications that the PhET simulations assisted them to observe the behaviour of the particles as well as how the increase and decrease in temperature affect the movement of the particles. Hence, the scientific reasoning skills of analysis and making informed inferences were acquired. By acquiring the scientific reasoning skills of analysis and making inferences, they were able to reason out when the temperature is at constant with what the energy referred to on the heating curve diagram. As a result, the SDDS pitch in to allow learners to draw conclusions after the visualisation of the particles regarding the temperature applied, arrangement of particles, behaviour of the particles, pressure and the speed of the particles- operating within the tenet “evaluate the evidence”.

Fourth, they were able to reason out why the temperature increases or decreases during phase change. Thus, the reason was given from the interview transcript. Learners were able to notice if the diagram is showing either cooling or heating curve. The reason emanated from visualising the behaviour of the particles with the temperature applied. Consequently, the scientific reasoning skill of evaluation was achieved by learners. According to one of SDDS tenets, “evaluation of evidence”, this proves that they were able to draw conclusions by giving the reason why the behaviour of particles depends on the decrease and increase in the temperature attained when PhET was used. Fifth, learners were able to characterise the states of matter on the physical changes of substances at atmospheric pressure. As a result, from the interview transcripts, they justify the ability to characterise using the arrangements of the particles through PhET simulation. In solid, particles are close to each other and vibrating; in liquid, they are slightly in motion; and in gas, the particles gain more kinetic energy. The two tenets of SDDS “search hypothesis” and “search experiment” indicate that learners were able to formulate the hypothesis relating to the change in states of matter. Afterwards, they were able to perform an experiment in collecting data on the change of states of matter through PhET simulation. During the experiment, some of them were unable to achieve the scientific reasoning skills of making an informed inference. Lastly, still some of the learners fail to find the relationship between temperature and the behaviour of the particles, arrangement of the particles, differences between the diagram of cooling and heating curve; and to characterise three states of matter in the diagram of the change in states of matter. Consequently, in interview transcripts, learners indicated that when observing the behaviour of the particles, it was too difficult to make informed inferences of the above-mentioned properties. Indeed, they were unable to find the relationship between arrangements of the particles and the temperature applied. Hence, the scientific reasoning skills of prediction, analysis, interpretation, evaluation and inference were not achieved. This shows that they were unable to find the trend between temperature and kinetic energy of the particles which flawed the evaluation of evidence.

Figure 4.27 proposed scientific reasoning skills of characterising states of matter as solid, liquid and gas using PhET simulation and the way the results were evaluated with the SDDS. Related to the two written tasks, interview transcripts and observations, learners answered the questions by formulating the hypothesis first and after that search for the experiment. To perform the experiment, PhET was used to visualise the behaviour of the particle in 3-dimensions. Through visualisation of the particles, learners were able to evaluate the evidence. For example, from the current study, they were able to conclude on the final states of matter by observing the arrangement of the particles. To evaluate the evidence, they started to exhibit scientific reasoning skills such as prediction, analysis, interpretation, evaluation and making inferences. Figure 4.27 is a cyclic process because if the experiment does obtain the outcome, the process keeps starting and repeating itself.

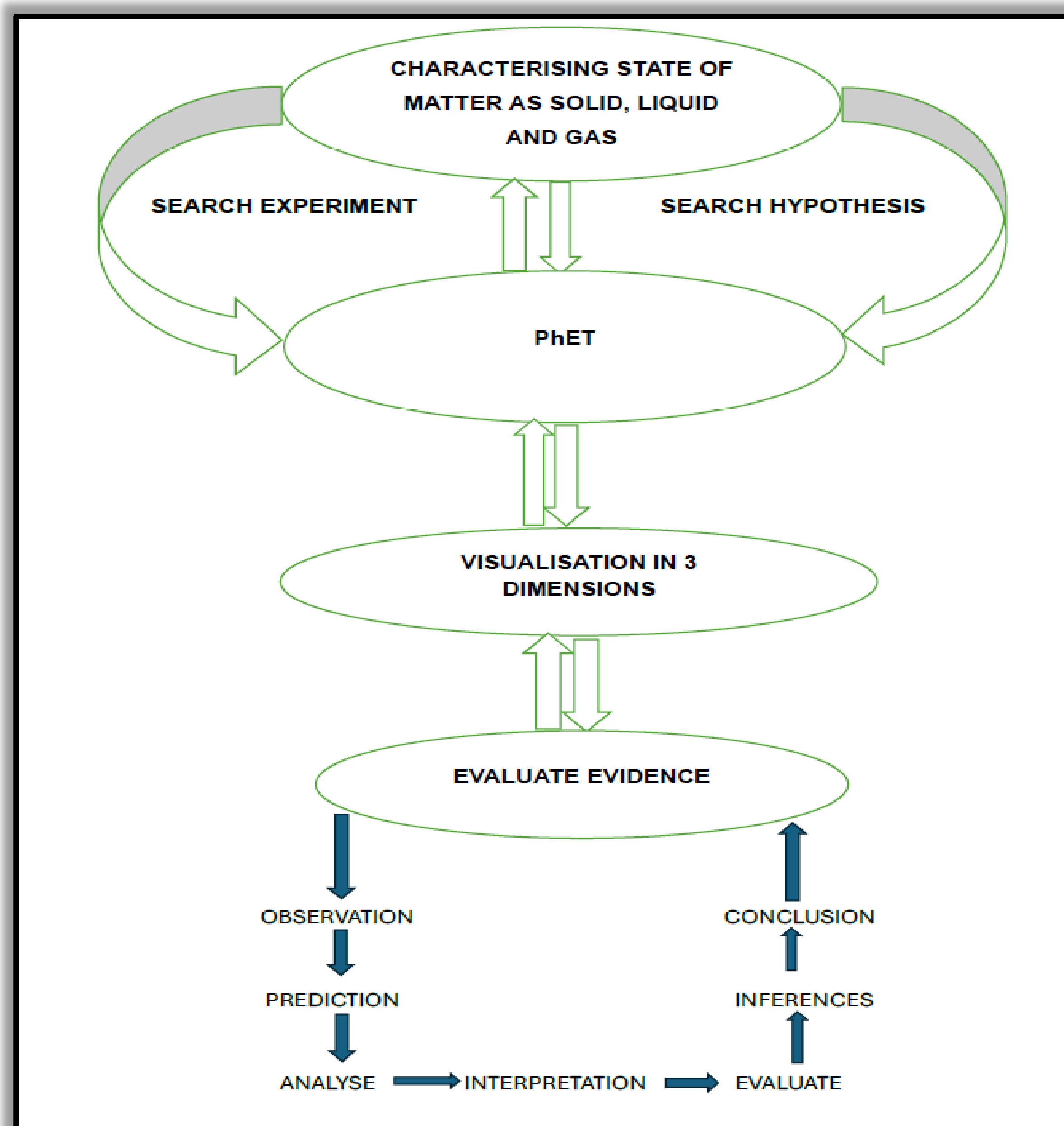


Figure 4.27: Synthesis of SDDS, scientific reasoning skills, PhET and the change in states of matter for the current study

4.6 Chapter summary

The chapter presented an analysis of data acquired, interpretation and discussion of results from two written tasks, observations and semi-structured interviews. Since five themes emerged from the two sets of data, the analysis was shown in each theme as a way of illustrating that Grade 10 learners displayed various scientific reasoning skills while responding to the two written tasks, observations and semi-structured interviews. The next chapter will focus on the limitations of the study, conclusions based on the research questions and recommendations.

CHAPTER 5:

CONCLUSIONS AND RECOMMENDATIONS

5.1 Introduction

The previous chapter focused on the data presentation, analysis and interpretation of results. This chapter presents the reflection on research design and method, research questions of the study, recommendations, contributions of the study, limitations of the study and the conclusions. Sequentially, the research design and methods are checked if they were followed. At the same time, I check if the sub-questions of this study were answered and recommendations are made. Additionally, the limitations of the study are addressed in this chapter. Over and above, the conclusions of the study will be made. Revisiting what was stated in chapter one, the purpose of this study was to explore scientific reasoning skills of state of matter using physics education technology (PhET).

5.2 Reflection on research design and method

This study adopted the exploratory case study design by Merriam and the qualitative approach. Three instruments were used to collect data: documents, observations and interviews. The 'what', 'why' and 'how' research questions were asked. During inductive data analysis, the data were categorised, grouped and coded. Thereafter, themes emerged from the coded data. Furthermore, the results of the study were generated, then interpreted using literature and the theoretical framework, the SDDS. Subsequently, the principal findings were generated.

5.3 The answers to the research questions

The research questions were categorised into the main research question and sub-research questions. The main research question was: How does the use of PhET explore scientific reasoning skills in characterising the state of matter? The sub-research questions were: What are the learners' scientific reasoning skills of state of matter when using PhET? The answers of this first sub-research question are as follows: a) prediction and analysis, which learners exhibited when they identified with ease the relationship between temperature and the behaviour of the particles by visualising the behaviour from the simulations; b) analysis and interpretation were executed by learners when drawing conclusions on the final states of matter through PhET simulations; c) making informed inferences was attained when learners indicated that the trend of the decrease in temperature results in the decrease in kinetic energy of the particles by observing the behaviour of the particles from PhET simulations; d) evaluation was achieved by learners through PhET simulations when reasoning out why the temperature increases or decreases during phase change; e) drawing conclusions emanated from learners' ease in characterising the states of matter on the physical changes of substance at atmospheric pressure through PhET simulation; f) learners fail to find the relationship between temperature and the behaviour of the particles, arrangement of the particles, difference between the diagram of cooling and heating curve, and to characterise three states of matter in the diagram of the change in states of matter due to lack of simultaneous use of prediction, analysis, interpretation, evaluation and making inferences.

Why do learners exhibit these particular scientific reasoning skills? The answers to this second sub-research question are given below: a) learners exhibited prediction and analysis because they highlighted this through the use of PhET. They could visually see the animations that clarify the microscopic increase and decrease in the temperature, resulting in increase in the kinetic energy of the particles; b) learners executed analysis and interpretation because they provided reasons that the simulations clearly displayed the various arrangement and behaviours of the particles; c) learners displayed the scientific reasoning skills of making informed inferences since they made justifications that the PhET simulations assisted them to observe the behaviour of the particles as well as how the increase and decrease in the temperature affect the movement of the particles; d) learners expressed evaluation because they were able to notice if the diagram is showing either cooling or heating curve, the reason emanated from visualising the behaviour of the particles with the temperature applied; e) learners were able to draw conclusions for the reason that they justified the ability to characterise using the arrangements of the particles through PhET simulation, such as that solid particles are close to each other and vibrating. In liquid, the particles are slightly in motion, and in gas they gain more kinetic energy; f) scientific reasoning skills of prediction, analysis, interpretation, evaluation and making inferences were not simultaneously achieved because learners indicated that when observing the behaviour of the particles, it was too difficult to make evaluations and informed inferences all at once.

5.4 Recommendation

The findings of the current study give informed suggestions on the teaching and learning of chemistry, specifically the change in states of matter: a) it suggested that teaching and learning of states of matter should use PhET simulations to visualise microscopic properties of states of matter. There should be learning intervention that will address the simultaneous achievement of scientific reasoning skills. b) Since the current study has revealed that it is almost impossible to achieve, predict, analyse, interpret, evaluate and make informed inferences simultaneously, future studies should focus on equipping learners with the necessary knowledge to develop all the scientific reasoning skills at once.

5.5 Contributions of the study

The purpose of the study was to explore scientific reasoning skills of the change in states of matter. The study contributed in equipping learners to observe the arrangement of the particles in different states of matter, solid, liquid and gas using PhET. Information that was unclear, and the scientific reasoning skills that learners exhibit when they use PhET has now been revealed. It is now clear that learners exhibit, predict, analyse, interpret, evaluate and make informed inferences when using PhET simulations. However, there is still a challenge related to the integration of reasoning skills which this study showed that PhET simulations cannot do. The use of SDDS proved to be relevant in evaluating the results to reach principal findings mentioned in the study. Hence, this study extends the use of the SDDS towards the realisation of learners' scientific reasoning skills of characterising states of matter using PhET simulation.

5.6 Limitations of the study

Some learners were unable to operate PhET simulation. For example, to increase and decrease the temperature. At the same time, even if they were observing the behaviour of the particles through PhET simulation, a facilitator was needed to clarify what is happening during the observation to develop scientific reasoning skills. Again, most learners were able to develop scientific reasoning skills, and it was too difficult for them to evaluate the evidence from visualisation. Network coverage disturbed the PhET simulation to visualise the behaviour of the particles when the temperature is applied. All in all, the use of PhET simulation can be blend with improvisation as the method in learning the change of states of matter. For example, while learners are visualising the change of states from liquid to gas using PhET, I can bring electrical hotplate and pot with water for boiling purpose. Consequently, learners can observe the behaviour of the particles when using PhET simulation and by improvisation. Hence, if I can be given another chance to conduct the study. In this way, the scientific reasoning skills of prediction, analyses, interpretation, evaluation and making informed inferences can be developed. Hopefully, learners can grasp the scientific reasoning skills simultaneously.

5.7 Conclusion

This study sought to explore scientific reasoning skills of the change in states of matter. The two research questions were answered, and learners were able to exhibit scientific reasoning skills when learning the change in states of matter. The data from the documents answered the first sub-research question, and interview data answered the second sub-research question. Moreover, PhET was used to visualise the behaviour of the particles in different states of matter. Subsequently, learners were able to find the relationship between the temperature and behaviour of the particles in different states of matter. As a result, scientific reasoning skills of prediction and analysis were achieved. Hence, the justifications that was given by learners during the interviews highlighted that through the use of PhET, they could visually see the animations that clarify the microscopic increase and decrease of the temperature, resulting in increased kinetic energy of the particles. At the same time, by observing the behaviour of the particles in terms of arrangements using PhET simulation, learners were able to conclude on the final states of matter. Consequently, the scientific reasoning skills of analysis and interpretation were achieved. This resulted in learners' provision of reasons that the simulations clearly displayed the various arrangements and behaviours of the particles.

Furthermore, the scientific reasoning skills of making informed inferences was exhibited. Making informed inferences emanated when learners generated the trend that the decrease in temperature results in decrease in kinetic energy of the particles. Accordingly, learners provided justifications that the PhET simulations assisted them to observe the behaviour of the particles as well as how the increase and decrease of temperature affects the movement of the particles. Another scientific reasoning skill of evaluation was clearly executed by learners in justifying why the temperature increases or decreases during phase change. Consequently, they were able to notice if the diagram is showing either cooling or heating curve. The reason emanated from visualising the behaviour of the particles with the temperature applied. In the same way, learners were able to characterise the states of matter on the physical changes of substance at atmospheric pressure. As a result, they justify the ability to characterise using the arrangements of the particles through PhET simulation. In solid, particles are close to each other and vibrating; in liquid, they are slightly in motion; and in gas, the particles gain more kinetic energy. Still, some of the learners failed to find the relationship between temperature and the behaviour of the particles, arrangement of the particles, difference between the diagram of cooling and heating curve, and to characterise three states of matter in the diagram of the change in states of matter. Hence, they indicated that when observing the behaviour of the particles, it was too difficult to exhibit scientific reasoning skills simultaneously.

REFERENCES

Abate, T., Michael, K., & Angell, C. (2020). Assessment of scientific reasoning: Development and validation of scientific reasoning assessment tool. *Eurasia Journal of Mathematics, Science and Technology Education*, *16*(1), 2-15. https://doi.org/10.29333/ejmste/9353.

Abate, T., Michael, K., & Angell, C. (2020). Assessment of scientific reasoning: Development and validation of scientific reasoning assessment tool. *EURASIA Journal of Mathematics, Science and Technology Education*, *16*(12), 5-17. https://doi.org/10.29333/ejmste/9353.

Aboagye, I. A., Oba, M., Koenig, K. M., Zhao, G. Y., & Beauchemin, K. A. (2019). Use of gallic acid and hydrolyzable tannins to reduce methane emission and nitrogen excretion in beef cattle fed a diet containing alfalfa silage. *Journal of Animal Science*, *97*(5), 2230-2244. https://doi.org/10.1093/jas/skz101

Abou Faour, M., & Ayoubi, Z. (2017). The effect of using virtual laboratory on grade 10 students' conceptual understanding and their attitudes towards physics. *Journal of Education in Science Environment and Health*, *4*(1), 54-68. https://doi.org/10.21891/jeseh.387482.

Adam, J., Bai, X., Baldini, A. M., Baracchini, E., Bemporad, C., Boca, G., & (MEG Collaboration). (2011). New limit on the lepton-flavor-violating decay. *Physical review letters*, *107*(17), 171-801. https://doi.org/10.1103/PhysRevLett.107.171801

Adbo, K., & Taber, K. S. (2009). Learners' mental models of the particle nature of matter: A study of 16-year-old Swedish science students. *International Journal of Science Education*, *31*(6), 757-786. https://doi.org/10.1080/09500690701799383

Adey, P., & Csapo, B. (2012). Developing and accessing scientific reasoning. *Framework for Diagnostic Assessment of Science. Budapest, Nemzeti Tankonyvkiado*. *26*(1) 17-49. https://journals.nied.edu.na/index.php/nerfj/article/view/124

Adri, H. T. (2023). Developing Science E-modules based on scientific reasoning skills for primary education course. *Jurnal Penelitian Pendidikan IPA*, *9*(8), 6480-6486. https://doi.org/10.29303/jppipa.v9i8.4727.

Al-Mashaqbeh, O. A., & McLaughlan, R. G. (2014). Effect of compost aging on zinc adsorption characteristics. *Journal of Environmental Chemical Engineering*, *2*(1), 392-397. https://doi.org/10.1016/j.jece.2014.01.011

Alamina, J. I., & Etokeren, I. S. (2018). Effectiveness of imagination stretch teaching strategy in correcting misconceptions of students about particulate nature of matter. *Journal of Education, Society and Behavioural Science, 27*(1), 1–11. https://doi.org/10.9734/jesbs/2018/43063.

Alfiyanti, I. F., & Jatmiko, B. (2020). The effectiveness of predict observe explain (POE) model with PhET to improve critical thinking skills of senior high school students. *Studies in Learning and Teaching*, *1*(2), 76-85. https://doi.org/10.46627/silet

Alsalhi, N., Alqawasmi, A. A., El-Saleh, M. S., Balawi, M., Ali, B. B. J., Alzboun, N., & Al Gharaibeh, F. (2024). Comparative effects of phet interactive simulations and conventional laboratory methods (CLM) on basic science process skills (BSPS) in physics: A case study in secondary school. *Arts Educa*, 40 (2024), *40*-69.

Ames, H., Glenton, C., & Lewin, S. (2019). Purposive sampling in a qualitative evidence synthesis: A worked example from a synthesis on parental perceptions of vaccination communication. *BMC Medical Research Methodology*, *19*(1), 1-9. https://doi.org/10.1186/s12874-019-0665-4.

Anisa, V. M., & Astriani, D. (2022). Implementation of PhET simulation with discovery learning model to improve understanding of dynamic electricity concepts. *Journal Pijar Mipa*, *17*(3), 292-301. https://doi.org/10.29303/jpm.v17i3.3438.

Arabacioglu, S., & Unver, A.O. (2016). Supporting inquiry-based laboratory practices with mobile learning to enhance students' process skills in science education. *Journal* *of Baltic Science Education*, *15*(2), 216-230. http://www.mu.edu.tr/tr/personel/ayseoguz.

Archibong-Eso, A., Aliyu, A. M., Yan, W., Okeke, N. E., Baba, Y. D., Fajemidupe, O., & Yeung, H. (2020). Experimental study on sand transport characteristics in horizontal and inclined two-phase solid-liquid pipe flow. *Journal of Pipeline Systems Engineering and Practice*, *11*(1), 19-40. http://doi.org/10.1061/%28ASCE%29PS.1949-1204.0000427.

Arslan, A. (2014). Transition between open and guided inquiry instruction. *Procedia-Social and Behavioural Sciences*, *141*(1), 407-412. https://doi.org/ 10.1016/j.sbspro.2014.05.071.

Ashley, C., James, S., Williams, A., Calma, K., Mcinnes, S., Mursa, R., ... & Halcomb, E. (2021). The psychological well-being of primary healthcare nurses during COVID-19: A qualitative study. *Journal of Advanced Nursing*, *77*(9), 3820-3828. https://doi.org/10.1111%2Fjan.14937.

Bandoy, J. V. B., Pulido, M. T. R., & Sauquillo, D. J. (2015). The effectiveness of using PhET simulations for physics classes: a survey. In *The Proceedings of the International Conference on Engineering Teaching and Learning Innovation [ICEE-PHILI 2015], Philippine Association of Engineering Schools (PAES) Inc, Iloilo*. https://www.researchgate.net/publication/282219928.

Bao, L., Koenig, K., Xiao, Y., Fritchman, J., Zhou, S., & Chen, C. (2022). Theoretical model and quantitative assessment of scientific thinking and reasoning. *Physical Review Physics Education Research*, *18*(1), 64-66. https://doi.org/ 10.1103/PhysRevPhysEducRes.18.010115.

Barelli, E., Branchetti, L., & Ravaioli, G. (2019). High school students' epistemological approaches to computer simulations of complex systems. In *Journal of Physics: Conference Series*, *1287*(1), 12-53. http://hdl.handle.net/10138/354548.

Baydere, F. K. (2021). Effects of a context-based approach with prediction–observation–explanation on conceptual understanding of the states of matter, heat and temperature. *Chemistry Education Research and Practice*, *22*(3), 640-652. https://doi.org/10.1039/D0RP00348D.

Beichumila, F., Bahati, B., & Kafanabo, E. (2022). Students' acquisition of science process skills in chemistry through computer simulations and animations in secondary schools in Tanzania. *International Journal of Learning, Teaching and Educational Research*, *21*(3), 166-195. https://doi.org/10.26803/ijlter.21.3.10.

Benli Ozdemir, E. (2021). The Impacts of STEM Supported Science Teaching on 8th Grade Students' Elimination of Misconceptions about" Solid, Fluid and Gas Pressure", and Their Attitudes towards Science and STEM. *International Online Journal of Education and Teaching*, *8*(1), 205-228. *https://iojet.org/index.php/IOJET*

Bhaw, N., Kriek, J., & Lemmer, M. (2023). Insights from coherence in students' scientific reasoning skills. *Heliyon 9*(7), 7-8. https://doi.org/10.1016/j.heliyon.2023.e17349.

Borghini, N., Borrell, M., & Roch, H. (2022). Early time behavior of spatial and momentum anisotropies in kinetic theory across different Knudsen numbers. *The European Physical Journal C*, *82*(10), 961-968. https://doi.org/10.1140/epjc/s10052-022-10914-9.

Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative Research in Psychology,* *3*(2), 77-101. https://doi.org/10.1191/1478088706qp063oa.

Brazhkin, V. V., Fomin, Y. D., Lyapin, A. G., Ryzhov, V. N., & Trachenko, K. (2012). Two liquid states of matter: A dynamic line on a phase diagram. *Physical Review E*, *85*(3), 3-12. https://doi.org/10.1103/PhysRevE.85.031203.

Bruckermann, T., Greving, H., Schumann, A., Stillfried, M., Börner, K., Kimmig, S. E., ... & Harms, U. (2023). Scientific reasoning skills predict topic-specific knowledge after participation in a citizen science project on urban wildlife ecology. *Journal of Research in Science Teaching*. https://doi.org/10.1002/tea.21835.

Byrne, S. (2020). *Effective use of phet simulations in middle school science classrooms* (Doctoral dissertation). Retrieved from http://hdl.handle.net/20.500.12648/4878.

Carpenter, Y., Moore, E. & Perkins, K. (2016) Using an interactive simulation to support development of expert practices for balancing chemical equations. Journal of Chemical Education, *93*(6), 1150-1151. https://confchem.ccce.divched.org/2015SpringConfChemP4.

Cassidy, A., McCoustra, M. R., & Field, D. (2023). A Spontaneously Electrical State of Matter. *Accounts of Chemical Research*, *56*(14), 1909-1919. https://doi.org/10.1021/acs.accounts.3c00094.

Chomanee, J., Nakarang, N., Handee, S., Choksuriwong, P., Katathikarnkul, S., & Poonsin, T. (2022). An experimental set for studying the changing state of matter with smart learning media displayed through the iot system for smart-lab. *ASEAN Journal of Scientific and Technological Reports*, *25*(4), 42-49. https://doi.org/10.55164/ajstr.v25i4.247317.

Chophel Y. (2022). Remediating misconceptions related to particulate nature of matter using video animation: Action research. *International Research Journal of Science, Technology, Education, and Management,* *2*(1), 65-77. https://doi.org/10.5281/zenodo.649677.

Cockrell, C., Brazhkin, V. V., & Trachenko, K. (2021). Transition in the supercritical state of matter: Review of experimental evidence. *Physics Reports*, *941*(1), 1-27. https://arsiv.org/pdf/2104.10619.

Cole, K., Brito-Parada, P. R., Hadler, K., Mesa, D., Neethling, S. J., Norori-McCormac, A. M., & Cilliers, J. J. (2022). Characterisation of solid hydrodynamics in a three-phase stirred tank reactor with positron emission particle tracking. *Chemical Engineering Journal*, *433*(1), 133-819. https://doi.org/10.1016/j.cej.2021.133819.

Correia, A.P., Koehler, N., Thompson, A., & Phye, G. (2019). The application of PhET simulation to teach gas behavior on the submicroscopic level: secondary school students' perceptions. *Research in Science & Technological Education, 37*(2), 193-217. https://doi.org/10.1080/02635143.2018.1487834.

Correia, A.-P., Koehler, N., Thompson, A., & Phye, G. (2019). The application of PhET simulation to teach gas behaviour on the sub microscopic level: Secondary school students' perceptions. *Research in Science & Technological Education, 37*(2), 193–217. https://doi.org/10.1080/02635143.2018.148783.

Dallaire, J., & Gosselin, L. (2016). Various ways to take into account density change in solid–liquid phase change models: Formulation and consequences. *International Journal of Heat and Mass Transfer*, *103*(1), 672-683. http://dx.doi.org/10.1016/j.ijheatmasstransfer.2016.07.045.

Dan Zainul, D. R. N. R., & Supardi, A. I. (2018). Implementation of guided inquiry learning model using phet simulation on momentum and inputs to improve student learning outcomes of smk informatika al qolam labang. *Inovasi Pendidikan Fisika*, *7*(2), 296-299. https://doi.org/10.26740/ipf.v7n2.p%25p.

Dantic, M. J. P., & Fluraon, A. (2022). PhET interactive simulation approach in teaching electricity and magnetism among science teacher education students. *Journal of Science and Education (JSE)*, *2*(2), 88-98. https://doi.org/10.56003/jse.v2i2.101.

Davidowitz, B., & Chittleborough, G. (2009). Linking the macroscopic and sub-microscopic levels. *Diagrams, Science Education, 4*(2), 169-191. https://doi.org/10.1007/978-1-4020-8872-8 9.

De Farias, B. G., Dutra-Thomé, L., Koller, S. H., & de Castro, T. G. (2021). Formulation of themes in qualitative research: logical procedures and analytical paths. *Trends in Psychology*, *29*(1), 155-166. https://doi.org/10.1007/s43076-020-00052-0.

De Sousa, R. T., & Alves, F. R. V. (2022). Quadratic functions and PhET: An investigation from the perspective of the theory of figural concepts. *Contemporary Mathematics and Science Education*, *3*(1), 3-4. https://doi.org/10.30935/conmaths/11929.

Doloksaribu, F. E., & Triwiyono, T. (2021). The reconstruction model of science learning based PhET-problem solving. *International Journal on Studies in Education (IJonSE)*, *3*(1), 37-47.

Doloksaribu, F., & Triwiyono. (2019). Development model of learning-based physics education technology problem solving to improve concept understanding in middle level student in Papua. *National Seminar in LPPM Uncen Jayapura.*

Dy, A. U., Lagura, J. C., & Baluyos, G. R. (2024). Using PhET Interactive Simulations to Improve the Learners' Performance in Science. *EduLine: Journal of Education and Learning Innovation*, *4*(4), 520-530. https://doi.org/10.35877/454RI.eduline2981

Efendi, N., & Sartika, S. B. (2021). The effect of distance learning practicum based on phet interactive simulations on science process skills of secondary school students. *Jurnal Pendidikan Sains (JPS)*, *9*(1), 91-96. https://doi.org/10.26714/jps.9.1.2021.91-96.

Erceg, N., Aviani, I., Mešić, V., Glunčić, M., & Žauhar, G. (2016). Development of the kinetic molecular theory of gases concept inventory: Preliminary results on university students' misconceptions. *Physical Review Physics Education Research*, *12*(2), 20-139. https://doi.org/10.1103/PhysRevPhysEducRes.12.020139.

Eveline, E., Wilujeng, I., & Kuswanto, H. (2019). The effect of scaffolding approach assisted by PhET simulation on students' conceptual understanding and students' learning independence in physics. In *Journal of Physics Conference Series*, *12*(33), 12-36. https://doi.org/10.1088/1742-6596/1233/1/012036.

Farcis, F. (2023). Analysis of junior high school students' science process skills through the implementation of PHET simulation media on the subject of light and optics.

International Conference on Teaching and Learning 4(1), 230-240. https://conference.ut.ac.id/index.php/ictl/article/view/1831.

Fencl, J. (2013). *Using PhET simulations in the physics first classroom: an alternative to traditional laboratories and teaching styles*. Doctoral dissertation.

Gani, A., Syukri, M., Khairunnisak, K., Nazar, M., & Sari, R. P. (2020). Improving concept understanding and motivation of learners through Phet simulation word. In *Journal of Physics Conference Series*, *1567*(4), 13-42. https://doi.org/10.1088/1742-6596/1567/4/042013.

Gift M, N., & CE, O. (2013). *Grade 10 physical science students' reasoning about basic chemical phenomena at sub-microscopic Level.*

Grabe, M. E., & Myrick, J. G. (2016). Informed citizenship in a media-centric way of life. *Journal of Communication*, *66*(2), 215-235. https://doi.org/10.1111/jcom.12215.

Guang-Wen, Z., Murshed, M., Siddik, A. B., Alam, M. S., Balsalobre-Lorente, D., & Mahmood, H. (2023). Achieving the objectives of the 2030 sustainable development goals agenda: Causalities between economic growth, environmental sustainability, financial development, and renewable energy consumption. *Sustainable Development*, *31*(2), 680-697. https://doi.org/10.1002/sd.2411

Guiselin, B., Tarjus, G., & Berthier, L. (2022). Is glass a state of matter? *Physics and Chemistry of Glasses-European Journal of Glass Science and Technology Part B*, *63*(5), 136-144. 2207.14204 (arxiv.org)

Gunawa, A., Heliawati, L., & Permanasari, A. (2023). Effectiveness of deep PhET interactive simulation improving understanding of the concept of material change. *Journal of Science Education and Practice*, *7*(2), 92-102. https://journal.unpak.ac.id/index.php/jsep.

Gunawan, A., Heliawati, L., & Permanasari, A. (2023). Effectiveness of deep Phet interactive simulation improving understanding of the concept of material change. *Journal of Science Education and Practice*, *7*(2), 40-51. https://journal.unpak.ac.id/index.php/jsep.

Guo, M., & Pfau, T. (2021). A new state of matter of quantum droplets. *Frontiers of Physics*, *16*(3), 32-202. https://doi.org/10.1007/s11467-020-1035-8.

Hadinugrahaningsih, T., Rahmawati, Y., & Ridwan, A. (2017). Developing 21st century skills in chemistry classrooms: Opportunities and challenges of STEAM integration. In *AIP Conference Proceedings, 1868*(1)*,* 4-30. https://doi.org/10.1063/1.4995107.

Han, J. (2013). *Scientific reasoning: Research, development, and assessment*. [Electronic Thesis or Dissertation, The Ohio State University]. https://etd.ohiolink.edu/

Hartmann, S., zu Belzen, A. U., Krüger, D., & Pant, H. A. (2015). Scientific reasoning in higher education. *Zeitschrift für Psychologie* Vol. 223(1):47–53. https://doi.org/10.1027/2151-2604/a000199.

Hasyim, F., Prastowo, T., & Jatmiko, B. (2020). *The use of android-based PhET simulation as an effort to improve students' critical thinking skills during the Covid-19 pandemic.* https://doi.org/10.3991/ijim.v14i19.15701.

Healy, B., Khan, A., Metezai, H., Blyth, I., & Asad, H. (2021). The impact of false positive COVID-19 results in an area of low prevalence. *Clinical Medicine*, *21*(1), 54-56. https://doi.org/10.7861/clinmed.2020-08391`

Herga, N. R., Čagran, B., & Dinevski, D. (2016). Virtual laboratory in the role of dynamic visualisation for better understanding of chemistry in primary school. *Eurasia Journal of Mathematics, Science and Technology Education*, *12*(3), 593-608. https://doi.org/10.12973/eurasia.2016.1224a

Higuera Martínez, O. I., Fernández-Samacá, L., & Serrano Cárdenas, L. F. (2021). Trends and opportunities by fostering creativity in science and engineering: a systematic review. *European Journal of Engineering Education*, *46*(6), 1117-1140. https://doi.org/10.1080/03043797.2021.1974350.

Hoepfl, M. C. (1997). Choosing qualitative research: A primer for technology education researchers. *Journal of Technology Education, 9(1)*, 47-61. https://scholar.lib.vt.edu/ejournals/JTE/v9n1/pdf/hoepfl.pdf

Hulshof, C., & De Jong, T. (2002). Using domain-specific and generic knowledge to support discovery learning about geometrical optics in a computer-based simulation. In *Annual Conference of the American Educational Research Association (AERA): Validity and Value in Education Research*.

Imaniah, E., Susilawati, S., Sutrio, S., & Kosim, K. (2023). The Effect of the PhET Assisted Problem Based Learning Model on Student Learning Outcomes in Wave Material. *Jurnal Penelitian Pendidikan IPA*, *9*(6), 4731-4737. https://doi.org/10.29303/jppipa.v9i6.3836.

Inaltekin, T., & Akcay, H. (2021). Examination the Knowledge of Student Understanding of Pre-Service Science Teachers on Heat and Temperature. *International Journal of Research in Education and Science*, *7*(2), 445-478. https://doi.org/10.46328/ijres.1805.

Jasien, P. G. (2018). Student understanding of a simple heating curve: Scientific interpretations and consistency of responses. *Journal of Education in Science Environment and Health*, *4*(2), 172-182. https://doi.org/10.21891/jeseh.432526.

Jayanagara, O., & Lukita, C. (2023). Evidence from SMA students' performance on the impact of physics education technology (PhET) simulations. *International Transactions on Education Technology*, *1*(2), 105-110. https://doi.org/10.33050/itee.v1i2.277.

Jenkins, J. L., & Howard, E. M. (2019). Implementation of modeling instruction in a high school chemistry unit on energy and states of matter. *Science Education International*, *30*(2), 97-104. https://doi.org/10.33828/sei.v30.i2.3.

Kalantzis, M., & Cope, B. (2012). *New learning: Elements of a science of education*. Cambridge University Press.

Karakoyun, G. Ö., & Asiltürk, E. (2022). The effect of heuristics on the reasoning of the pre-service science teachers on the topic of melting and boiling point. *Acta Chimica Slovenica*, *69*(1), 60–72. https://doi.org/10.17344/acsi.2021.6899.

Karpatne, A., Atluri, G., Faghmous, J. H., Steinbach, M., Banerjee, A., Ganguly, A., ... & Kumar, V. (2017). Theory-guided data science: A new paradigm for scientific discovery from data. *IEEE Transactions on Knowledge and Data Engineering*, *29*(10), 2318-2331. https://doi.org/10.1002/sce.20259.

Klahr, D., & Dunbar, K. (1988). Dual space search during scientific reasoning. *Cognitive Science*, *12*(1), 1-48. https://doi.org/10.1207/s15516709cog1201_1.

Kocagül, M., & Çoban, G. Ü. (2022). A case study for evaluating scientific reasoning skills training program. *Mehmet Akif Ersoy Üniversitesi Eğitim Fakültesi Dergisi*, *62*(1), 405-430. https://doi.org/10.21764/maeuefd.1033790.

Kotur, B. R. (2023). Kinetic energy of a particle independent of its mass & velocity. *IOSR Journal of Applied Physics,15*(1), 34-41. https://doi.org/10.9790/48611501013441.

Koyunlu Ünlü, Z., Babayiğit, Ö., & Ünlü, V. (2024). Development of preservice elementary teachers scientific reasoning skills through scientific inquiry. *Research in Science & Technological Education*, 1-18. https://doi.org/10.1080/02635143.2024.2332720

Krajcik, J. S., McNeill, K. L., & Reiser, B. (2006). A learning goals driven design model for developing science curriculum. In *Annual Meeting of the American Educational Research Association, San Francisco, California*.

Kulgemeyer, C. (2018). Impact of secondary students' content knowledge on their communication skills in science. *International Journal of Science and Mathematics Education*, *16*(1), 89-108. https://doi.org/10.1007/s10763-016-9762-6

Kusumaningdyah, R., Devetak, I., Utomo, Y., Effendy, E., Putri, D., & Habiddin, H. (2023). Teaching stereochemistry with multimedia and hands-on models: the relationship between students' scientific reasoning skills and the effectiveness of model type. *Center for Educational Policy Studies Journal*, 27-27. https://doi.org/10.26529/cepsj.1547.

Lester, J. N., Cho, Y., & Lochmiller, C. R. (2020). Learning to do qualitative data analysis: A starting point. *Human Resource Development Review*, *19*(1), 94-106. https://doi.org/10.1177/1534484320903890.

Li, R., Pei, S., Chen, B., Song, Y., Zhang, T., Yang, W., & Shaman, J. (2020). Substantial undocumented infection facilitates the rapid dissemination of novel coronavirus (SARS-CoV-2). *Science*, *368*(6490), 489-493. https://doi.org/10.1126/science.abb3221.

Liu, C., Dong, Q., Han, Y., Zang, Y., Zhang, H., Xie, X., ... & Liu, Z. (2022). Understanding fundamentals of electrochemical reactions with tender X-rays: A new lab-based operando X-ray photoelectron spectroscopy method for probing liquid/solid and gas/solid interfaces across a variety of electrochemical systems. *Chinese Journal of Catalysis*, *43*(11), 2858-2870. https://doi.org/10.1016/S1872-2067(22)64092-0.

Löffelsender, S., Schwerdtfeger, P., Grimme, S., & Mewes, J. M. (2021). It's complicated: On relativistic effects and periodic trends in the melting and boiling points of the group 11 coinage metals. *Journal of the American Chemical Society*, *144*(1), 485-494. https://doi.org/10.1021/jacs.1c10881.

Lopez, V., & Pinto, R. (2017). Identifying secondary-school students' difficulties when reading visual representations displayed in physics simulations. *International Journal of Science Education*, *39*(10), 1353-1380. http://dx.doi.org/10.1080/09500693.2017.1332441.

Luo, M., Wang, Z., Sun, D., Wan, Z. H., & Zhu, L. (2020). Evaluating scientific reasoning ability: the design and validation of an assessment with a focus on reasoning and the use of evidence. *Journal of Baltic Science Education*, *19*(2), 261-275. https://doi.org/10.33225/jbse/20.19.261.

Maghan, M. (2017). Problem Solving Style and Coping Strategies: Effects of Perceived Stress. *Jurnal: Creative Education*, 8(14), 3-9. https://doi.org/10.4236/ce.2017.814160.

Malik, A., Setiawan, Y., & Setya, W. (2021). Development of quizizz-based interactive questions to measure scientific reasoning skills. *Jurnal Pendidikan Fisika dan Keilmuan (JPFK)*, *7*(1), 39-52. http://doi.org/10.25273/jpfk.v7i1.9474.

Map. *Journal of Turkish Science Education,* 14(4), 77-91. https://doi.org/10.12973/tused.10214a

Martin, J. D. (2019). When condensed-matter physics became king. *Physics Today*, *72*(1), 30-37. https://doi.org/10.1063/PT.3.4110.

Mashami, R. A., Kurniasih, Y., & Khery, Y. (2023). Use of PhET simulations as a virtual laboratory to improve students' problem-solving skills. *Jurnal Penelitian Pendidikan Ipa,* 9(12), 11455-11465. https://doi.org/10.29303/jppipa.v9i12.6549.

Masruroh, N. C., Vivianti, A., Anggraeni, P. M., Waroh, S. N., & Wakhidah, N. (2020). Application of PhET simulation to electrical circuits material in online learning. *INSECTA: Integrative Science Education and Teaching Activity Journal*, *1*(2),130-142. https://jurnal.iainponorogo.ac.id/index.php/insecta/article/view/2312.

Maulidah, S. S., & Prima, E. C. (2018). Using physics education technology as virtual laboratory in learning waves and sounds. *Journal of Science Learning*, *1*(3), 116-121. https://doi.org./10.17509/jsl.v1i3.11797.

McKagan, S. B., Perkins, K. K., Dubson, M., Malley, C., Reid, S., LeMaster, R., & Wieman, C. E. (2008). Developing and researching PhET simulations for teaching quantum mechanics. *American Journal of Physics*, *76*(4), 406-417. https://doi.org/10.1119/1.2885199.

Meliniasari, F., & Setyarini, M. (2024). Using phet simulations to improve students'representation ability on the topic of chemical reactions. In *Proceedings of International Conference on Education*, *2*(1), 144-152). https://doi.org/10.32672/pice.v2i1.1331

Merchant, N. (2019). *Virtual experiments and simulations in the science classroom.*

Merritt, C., Rasoloson, D., Ko, D., & Seydoux, G. (2008). 3′ UTRs are the primary regulators of gene expression in the C. elegans germline. *Current Biology*, *18*(19), 1476-1482. https://doi.org/10.1016/j.cub.2008.08.013

Mezmir, E. A. (2020). Qualitative data analysis: An overview of data reduction, data display, and interpretation. *Research on Humanities and Social Sciences*, *10*(21), 15-27. https://doi.org/10.7176/RHSS/10-21-02.

Michael, L., Millmore, S. T., & Nikiforakis, N. (2020). A multi-physics methodology for four states of matter. *Communications on Applied Mathematics and Computation*, *2*(3), 487-514. https://doi.org/ 10.1007/s42967-019-00047-4.

Mrani, C. A., El Hajjami, A., & El Khattabi, K. (2020). Effects of the integration of PhET simulations in the teaching and learning of the physical sciences of common core (Morocco). *Universal Journal of Educational Research*, *8*(7), 3014-3025. https://doi.org/ 10.13189/ujer.2020.080730.

Murphy, C. H. (2022). Volunteer study on the efficacy of online simulations. https://escholarship.org/uc/item/5ss4545x.

Ndihokubwayo, K., Uwamahoro, J., & Ndayambaje, I. (2020). Effectiveness of PhET simulations and youtube videos to improve the learning of optics in Rwandan Secondary Schools. *African Journal of Research in Mathematics, Science and Technology Education,* 24(2), 253–265. https://doi.org/10.1080/18117295.2020.1818042.

Niaz, M. (2017). *Evolving nature of objectivity in the history of science and its implications for science education*. New York: Springer.

Nkosi, L. B., Chinaka, T. W., Sondlo, A., & Mpuangnan, K. N. (2024). Effect of physics education technology project simulation on improvement of retention ability of grade six learners in state of matter. *Edelweiss Applied Science and Technology*, *8*(6), 2056-2071. http://doi.org/10.55214/25768484.v8i6.2385

Novia, N., & Riandi, R. (2017). The analysis of students scientific reasoning ability in solving the modified Lawson Classroom Test of scientific reasoning (MLCTSR) problems by applying the levels of inquiry. *Jurnal Pendidikan IPA Indonesia*, *6*(1). https://doi.org/10.15294/jpii.v6i1.9600.

Noyes, J., Booth, A., Cargo, M., Flemming, K., Garside, R., Hannes, K., ... & Thomas, J. (2018). Cochrane qualitative and implementation methods group guidance series—paper 1: introduction. *Journal of Clinical Epidemiology*, *97*(1), 35-38. https://doi.org/10.1016/j.jclinepi.2017.09.025.

Nuraida, O., Akbar, G. S., Farida, I., & Rahmatullah, S. (2021). Using PhET simulation to learning the concept of acid-base. In *Journal of Physics: Conference Series.* 1869 (1), 012020). IOP Publishing. https://doi.org/10.1088/1742-6596/1869/1/012020.

Nurhuda, T., Rusdiana, D., & Setiawan, W. (2017, February). Analyzing students' level of understanding on kinetic theory of gases. *Journal of Physics: Conference Series*, 812(1), 012105). https://doi.org/10.1088/1742-6596/812/1/012105.

Nyanhi, G. M., & Ochonogor, C. E. (2012). Grade 10 physical science students' reasoning about basic chemical phenomena at sub-microscopic Level: *International conference on mathematics, science and technology education*.

Nyanhi, G. M., & Ochonogor, C. E. Reasoning pattern of grade 10 physical science students about basic chemical phenomena at sub-microscopic level: *The International Journal of Multi-Disciplinary Research.*

Nyirahabimana, P., Minani, E., Nduwingoma, M., & Kemeza, I. (2022). *Prime indicators of current teaching methodologies and students' perceptions in quantum physics.* https://doi:10.11591/ijere.v11i3.22078.

Obaya, A. V., Barocio, Y. R., & Rodríguez, Y. M. V. (2021). Online simulators for the teaching of the law of conservation of matter and chemical reactions in high school. *Science Education International*, *32*(3), 209-219. https://doi.org/10.33828/sei.v32.i3.4.

Ogegbo, A. A., & Ramnarain, U. (2022). Teaching and learning Physics using interactive simulation: A guided inquiry practice. *South African Journal of Education*, *42*(1), 5-7. https://doi.org/10.15700/saje.v42n1a1997.

Olsen, A., Lange, N., Key, R. M., Tanhua, T., Bittig, H. C., Kozyr, A., & Woosley, R. J. (2020). An updated version of the global interior ocean biogeochemical data product. *Earth System Science Data*, *12*(4), 3653-3678. https://doi.org/10.5194/essd-12-3653-2020

Olugbade, D., Oyelere, S. S., & Agbo, F. J. (2024). Enhancing junior secondary students' learning outcomes in basic science and technology through PhET. *Education and Information Technologies*, 1-23. https://doi.org/10.1007/s10639-023-12391-3.

Özdeniz, Y., Aktamış, H., & Bildiren, A. (2023). The effect of differentiated science module application on the scientific reasoning and scientific process skills of gifted students in a blended learning environment. *International Journal of Science Education*, *1*(1) 1-23. https://doi.org/10.1080/09500693.2023.2175627.

Özmen, H., & Alipaşa, A. Y. A. S. (2003). Students'difficulties in understanding of the conservation of matter in open and closed-system chemical reactions. *Chemistry Education Research and Practice*, *4*(3), 279-290. https://doi.org/10.1039/B3RP90017G

Perkins, K., Adams, W., Dubson, M., Finkelstein, N., Reid, S., Wieman, C., & LeMaster, R. (2006). PhET: Interactive simulations for teaching and learning physics. *The Physics Teacher*, *44*(1), 18-23. https://doi.org/10.1119/1.2150754.

Potane, J., & Bayeta Jr, R. (2018). Virtual learning through PhET interactive simulation: A proactive approach in improving students' academic achievement in science: *The rapids crossers. An official research journal of the Division of Cagayan de Oro City. https://portal. .org/resource/ISSN/2545-9589*.

Pratidhina, E., & Sumardi, Y. (2019). Developing Computer Program as a Learning Resource on Gas Law Topics for High School Students. *International Journal of Instruction*, *12*(2), 133-146. https://doi.org/10.29333/iji.2019.1229a.

Prihatiningtyas, S., Prastowo, T., & Jatmiko, B. (2013). Implementasi simulasi PhET dan kit sederhana untuk mengajarkan keterampilan psikomotor peserta didik pada pokok bahasan alat optik. *Jurnal Pendidikan IPA Indonesia,* 2(1), 18-22. https://doi.org/10.15294/jpii.v2i1.2505.

Proctor, J. E. (2020). *The liquid and supercritical fluid states of matter*. CRC Press.

Putranta, H., & Kuswanto, H. (2018). Improving students' critical thinking ability using problem based learning (PBL) learning model based on PhET simulation. *SAR Journal*, *1*(3), 77-87. https://dx.doi.org/10.18421/SAR13-02.

Pyatt, K., & Sims, R. (2012). Virtual and physical experimentation in inquiry-based science labs: Attitudes, performance and access. *Journal of Science Education and Technology*, 21(1), 133–147. https://doi.org/10.1007/S10956-01 1-9291-6.

Rahman, M. M. (2019). *21st century skill 'problem solving': Defining the concept.*

Rahman, M.M (2019). *21st* century skill "problem solving": defining the concept. *Asian Journal of Interdisciplinary Research*, *2*(1), 64-74. https://doi.org/10.34256/ajir1917.

Rahmawati, Y., Hartanto, O., Falani, I., & Iriyadi, D. (2022). Students' Conceptual Understanding in Chemistry Learning Using PhET Interactive Simulations. *Journal of Technology and Science Education*, *12*(2), 303-326. https://doi.org/10.3926/jotse.1597.

Rahmawati, Y., Hartanto, O., Falani, I., & Iriyadi, D. (2022). Students' conceptual understanding in chemistry learning using PhET Interactive Simulations. *Journal of Technology and Science Education*, *12*(2), 303-326. https://doi.org/10.3926/jotse.1597.

Ramadan, E. M., & Astuti, D. P. (2020). Application of e-handout based on PhET simulation to improve critical thinking skills and learning independence of high school students. *Journal of Physics: Conference Series,* 1440(1).

Ray, G. B., Ghosh, S., & Moulik, S. P. (2009). Physicochemical studies on the interfacial and bulk behaviors of sodium N-dodecanoyl sarcosinate (SDDS). *Journal of Surfactants and Detergents*, *12*, 131-143. https://doi.org/10.1007/s11743-008-1105-3.

Rayan, B., Daher, W., Diab, H., & Issa, N. (2023). Integrating PhET Simulations into Elementary Science Education: A Qualitative Analysis. *Education Sciences*, *13*(9), 4-9. https://doi.org/10.3390/educsci13090884.

Reis, E. F., & Rehfeldt, M. J. R. (2019). Software PhET and mathematics: Possibility for the teaching and learning of the multiplication. REnCiMa–Revista de Ensino de Ciências e Matemática. *[REnCiMa–Journal of Science and Mathematics Teaching],* 10(1), 194- 208. https://doi.org/10.26843/rencima.v10i1.1557.

Renati, P. (2022). Relationships and causation in living matter: reframing some methods in life Sciences? *Phys. Sci. Biophys. J*, *6*(1), 1-25. https://doi.org/10.23880/psbj-16000217.

Rodrigo, P., Arakpogun, E. O., Vu, M. C., Olan, F., & Djafarova, E. (2024). Can you be mindful? The effectiveness of mindfulness-driven interventions in enhancing the digital resilience to fake news on COVID-19. *Information Systems Frontiers*, *26*(2), 501-521. https://doi.org/1007/s10796-022-10258-5.

Rodriguez, J., & Castro, D. (2014). Children's ideas of changes in the state of matter: solid and liquid salt. *Journal: Journal of Advances in Humanities*, *1*(1) 2-5. https://www.researchgate.net/publication/272154348.

Rohmah, N. U., & Hidayah, F. F. (2022). The effectiveness of using 3d simulation media in online learning of molecular geometry on improving learning. *JCER (Journal of Chemistry Education Research),* 6(1), 19-25. https://doi.org/10.26740/jcer.v6n1.p19-25.

Ruwiyah, S., Rahman, N. F. A., Rahim, A. A., Yusof, M. Y., & Umar, S. H. (2021). Cultivating science process skills among physics students using PhET simulation in teaching. *Journal of Physics Conference Series*, *2126*(1), 7-12. https://doi.org/10.1088/1742-6596/2126/1/012007.

Sa'diyah, A., & Lutfi, A. (2023). Atomic structure teaching module with PhET simulation to increase student motivation and learning outcomes. *Hydrogen: Jurnal Kependidikan Kimia*, *11*(4), 459-468. https://doi.org/10.33394/hjkk.v11i4.8436.

Saiful, A. M. İ. N., Utaya, S., Bachri, S., Sumarmi, S., & Susilo, S. (2020). Effect of problem based learning on critical thinking skill and environmental attitude. *Journal for the Education of Gifted Yo ung Scientists*, *8*(2), 743-755. http://dx.doi.org/10.17478/jegys.650344.

Salame, I. I., & Makki, J. (2021). Examining the use of PhET simulations on students' attitudes and learning in general chemistry II. *Interdisciplinary Journal of Environmental and Science Education*, *17*(4), 22-47. https://doi.org/10.21601/ijese/10966.

Sánchez-Santamaría, J., Cervantes, B. I. B., & Friant, N. (2023). Education policies in the context of the 2030 Agenda: challenges when promoting more equitable education systems. *Foro de Educación*, *21*(1), 1-4. http://dx.doi.org/10.14516/fde.1278

Santika, A. R., Purwianingsih, W., & Nuraeni, E. (2018). Analysis of students critical thinking skills in socio-scientific issues of biodiversity subject. In *Journal of Physics: Conference Series*, 1013 *(1)*, 4-24. https://doi.org/10.1088/1742-6596/1013/1/012004.

Sarwoto, T. A., Jatmiko, B., & Sudibyo, E. (2020). Development of online science teaching instrument based on scientific approach using PhET simulation to improve learning outcomes at elementary school. *IJORER: International Journal of Recent Educational Research*, *1*(2), 90-107. https://doi.org/10.46245/ijorer.v1i2.40.

Saudelli, M. G., Kleiv, R., Davies, J., Jungmark, M., & Mueller, R. (2021). PhET simulations in undergraduate physics: Constructivist learning theory in practice. *Brock Education Journal*, *31*(1). https://journals.library.brocku.ca/brocked.

Schmidt, J., Marques, M. R., Botti, S., & Marques, M. A. (2019). Recent advances and applications of machine learning in solid-state materials science. *NPJ Computational Materials*, *5*(1), 83-106. https://doi.org/10.1038/s41524-019-0221-0.

Schultz, D., Duffield, S., Rasmussen, S. C., & Wageman, J. (2014). Effects of the flipped classroom model on student performance for advanced placement high school chemistry students. *Journal of Chemical Education*, *91*(9), 1334-1339. https://doi.org/10.1021/ed400868x.

Science Education Resource Center. (2021). *What is PHET? Pedagogy in Action.* Carleton College. https://serc.carleton.edu/sp/library/phet/what.htm.

Seredyuk, M., Gaspar, A. B., Ksenofontov, V., Galyametdinov, Y., Kusz, J., & Gütlich, P. (2008). Does the solid− liquid crystal phase transition provoke the spin-state change in spin-crossover metallomesogens? *Journal of the American Chemical Society*, *130*(4), 1431-1439. https://doi.org/10.1021/ja077265z.

Shah, P., Michal, A., Ibrahim, A., Rhodes, R., & Rodriguez, F. (2017). What makes every day scientific reasoning so challenging. *Psychology of learning and motivation*, *66*(1), 251-299). Academic Press. https://doi.org/10.1016/bs.plm.2016.11.006

Sharma, R. K., Ganesan, P., Tyagi, V. V., Metselaar, H. S. C., & Sandaran, S. C. (2015). Developments in organic solid–liquid phase change materials and their applications in thermal energy storage. *Energy Conversion and Management*, *95(2)*, 193-228. http://dx.doi.org/10.1016/j.enconman.2015.01.084

Shaw, V. F. (2010). The cognitive processes in informal reasoning. *Thinking & Reasoning,* 56*(3)* 51-80. https://doi.org/10.1080/135467896394564

Shutaleva, A., Martyushev, N., Nikonova, Z., Savchenko, I., Kukartsev, V., Tynchenko, V., & Tynchenko, Y. (2023). Sustainability of inclusive education in schools and higher education: Teachers and students with special educational needs. *Sustainability*, *15*(4), 5-7. https://doi.org/10.3390/su15043011

Suits, J. P., & Sanger, M. J. (2013). Dynamic visualizations in chemistry courses. In *Pedagogic roles of animations and simulations in chemistry courses* (pp. 1-13). American Chemical Society. https://doi.org/10.1021/bk-2013-1142.ch001

Sun, D. (2023). Gas-particle flow of pneumatic conveying in vertical pipes simulated using four-way coupled second-order moment method: *Powder technology*.

Supurwoko, S., Cari, C., Sarwanto, S., Sukarmin, S., Budiharti, R., & Dewi, T. S. (2017). Virtual lab experiment: physics educational technology (PhET) photo electric effect for senior high school. *International Journal of Science and Applied Science: Conference Series*, 2(*1),* 356- 381. https://doi.org/10.20961/ijsascs.v2i1.16750.

Susilawati, S., Doyan, A., Rokhmat, J., Gunawan, G., Gunada, I. W., & Hikmawati, H. (2023). Validation of PhET-based core physics teaching materials to improve activities and learning outcomes of physics education students. *Jurnal Penelitian Pendidikan IPA*, *9*(5), 2715-2719. https://doi.org/10.29303/jppipa.v9i5.3929.

Taibu, R., Mataka, L., & Shekoyan, V. (2021). *Using PhET simulations to improve scientific skills and attitudes of community college students.* https://doi.org/10.46328/ijemst.1214.

Tajudin, N. A. M., & Chinnappan, M. (2015). *Exploring relationship between scientific reasoning skills and mathematics problem solving.* Mathematics education research group of Australasia.

Tangerine Education. (2018). *States of matter.* Instagram. https://www.youtube.com/@TangerineEducation.

Tembrevilla, G., Milner-Bolotin, M., & Petrina, S. (2019). *Electric fluid to electric current: The problematic attempts of abstraction to concretization.* https://doi.org/XXXX/XXXX.

Tracy, S. J. (2010). Qualitative quality: Eight “bigtent” criteria for excellent qualitative research. *Qualitative Inquiry*, *16*(10), 837-851. https://doi.org/10.1177/1077800410383121.

Treagust, D. F., Chandrasegaran, A. L., Crowley, J., Yung, B. H., Cheong, I. P. A., & Othman, J. (2010). Evaluating students’ understanding of kinetic particle theory concepts relating to the states of matter, changes of state and diffusion. A cross-national study: *International Journal of Science and Mathematics Education*, *8*(1), 141-164.

Verawati, N. N. S. P., Handriani, L. S., & Prahani, B. K. (2022). The experimental experience of motion kinematics in biology class using PhET virtual simulation and its impact on learning outcomes. *International Journal of Essential Competencies in Education*, *1*(1), 11-17. https://doi.org/10.36312/ijece.v1i1.729.

Verawati, N. N. S. P., Handriani, L. S., & Prahani, B. K. (2022). The experimental experience of motion kinematics in biology class using PhET virtual simulation and its impact on learning outcomes. *International Journal of Essential Competencies in Education*, *1*(1), 11-17. https://doi.org/10.36312/ijece.v1i1.729.

Vieira, H., & Morais, C. (2021). Bridging music and chemistry: a marching band analogy to teach kinetic-molecular theory. *Journal of Chemical Education*, *99*(2), 729-735. https://doi.org/10.1021/acs.jchemed.1c00864.

Wati, D. A., & Sunarti, T. (2020, March). Implementation of case-based learning (CBL) to improve scientific reasoning skill on simple harmonic vibration topic. In *Journal of Physics: Conference Series*, 1491*(1),* 12-40. https://doi.org/10.1088/1742-6596/1491/1/012040.

Wazzan, S., & Ahmed, H. (2024). Unveiling novel eccentric neighborhood forgotten indices for graphs and graph operations: A comprehensive exploration of boiling point prediction. *Aims Mathematics*, *9*(1), 1128-1165. http://dx.doi.org/%2010.3934/math.2024056

Weart, S. (2019). *Solid State Insurrection*: *How the science of substance made American physics matter*. https://doi.org/10.1119/1.5086023

Wibowo, F. C., Suhandi, A. N. D. I., Rusdiana, D., Darman, D. R., Ruhiat, Y., Denny, Y. R., & Fatah, A. (2016). Microscopic virtual media (MVM) in physics learning: Case study on students understanding of heat transfer. *Journal of Physics: Conference Series*, 739*(1),* 012-44). https://doi.org/10.1088/1742-6596/739/1/012044.

Wieman, C. E., Adams, W. K., & Perkins, K. K. (2008). PhET: Simulations that enhance learning. *Science*, *322(5902),* 682-683. http://dx.doi.org/10.1126/science.1161948.

Wiltgen, F. (2022). Physical states of matter. *Transformacje*, *3*(114), 5-12. http://creativecommons.org/licenses/by/4.0.

Wulandari, F. E., & Shofiyah, N. (2018). Problem-based learning: effects on student's scientific reasoning skills in science. *Journal of Physics: Conference Series*, *1006*(1), 12-29. https://doi.org/10.1088/1742-6596/1006/1/012029.

Xu, L., van Driel, J., & Healy, R. (2021). A multi-layered framework for analyzing primary students' multimodal reasoning in science. *Education Sciences*, *11*(12), 758-766. https://doi.org/10.3390/educsci11120758.

Yannier, N., Hudson, S. E., Koedinger, K. R., Hirsh-Pasek, K., Golinkoff, R. M., Munakata, Y., ... & Brownell, S. E. (2021). Active learning: "Hands-on" meets "minds-on". *Science*, *374*(6563), 26-30. https://doi.org/10.1126/science.abj9957

Yanto, B. E., Subali, B., & Suyanto, S. (2019). Improving students' scientific reasoning skills through the three levels of inquiry. *International Journal of Instruction*, *12*(4), 689-704. https://doi.org/10.29333/iji.2019.12444a.

Yanto, B. E., Subali, B., & Suyanto, S. (2019). Improving students' scientific reasoning skills through the three levels of inquiry. *International Journal of Instruction*, *12*(4), 689-704. https://doi.org/10.29333/iji.2019.12444a.

Yuliati, L., Riantoni, C., & Mufti, N. (2018). Problem solving skills on direct current electricity through inquiry-based learning with PhET Simulations. *International Journal of Instruction*, *11*(4), 123-138. *http://www.e-iji.net.*

Yulianti, E., Zhafirah, N. N., & Hidayat, N. (2021). Exploring guided inquiry learning with phet simulation to train junior high school students think critically. *Berkala Ilmiah Pendidikan Fisika*, *9*(1), 96-104. https://doi.org/10.20527/bipf.v9i1.9617.

Yunzal Jr, A. N., & Casinillo, L. F. (2020). Effect of physics education technology (PhET) simulations: evidence from stem students' performance. *Journal of Education Research and Evaluation*, *4*(3), 221-226. https://ejournal.undiksha.ac.id/index.php/JERE.

Zacharia, Z. C., & Olympiou, G. (2011). Physical versus virtual manipulative experimentation in physics learning. *Learning and Instruction,* 21(3), 317–331. https://doi.org/10.1016/j.learninstruc.2010.03.001.

Zakharov, A. Y., & Zubkov, V. V. (2022). Field-theoretical representation of interactions between particles: classical relativistic probability-free kinetic theory. *Universe*, *8*(5), 281. https://doi.org/10.3390/universe0..8050281.

Zimmerman, C. (2007). The development of scientific thinking skills in elementary and middle school. *Developmental Review*, *27*(2), 172-223. https://doi.org/10.1016/j.dr.2006.12.001

Zubaıdah, S., Fuad, N. M., Mahanal, S., & Suarsını, E. (2017). Improving creative thinking skills of students through differentiated science ınquiry ıntegrated with mind map. *Journal of Turkish Science Education*, *14*(4), 77-91. https://doi.org/10.36681/

Zulkipli, Z. A., Yusof, M. M. M., Ibrahim, N., & Dalim, S. F. (2020). Identifying scientific reasoning skills of science education students. *Asian Journal of University Education*, *16*(3), 275-280. http://doi.org/10.24191/ajue.v16i3.10311.

APPENDICES

Appendix A: Approval from university

University of Limpopo
Faculty of Humanities
Executive Dean
Private Bag X1106, Sovenga, 0727, South Africa
Tel: (015) 268 4895, Fax: (015) 268 3425, Email:Satsope.maoto@ul.ac.za

DATE: 6 September 2023

NAME OF STUDENT: **RADINGWANA TM**
STUDENT NUMBER: **[201605472]**
DEPARTMENT: **MED – Science Education**
SCHOOL: **Education**

Dear Student

FACULTY RATIFICATION OF PROPOSAL (PROPOSAL NO. FHDC2023/8/1/4.1.5)

I have pleasure in informing you that your MEd proposal and Ethical Clearance application was ratified at the Faculty Higher Degrees Meeting on 7 August 2023.

TITLE: Grade 10 learners' scientific reasoning skills in characterising state of matter using physics education technology (PhET) at Seotlong Circuit, Sekhukhune District in Limpopo, South Africa.
Note the following:

Ethical Clearance	Tick One
In principle the study requires no ethical clearance, but will need a TREC permission letter before proceeding with the study	
Requires ethical clearance (Human) (TREC) (apply online) Proceed with the study only after receipt of ethical clearance certificate	√
Requires ethical clearance (Animal) (AREC) Proceed with the study only after receipt of ethical clearance certificate	

Yours faithfully

Maoto RS

Prof RS Maoto,
Executive Dean: Faculty of Humanities
Director: Prof MW Maruma
Supervisor: Dr Maumela M
Co-supervisors: Prof SK Singh
DR ZB Dhlamini

Appendix B: Ethical clearance certificate

University of Limpopo
Department of Research Administration and Development
Private Bag X1106, Sovenga, 0727, South Africa
Tel: (015) 268 3935, Fax: (015) 268 2306, Email: tukiso.sewapa@ul.ac.za

TURFLOOP RESEARCH ETHICS COMMITTEE

ETHICS CLEARANCE CERTIFICATE

MEETING: **04 December 2023**

PROJECT NUMBER: **TREC/1715/2023: PG**

PROJECT:

Title:	Grade 10 learners' scientific reasoning skills in characterising state of matter using physics education technology (PhET) at Seotlong Circuit, Sekhukhune District in Limpopo, South Africa
Researcher:	TM Radingwana
Supervisor:	Dr M Maumela
Co-Supervisor/s:	Prof SK Singh Dr Z Dhlamini
School:	Education
Degree:	Master of Education (Science)

PROF D MAPOSA
CHAIRPERSON: TURFLOOP RESEARCH ETHICS COMMITTEE

The Turfloop Research Ethics Committee (TREC) is registered with the National Health Research Ethics Council, Registration Number: **REC-0310111-031**

Note:

i) **This Ethics Clearance Certificate will be valid for one (1) year, as from the abovementioned date. Application for annual renewal (or annual review) need to be received by TREC one month before lapse of this period.**

ii) **Should any departure be contemplated from the research procedure as approved, the researcher(s) must re-submit the protocol to the committee, together with the Application for Amendment form.**

iii) **PLEASE QUOTE THE PROTOCOL NUMBER IN ALL ENQUIRIES.**

Finding solutions for Africa

Appendix C: Letter seeking permission from department of education: Limpopo

PO. BOX 530

ATOK

0749

30 NOVEMBER 2023

The Head of Department

Limpopo Department of Education

Dear sir/madam

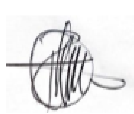
APPLICATION FOR PERMISSION TO CONDUCT RESEARCH STUDY FOR MASTER OF EDUCATION; SCIENCE EDUCATION:

I kindly request for your permission to conduct research. My name is Radingwana Mike Tshegofatso. I am a physical science teacher and a student at the University of Limpopo under supervision of Dr M Maumela, Professor S.K. Singh and Dr Z.B. Dhlamini. The title of my study is: **Grade 10 learners' scientific reasoning skills in characterising state of matter using physics education technology (PhET) at Seotlong Circuit, Sekhukhune District in Limpopo, South Africa.** Ethical clearance from the University and approval from the Faculty of Humanities is attached. I will use SBL to collect my data at Seotlong circuit Sekhukhune district.

I hope all is in order and looking forward for a positive response.

Yours in Education

Radingwana T.M



Appendix D: Letter of Approval: Department of education Limpopo province

`

LIMPOPO
PROVINCIAL GOVERNMENT
REPUBLIC OF SOUTH AFRICA

DEPARTMENT OF
EDUCATION

CONFIDENTIAL

Ref: 2/2/2 Enq: Makola MC Tel No: 015 290 9448 E-mail:MakolaMC@edu.limpopo.gov.za

Radingwana TM
PO BOX 129
MALIPSDRIFT
ATOK
0749

RE: REQUEST FOR PERMISSION TO CONDUCT RESEARCH

1. The above bears reference.
2. The Department wishes to inform you that your request to conduct research has been approved. Topic of the research proposal: **"Grade 10 learners' scientific reasoning skills in characterising state of matter using physics education technology (PhET) at Seotlong Circuit, Sekhukhune District in Limpopo, South Africa."**

3.The following conditions should be considered:

3.1 The research should not have any financial implications for Limpopo Department of Education.

3.2 Arrangements should be made with the District or Circuit Office and the School concerned.

3.3 The conduct of research should not in anyhow disrupt the academic programs at the schools.

3.4 The research should not be conducted during the time of Examinations especially the fourth term.

3.5 During the study, applicable research ethics should be adhered to; in particular the principle of voluntary participation (the people involved should be respected).

3.6 Upon completion of research study, the researcher shall share the final product of the research with the Department.

REQUEST FOR PERMISSION TO CONDUCT RESEARCH : RADINGWANA TM Page 1

Cnr 113 Biccard & 24 Excelsior Street, POLOKWANE, 0700, Private Bag X 9489, Polokwane, 0700
Tel:015 290 7600/ 7702 Fax 086 218 0560

The heartland of Southern Africa-development is about people

4 Furthermore, you are expected to produce this letter at Schools/ Offices where you intend conducting your research as an evidence that you are permitted to conduct the research.

5 The department appreciates the contribution that you wish to make and wishes you success in your investigation.

Best wishes.

09/01/2024

Dr. Makola MC **Date**

Director: IPR & R

10/01/2024

Mashaba KM **Date**

DDG: CORPORATE SERVICES

REQUEST FOR PERMISSION TO CONDUCT RESEARCH : RADINGWANA TM [redacted] Page 2

Cnr 113 Biccard & 24 Excelsior Street, POLOKWANE, 0700, Private Bag X 9489, Polokwane, 0700
Tel:015 290 7600/ 7702 Fax 086 218 0560

The heartland of Southern Africa-development is about people

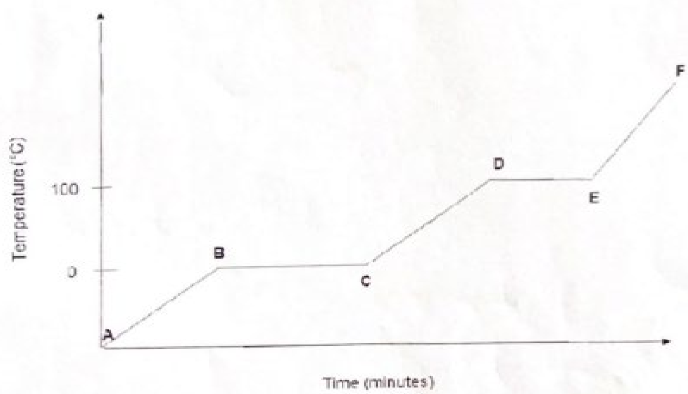
Appendix E: Data collection instrument (Documents)

The following was written task 1 section A

(EC/NOVEMBER 2020) PHYSICAL SCIENCES P2 7

QUESTION 3

The following diagram, not drawn to scale, represents the heating curve for a certain substance. Point **A** represents t = 0 minutes where the substance is a solid.



3.1 Define the term *melting point*. (2)

Use the information in the diagram to answer the following questions.

3.2 Write down:

3.2.1 Between which two letters is the vapour pressure equal to the atmospheric pressure? (1)

3.2.2 The phase of a substance between letters **E** and **F** (1)

3.2.3 The process taking place between letters **B** and **C** (1)

3.3 Is the energy ABSORBED, RELEASED or UNCHANGED between **D** and **E**? Give a reason for your answer. (2)

3.4 State how spaces between the particles change between letters **A** and **B**.

Write only INCREASE, DECREASE or UNCHANGED. (1)
[8]

 Please turn over

The following was written task 1 section B

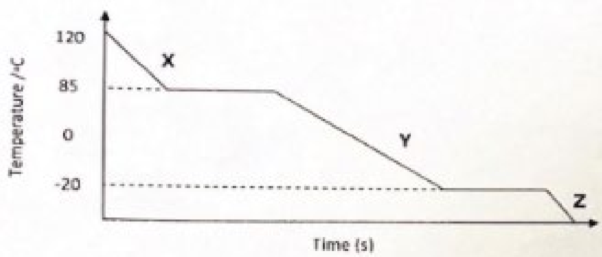
Physical Sciences P2 | 6 | September 2019 Common Test
Grade 10

QUESTION 3

3.1 Define ***sublimation***. (2)

3.2 When you take a block of margarine out of the fridge, it is hard. However, after 30 minutes at room temperature it is soft enough to spread. Use kinetic molecular theory to explain this observation? (2)

The diagram below, not drawn to scale, shows the physical changes of a substance at atmospheric pressure.



3.3 Is the diagram above showing a COOLING or HEATING curve? (1)

3.4 Name phase(s) of the substance at:

3.4.1 Point **X** (1)

3.4.2 -20 °C. (2)

3.5 Write down the stage of this substance at 85 °C. (1)

3.6 Write down the particle arrangement of this substance at:

3.6.1 Point **Z** (2)

3.6.2 Point **Y** (2)

3.7 The above substance is not water. By referring to the diagram, explain why this curve does not represent water? (2)

3.8 What happens to the temperature of the substance during a PHASE CHANGE? Write down only INCREASES, DECREASES or REMAINS THE SAME. Give a REASON for the answer. (2)

[17]

The following was written task 2

Written task 2: Written task using PhET.

Grade 10 Time: 45 minutes

Questions

1. Name three states of matter and describe each. (3)
2. On which factors does the average kinetic energy of gas molecule depend (2)
    a) Temperature
    b) Mass
    c) Volume
    d) Nature of gas
3. Gases _________ and occupy all the available space. (2)
    a) Contract
    b) Compress
    c) Expand
    d) Shrink
4. There is an increase in the temperature of an object and then the kinetic energy of an object (2)
    a) Decreases
    b) Increases
    c) Remains constant
    d) It is not related to the temperature.
5. How do the solids, liquids, and gases differ in their following properties? (6)
    a) Size
    b) Shape
    c) Density

Total: [15]

Appendix F: Semi-structured interview schedule

Topic: state of matter Grade: 10

Questions	Answers from learners
1. What is your understanding of the state of matter? and its important? Explain the importance of this PhET in a few lines.	
2. What is your understanding of behavior of particles in solid, liquid and gas? How useful is this in this subject physical science.	
3. Which Source of information help you to learn this? which are most preferable source to learn this.	
4. What are the challenges you faced characterizing state of matter when answering the written task? Explain.	
5. Differentiate gas, liquid, solid? Using kinetic molecular theory	
6. How helpful can PhET be, in assisting you to understand the topic state of matter.	

Appendix G: Observation schedule

During the use of PhET.

QUESTIONS	YES	NO	COMMENTS
1. Learners can grasp high cognitive reasoning skills when performing the experiments			
2. Learners can explain the particles using kinetic molecular theory			
3. From the experiments, learners can characterise solid, liquid, and gas			
4. Learners can explain the effect of temperature to find the difference between the three phases.			

Appendix H: Consent form

Consent form

Dear respondent

I Radingwana Tshegofatso Mike: 201605472 I am a postgraduate student doing master's degree in science education in Department of Education at university of Limpopo. I am conducting research to explore Grade 10 learners scientific reasoning skills when characterising the states of matter using PhET simulation. I kindly like you to sign and return the consent form to together with your parent if you agree to participate in this proposed study. This proposed study will therefore assist in developing learners scientific reasoning skills in characterising states of matter using PhET simulation. The data will be collected using written tasks, observation and semi-structured interview. Thereafter the data will be stored in a locked room of the supervisor at university of Limpopo for privacy and confidentiality of the participants. Bear in mind that your participation is voluntary and you are free to discontinue anytime. However, those who wish to participate, will be treated equally. For more information regarding the study do not hesitate, contact me for clarity on 0721334091.

Signatures:

Participant ____________________

Parent ____________________

Researcher ____________________

Appendix I: Letter for editing

MAFUMISI GROUP

Stand 507 Caledon Village, Cell +27794848449, Email: kubayijoe@gmail.com

22 August 2024

Dear Sir/Madam

SUBJECT: EDITING OF DISSERTATION

This is to certify that the dissertation entitled 'Grade 10 learners' scientific reasoning skills in characterising state of matter using physics education technology (PhET) at Seotlong Circuit, Sekhukhune District in Limpopo, South Africa' by Radingwana TM has been copy-edited, and that unless further tampered with, I am satisfied that the dissertation adheres to editorial principles of consistency, cohesion, clarity of thought and precision.

Kind regards

Prof SJ Kubayi

Appendix J: Learners using PhET simulation to characterise states of matter (links)

1. https://youtu.be/PlbPkEIqFFo?si=C_CXiLhERiUv57Py
2. https://youtu.be/1N_39_6Pcfo?feature=shared
3. https://youtu.be/P0A7Kzha0xo?feature=shared