THE EFFECT OF USING VISUAL MODELS IN TEACHING AND LEARNING MOLECULAR BIOLOGY ON LEARNER PERFORMANCE IN GRADE 10 AT SELECTED SECONDARY SCHOOLS IN MALEGALE CIRCUIT, LIMPOPO

By

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ABSTRACT

The usage of visual models for teaching and learning molecular biology is increasing due to the difficulties associated with understanding complicated concepts. Hence, this study intended to determine the extent to which teachers utilise visual models when teaching molecular biology topics in Grade 10 Life Sciences, as well as the impact of using such visual models. Learners report misconceptions and learning difficulties associated with various concepts that exist in molecular biology, thus teaching molecular biology is difficult. A qualitative research approach was chosen to address the main research question and aim, together with the usage of a case study design to allow the researcher to be flexible when collecting data. This allowed the researcher to use qualitative and quantitative methods for the first, second and third research sub-questions respectively. Purposive sampling was used to identify 7 participants who participated in the interviews and responded to an open-ended questionnaire. The use of interviews and the open-ended questionnaire allowed for data triangulation, which assisted researcher to understand how participants view the outcome of the research. Furthermore, thematic data analysis was used. Findings showed that using visual models improves learner's visualisation skills and performance related to molecular biology topics. Furthermore, visual models can serve as a tool to be utilised by teachers to support learners who have different learning needs.

Keywords: visual models, molecular biology, visualisation, Life Sciences, visual literacy, Grade 10, learner performance, teaching molecular biology, learning molecular biology.

DECLARATION

Title: The effect of using visual models in teaching and learning molecular biology on learner performance in Grade 10 at selected secondary schools in Malegale circuit, Limpopo.

I, MAKHURA SELLO ISAAC, declare that the work contained in this study is my own and all the sources I have used have been indicated and acknowledged by means of references. I further declare that I submitted the dissertation to original checking software and that it falls within the accepted requirements for originality. I also declare that I have not submitted this dissertation anywhere to any University in order to obtain a degree.

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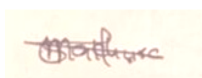
Signature : 

Date : 27 DECEMBER 2023

DEDICATION

This study is dedicated to my grandmother, parents, siblings, supervisor and participants, and most importantly, my children, Thapelo and Amogelang, your support is really appreciated. To God and my Ancestors, thank you.

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CHAPTER 1: INTRODUCTION

1.1 BACKGROUND OF THE STUDY

Mnguni (2014) defines visualisation as the capability to choose and efficiently utilise a range of cognitive abilities to perceive, process, and generate visual models. In addition, Grant (2018) mentions that visualisation is useful in processing visual images and diagrams to communicate a message and visual models can be found throughout all scientific disciplines. Visual models and visualisation are key components of learning and teaching in molecular biology. Therefore, visual models are said to be models that can be seen and used to understand processes or any number of observable concepts in the chemistry of life, models include flow charts, pictures and diagrams (Ramadas, 2009; Goetschalckx *et al*., 2019). Visual models, like diagrams, pictures and charts, are utilised in science for interpreting difficult concepts, and can be used in the analysis to develop an explanation of concepts (Gilbert, 2008). According to Lohr (2008); and Arneson (2018), visual literacy refers to the way a person understands, develops and uses the visual models in effective ways. Taukobong (2017) states that the utilisation of educational visual models in molecular biology is increasing, as they are being used as a learning and teaching resource. Hence, they are becoming more important in learning and teaching molecular biology.

Life Sciences is defined as the discipline that deals with the understanding of living organisms, which includes biology, zoology, biochemistry, and microbiology (Tomaszewski & Gallies, 2021). Life Sciences is taught in Grades 10 to 12, focusing on different topics. This study focuses on Life Sciences in Grade 10. Some of the topics covered in Grade 10 for Life Sciences include, the chemistry of life, cells, plant, and animal tissues. The topics mentioned are covered by the branch of science called molecular biology. Therefore, the focus of the study is based on Grade 10 Life Sciences, molecular biology topics. Furthermore, in molecular biology topics, the use of images in chemistry texts often involves illustrating atoms and molecules, as well as their processes and changes (Guney, 2019). The molecular biology topics consist of complex content and processes. Therefore, a common way to teach and learn molecular biology topics is through the use of visual models. When it comes to processing information presented through visual models in molecular biology topics, learners often face challenges due to a lack of visual literacy (Noble, 2021).

Molecular biology is a rapidly growing, increasingly interconnected field that presents many challenges for both teachers and learners (Bucchi & Saracino, 2016). Due to their size, biological molecules cannot be visualised with the naked eye due to their complex concepts, which occur at various levels of organisation, from microscopic to molecules in different relative sizes (Schönborn & Anderson, 2006). In this regard, the current study depicts that learners consider that the structures and molecules are more likely to be problematic for them (Fernandez & Tejada, 2018). Thus, such biological molecules become very difficult for learners to comprehend if teachers do not use visual models in the classroom. According to Offerdahl *et al*. (2017), modern techniques for molecular biology discover the basic workings of the world invisible to the naked eye, developing huge data sets from which more dynamic models of difficult systems can be developed. Molecular biology is connected to our ability to model abstract and complex content and visualise it as a source of information and learning (Tan & Waugh, 2013). Dori and Barak (2001) mention that to improve teaching and learning, visual models like diagrams, pictures, and other models, are employed in explaining biological concepts. Therefore, to visualise such concepts, visual models aid learners in building their understanding of how biological concepts occur in reality (Sukardi, 2019).

Schönborn and Anderson (2009), state that visual literacy and visualisation of new scientific knowledge cannot be accomplished with simple diagrams and pictures. Hence, competency in visual literacy in science education is now required, so that it has become a necessity for teachers to be able to utilise visual models for the purpose of learning. In science education, visual models and visualisation are significant for learners' mental skills, so that learners are able to develop their knowledge in science (Gilbert, 2008). Thus, teachers are tasked with creating visual models to connect the existing understanding of difficult biological concepts in the chemistry of life. According to Aisami (2014), teaching learners with the use of visual models is not something new; teachers in previous years have often used various visual models to show definite learning concepts. In this regard, visual models have been used broadly in science education to present many scientific concepts (Cook, 2006; Gilbert, 2008).

As mentioned above, it is claimed that using visual models will lead to a greater understanding of scientific content in molecular biology topics (Arneson & Offerdahl, 2018). In addition, visual models can play a vital role in both learning and teaching in the classroom. Taukobong (2017) states that educational visual models in molecular biology are increasingly being used as a learning and teaching resource. As mentioned, the use of visual models is becoming more important in learning and teaching molecular biology. Thus, the usefulness of models is restricted to learners who encounter learning difficulties because they lack the visual skills to work with visual models (Taukobong, 2017).

In molecular biology there are many components that are difficult, if not impossible, to see with the naked eye (Noble, 2021). Therefore, such components become more complex for learners to interpret and understand if they are not educated using visual models. Teachers can assist learners to develop skills in visual literacy, which can result in learners failing to perform well. Studies have suggested that using visuals in teaching enhances strong learning and results in more effective learning, hence it is important for teachers to utilise it well. As the study of learning and teaching molecular biology is recorded for its complexity, further investigation is still needed to help with teaching strategies.

1.2 RESEARCH PROBLEM STATEMENT

It is known that visual models are recognised as an important teaching tool and are essential for teaching molecular biology topics (Aisami, 2014). Mnguni (2014) mentions that molecular biology has complicated microscopic and molecular concepts; this leads to visual literacy and visualisation being some of the critical competencies in molecular biology. Learners fail to connect biological molecules which results in confusion and interferes with their learning and understanding of biological processes (Noble, 2021). This can lead to teachers and learners struggling to learn and teach molecular biology. Teachers placing little emphasis on different concepts found in molecular biology topics can be a source of misconceptions and learning difficulties (Wright *et al*., 2022). In addition, multiple visual models can assist teachers to construct knowledge and incorporate explanations of scientific concepts and structures (Ainsworth *et al*., 2015. At the same time, one visual model is rarely adequate to capture the entirety of molecular biology concepts in Grade 10. In this regard, learners experience learning difficulties when dealing with the concepts and this leads to poor learner performance (Wright *et al.*, 2018). Thus, at utmost teachers do not use adequate visual models as teaching molecular biology in Grade 10, creating obstacles to the teaching and learning process, which has a direct impact on learning outcomes.

Adding to the complexity of using visual models in the classroom is that teachers lack skills in learning visual models which is a key pedagogical consideration in teaching molecular biology (Deslauriers *et al*., 2019). The complexity and scope of information provides a challenge for teaching learners without visual models (LaDue *et al*., 2015). As mentioned, understanding molecular biology is one of the challenges that can be addressed using visual models (Jenkinson, 2018). In this regard, learners' should have a certain level of spatial cognitive processing demanded by visualisation. However, teachers and learners do not always have the skills needed to interpret, incorporate and understand visual models in the same way they would learn. Furthermore, molecular biology is increasingly developing and is becoming a more interdisciplinary field, within which teachers face challenges incorporating visual models during lessons (Jenkinson, 2018). According to Rundgren and Tibell (2010), visualisation can be understood through the use of various perceptions and different views of people. However, visualisation has proven to be important in learning processes (Phillips *et al*., 2010).

As the study of teaching molecular biology is difficult, there is a need for further research in order to support teaching strategies (Rasol *et al*., 2020). The existing literature shows that there is a limited number of different visual models in science education (Canla, 2020). Thus, similar literature shows that more research has been conducted on using visual models in molecular biology topics (Stokes, 2002; Glazer, 2011; Taukobong, 2017; Mnguni, 2014). Due to today's advanced technology, different models are utilised as learning enhancers because of their ability to convey the required message. In this regard, visual models have become a competency for teachers and learners (Salam *et al*., 2019). According to Rundgren and Tibell (2010), visualisation can be understood through the use of various perceptions and different views of people. Although visualisation has proven to be important in learning processes (Phillips *et al*., 2010), it is necessary to point out the effect of using visual models for teaching and learning.

1.3 THE RESEARCH QUESTION

In light of the above discourse, the proposed research sought to respond to the following research questions:

Main research question

1. To what extent do teachers utilise visual models when teaching molecular biology topics in Grade 10 Life Sciences?
   1.1. What pedagogical principles inform teachers' use of visual models when teaching molecular biology topics in Grade 10 Life Sciences?
   1.2. How do teachers incorporate visual models when teaching molecular biology topics in Grade 10 Life Sciences?
   1.3. What is the perceived impact of using visual models on learners' content understanding of molecular biology topics in Grade 10 Life Sciences?

1.4 RATIONALE

According to Aisami (2014), the presence of visual models in teaching and learning complex microscopic and molecular concepts in molecular biology is increasing. The current Life Sciences curriculum places little emphasis on teachers developing the use of visual models within the context; which leads to teachers assuming learners are aware of the content of visual models, but failing to bridge the knowledge gap between themselves and learners (Acar *et al*., 2015). As mentioned above, the findings of the study significantly contribute to the literature on visual models for teaching and learning molecular biology in Grade 10.

The goal of this study is to increase the visibility of using visual models as a skill in teaching molecular biology and to provide a framework to promote the research and implementation of best practices. In addition, the findings of this study rely on its potential to generate knowledge about utilising visual models as a tool for struggling teachers who lack the ability to incorporate visual models in molecular biology concepts in Grade 10 Life Sciences. Thus, the study's rationale could help the government consider curriculum design and the most effective ways for teachers to utilise visual models in teaching molecular biology topics in Grade 10 Life Sciences. In short, the study's findings aim to provide molecular biology teachers with the best teaching practices and pedagogy to aid in positive learning and support for learners, in order to improve their academic performance.

1.5 AIM AND OBJECTIVES OF THE STUDY

This study aims to determine the extent to which teachers utilise visual models when teaching molecular biology topics in Grade 10 Life Sciences, as well as the impact of using these visual models. The study focuses on a case study of Grade 10 teachers at selected secondary schools in the Malegale circuit, Limpopo Province. The proposed study's specific objectives are to determine:

- The pedagogical principles that inform teachers' use of visual models when teaching molecular biology topics in Grade 10 Life Sciences;
- Strategies used by teachers to incorporate visual models when teaching molecular biology topics in Grade 10 Life Sciences; and
- The perceived impact of using visual models on learners' content understanding of molecular biology topics in Grade 10 Life Sciences.

1.6 THEORETICAL FRAMEWORK

The theoretical framework consists of the theories expressed by experts in the field where the researcher aims to conduct the study, and it acts as the framework that sustains or backs up the study's theory (Swanson & DeVereaux, 2013). Every study is based on a theory that influences the researcher's topic selection, research questions, methodology, and epistemological underpinning. The theoretical framework of this study communicates the philosophical basis on which the study is founded and forms the connection between the theoretical facts and practical components of the study. Thus, the theoretical framework has implications for every decision made in the study.

1.6.1 Theories of learning visual model

Krathwohl's taxonomy of effective domain (Krathwohl *et al*., 1956) can be used as a tool to plan and determine if active learning has taken place. The role of the taxonomy of effective domain is to describe how an individual's processes are internalised based on learning objectives in an effective or emotional level (Buma, 2018). Rogan and Grayson's (2003) profile of implementation within a feasible zone posits that new strategies and knowledge are attained in small manageable steps. Mayer (2014) suggests that learning from different visual models is a cognitive process that necessitates multiple mental processes, as explained by the cognitive theory of multimedia learning. This theory states that external images are inputted into the cognitive system through the eyes during learning, where they are then focused on specific aspects of the visual model, which leads to the storage of information of mental pictorial images in the working memory (Mnguni, 2014).

The cognitive theory of multimedia learning suggests that combining visual images and text can aid in processing more information (Mayer, 2014). Multimedia resources are becoming an integral part of teaching and learning practices in schools. Thus, multimedia learning theory places an emphasis on learning through text and visual models, as described by Rau (2018), who analyses the way learners perceive and learn through the use of visual models. Learners in multimedia learning create mental representations using words and visual models, and then combine them with relevant prior knowledge (Van Merrienboer & Kester, 2014). Mayer's cognitive multimedia theory stresses the importance of helping learners understand principles and retain information for meaningful use (Mayer, 2009). According to Lohr (2008), learners are inclined to consider visuals in ways that their minds are predisposed to comprehend.

The use of multimedia learning cognitive theory is becoming a popular method of gathering evidence from educational practices and cognitive load theory (Clark & Mayer, 2016). Although rooted in cognitive load theory, the cognitive theory of multimedia learning includes two prevalent working memory models to examine how information modalities move through working memory (Mayer & Moreno, 2002). First, Paivio's dual-coding theory (1986) presents a model for working memory that describes a dual channel system where language is processed by the verbal and non-verbal channels which are used to process non-articulated sound and images. Secondly, Baddeley's model (Baddeley, 2015) provides a sensory-modality model with a dual channel system that begins with the sensory before being assigned to either a verbal or pictorial category. According to Mayer (2002), in Figure 1.1., the cognitive theory of working memory states that working memory processes information using a dual audio-visual channel.

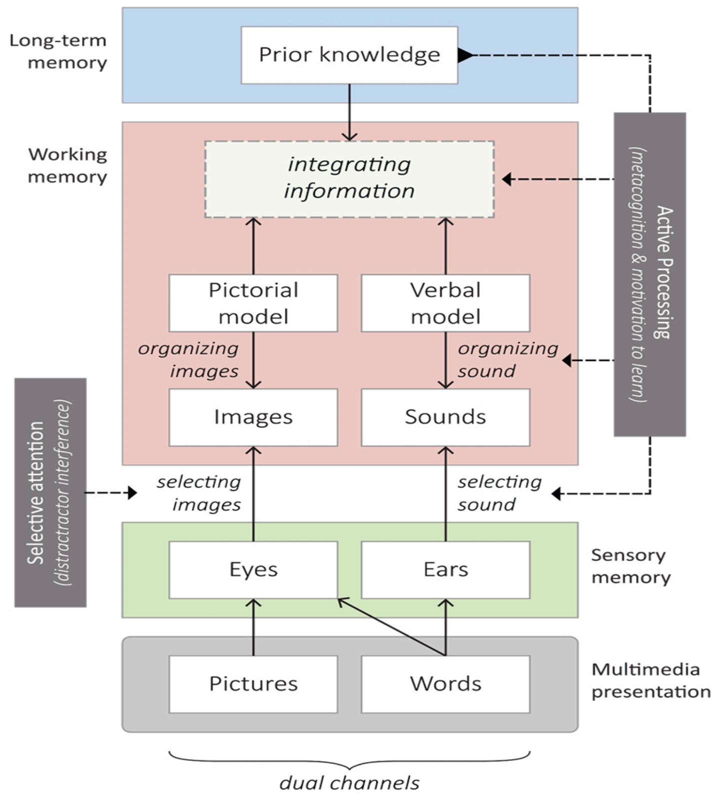

Figure1.1: Mayer's model of the cognitive theory of multimedia learning (adapted from Mayer, 2005)

Thus, learners often encounter elements of a visual model, which results in the creation of mental pictorial images (Mayer & Estrella, 2014). According to Mayer (2005), the constructivist epistemology of learning is connected to the cognitive theory of multimedia learning. Constructivism suggests that learners learn best when they create their own understanding of the world instead of being given it (Thompson, 1995; Rehman & Alharthi, 2016). Thus, the general principle of constructivism in science is that knowledge and images cannot be passively transferred from the teacher to the learners' brains (Von

Glasersfeid, 1989; Mvududu & Thiel-Burgess, 2012). However, individual learner's construct their own meaning and mental models through active learning (Clark, 2018). Thus, it is important for teachers of molecular biology to motivate learners to become mentally engaged during the active visualisation process (Jenkinson, 2018).

Mascolo and Fischer (2010) define constructivism as a learning theory that emphases the importance of reflection and active construction in the mind when gaining knowledge. Constructivism, which some educational theorists consider a sub-discipline of cognitivist theory, involves the study of a learners own construction of knowledge (Clark, 2018). Constructivism dictates that learners are responsible for creating their own knowledge from their understanding and experiences by selecting, absorbing and adjusting what they experience in their surroundings (Kim, 2014). Nickson (2004), states that individuals have different representations of reality, so they must create their own mental representations of situations, events and conceptual structures. The concept of constructivism is centred on learners who actively construct meaning to new information and teachers, who facilitate learning by giving detailed feedback and asking guiding questions (Clark, 2018).

Constructivists suggest that, learners do not just absorb information; they also construct knowledge based on what they experience. Existing structures are used to build knowledge as learners assimilate new information in existing schemes (Zambo & Zambo, 2008). Thus, individuals learn most effectively when they construct their own process or relate new information to their beliefs, attitudes and experiences. As a result, constructivism enables researchers to think critically and creatively about the teaching-learning process. Different visual models may evoke various processes and rates of success in an intended task, as predicted by this learning theory (Mayer, 2011).

1.7 DELIMITATION OF THE STUDY

The boundaries and environment in which the study was conducted are referred to as delimitations (Theofanidis & Fountouki, 2019). The aim of the study is to determine the extent to which teachers utilise visual models when teaching molecular biology topics in selected schools at Malegale circuit, Limpopo. The study included seven of the targeted secondary schools. The schools in this study shared the attribute of having teachers who have experience in teaching molecular biology. Schools without Life Sciences were excluded based on the researcher's premise that strong outcomes reflected that molecular biology requires teachers who have Life Sciences as a subject and in the curriculum of the school, and also the experience in teaching Life Sciences. As a result, the findings of this study should be limited to the setting in which the data were acquired. Generalising the study's conclusions beyond the scope and boundaries described above is thus discouraged and should be done with caution.

1.8 KEY CONCEPTS

The following definitions are aimed at making sure that these terms are understood throughout the study:

- *Visual literacy*: The capacity to select and efficiently utilise a set of cognitive abilities to process external representations in response to scientific knowledge (Mayer, 2003).
- *Life Sciences*: The study of organisms from the molecular level to their ecology, which encompasses the connections between various organisms and their surroundings (DBE 2011).
- *Visualisation*: The ability to rationally create visual representations of things that are invisible to the naked eye (Schönborn & Anderson, 2006).
- *Molecular biology*: A dynamic, modern discipline having emerged strongly in science (Bucchi & Saracino, 2016).
- *Visual model:* Refers to objects that are believed to have some kind of material or physical existence such as pictures, diagrams, tables, charts and videos (Pauwels, 2012).

1.9 CHAPTER SUMMARY

The first chapter details the study’s background and research problem statement, as well as the research questions, objectives, and aim. The theoretical framework and concepts used in the study were also clarified. The next chapter investigates what literature suggests about the effect on learner performance when using visual models in teaching and learning molecular biology. Chapter 3 describes the research methods, from research design through sampling strategies to data collection and analysis. In chapter 4, data from interviews, document reviews and open-ended questionnaires are presented and interpreted, as well as discussion of vitality of the findings. The study is summarised and concluded in Chapter 5, with recommendations and proposal for future research.

CHAPTER 2: LITERATURE REVIEW

2.1 INTRODUCTION

This chapter provides an overview of the study's introduction and background as well as a discussion of international and local literature that supports the study. Conducting a literature review is done to provide perspectives on what has been researched regarding particular aspects and to discuss the outcomes of other studies that are connected to this study (Creswell, 2009). By reviewing literature, one can comprehend the significance of visual models in molecular biology and respond effectively to assessments that incorporate their use among learners. The related literature shows the importance of introducing visual models into molecular biology lessons, but also the challenges that teachers face with incorporating visual models into their lessons.

The evolution of new technology and learning in the 21st century is exposing challenges for teachers with the usage of technology with visual models for the purpose of communication, encompassing scientific journals and textbooks (McTigue & Flowers, 2008). As part of the transition, visualisation and visual literacy are grounded in learners and their progress, and learning can be enhanced by the use of visual models' ideas and strategies, which have been documented (Stokes, 2002). Therefore, visual literacy is an essential skill for learners studying molecular biology. However, without the visual models and visual skills used to interpret molecular biology topics, learning and teaching would be difficult. McTigue and Flowers (2011) show that learners prefer visual models that are accessible like drawings, videos, pictures and diagrams, which are not aligned to choices of grade level diagrams. This study intends to determine the extent to which teachers utilise visual models when teaching molecular biology topics in Grade 10 Life Sciences, as well as the impact of using such visual models. The main research question framing this is: "To what extent do teachers utilise visual models when teaching molecular biology topics in Grade 10 Life Sciences?" Hence, this literature review will provide suggestions for the following features and clear details regarding the following areas are provided in the following sections.

- To what extent are visual models used in molecular biology lessons?

- What is the impact of using visual models in molecular biology lessons?
- Learning problems related to visual models
- Incorporation of the visual models and visual skills
- The importance of using visual literacy and visualisation in teaching.

2.2 THE USE OF VISUAL MODELS IN TEACHING AND LEARNING MOLECULAR BIOLOGY

According to Coley and Tanner (2012), there is a great deal of complexity to molecular biology which creates certain challenges for learners and teachers which need to be addressed. Some of these challenges include molecular shapes and the natural hierarchy from molecular to ecosystem levels. The subject matter of molecular biology is made up of extremely complex, interacting, perceptual substances and processes. Visual models are a common approach to handling this material (Rundgren & Tibell, 2010). Visual models have become more prominent in the field of molecular biology. Hence, there has been a rapid growth in the kinds of images and diagrams and their purpose to convey information and help conceptual understanding in both teaching and research contexts (Gilbert, 2008). The researcher further explains that different teaching strategies, such as verbal text methods, are commonly used in biology. In almost every instance of molecular biology, the problems encountered include misconceptions. Thus, a vital aspect in molecular biology is providing learners with a means to grasp the structures and understanding of visual models (Bucchi & Saracino, 2016).

The transformational influence of scientific visualisation in its many forms has impacted learners' perceptions and understanding of molecular topics (Bucchi & Saracino, 2016). Visual models in science are defined as objects that are thought to have specific material or a physical presence such as pictures, diagrams, tables, charts and videos (Pauwels, 2012). Furthermore, visual models can be found for phenomena that cannot be seen with the naked eyes such as microscopic and macroscopic bodies, and there are phenomena that are not represented by visual models, but can be translated to provide visual data representations. Mnguni (2014) explains that visual models undergo three stages of cognitive processing that overlap and are interrelated: internalisation, conceptualisation, and externalisation. Tsui and Treagust (2013) posit that abstraction is a continuum for the form of visual models, which can be applied to difficult systems that have models that can be both abstract and concrete. Verhoeff *et al*., (2008) utilise a visual method to learn cellular biology using their system-thinking approach, which involves iteratively observing, evaluating, and revising models. The extent of learners' visual model experiences could involve physical models of small molecules. According to Sandoval (2005), the researcher believes that learners can acquire a more sophisticated understanding of essential aspects of modelling by interacting with visual molecular dynamics to visualise proteins.

Despite additional visual models being studied in science education, with a strong emphasis on conceptual understanding when using them, there is less emphasis placed on their importance as epistemic objects (Osborne, 2014). As previously stated, the purpose of the Next Generation Science Standards, which are currently guiding science instruction in a significant portion of the United States, is to involve students in the actual teaching methods used by teachers. Using visual models is one of the authentic practices used by biochemists, and the resulting models are a form of scientific knowledge (Sandoval, 2005). According to Treagust *et al*., (2002), visual models have five distinct factors that science learners should understand. The nature of models is subject to change, whether they are exact copies, explanatory tools, multiple representations, or used in scientific research. Coll and Lajium (2011) point out that there is a real need for more research on teaching and learning visual model practices in molecular biology to establish a solid basis for its importance in biology. Modelling in the field of Life Sciences is commonly classified into three levels: macroscopic, microscopic, and symbolic. At the microscopic level, proteins are too small to be observed, and macromolecules of chemistry can be modelled in the context of molecular biology (Gilbert, 2008).

2.2.1 Integration of visual models in molecular biology

In order to teach science, educators must practice reform-based scientific methods that involve social interactions and constructing and conveying scientific knowledge through the use of visual tools (Duschl *et al*., 2011). The development of molecular graphics has been, and is, on-going to meet the growing demands of structural biology, and they are currently very effective. Using visual models in molecular biology can range from straightforward to complicated situations (Pauwels, 2012). Because of the difficulty of science, particularly when studying the chemistry of life, Ben-Zvi Assarf and Orion (2010) advocate for the utilisation of visual models as a way to elucidate the components and processes happening in molecular biology. Literature has demonstrated that visual models are essential in providing learners with a more concrete understanding of scientific phenomena (Coleman & Oakley-Brown 2017). In addition, Mnguni (2018) states that the utilisation of visual models in science education continues to increase and that this is caused by an increased use of technology in learning and teaching. Moreover, it requires that learners create a new set of skills for comprehension, communication and construct knowledge in molecular biology.

According to Carney and Levin (2002), visual models can be a powerful learning tool in biology; therefore, their selection is significant. Moreover, visual models that are utilised as explanations have been proven to generate high levels of cognitive processing. Diagrams, and photographs with the more relevant structures of molecular biology identified, can make visual models more understandable and comprehensible (Ma*et al*., 2016). Reasoning or meaningful interpretation of visual models is possible when learners engage the information about the mode of presentation and the conceptual knowledge to interpret the overall content of the biology represented (Schönborn & Anderson, 2006). Research has shown that attempting to increase learners' interest and motivation towards content material with diagrams or illustrations has not been beneficial for learners' learning (Park & Lim, 2007). However, the teacher's own views and experience play a key role in selecting the perfect visual models. According to a previous study, the flow diagram is the visual model that is most commonly used in biology instruction (Osborne, 2014). Coleman and Oakley-Brown (2017) found that teachers who possess representational competency are important in choosing the correct visual models to promote effective learning, according to the views of learners and teachers on visual models.

According to Rundgren and Tibell (2010), it is vital to understand the development of visualisation and the concepts that were incorporated into different features. Accordingly, there are three aspects teachers should consider before using visual models in biology.

Firstly, teachers must be aware of the features that are connected to concepts that are rooted in specific visuals and how to direct learners' attention towards these biological concepts. Secondly, teachers must understand how to encourage the meaningful integration of a learners' prior knowledge by providing proper scaffolding strategies. Thirdly, assessing learners' understanding of target biological concepts is important. Identifying gaps in prior knowledge, and acquiring the necessary knowledge in molecular biology is the responsibility of teachers. Tasker and Dalton (2008) suggest that effective visual models' design should prioritise facilitating a deep understanding of science concepts for learners. However, the complexity of visual representation and the design of visual models are difficult to balance with molecular biology concepts. Gilbert (2008) notes that science education is further complicated by the placement of visual models of any phenomenon in an expressed and scientific model using the five modes of representation below:

- The *concrete mode* is constructed with tough materials, including a three-dimensional model of an ion lattice using plastic balls and sticks or a plaster representation of a section.
- The *verbal mode* involves describing entities and their relationship in a representation.
- The *symbolic mode* comprises of chemical symbols, formulas, mathematical expressions, and chemical equations.
- In the *visual mode*, graphs, diagrams, and animations are utilised. Chemical structures are represented in two dimensions through diagrams and universal examples.
- The *gestural mode* involves utilising movement of the body or its parts.

According to the literature, the review provides an overview of what we know about the selection and utilisation of visual models by teachers, and this selection process's importance for learners in learning science, and its influence on the promotion of scientific modelling practices during teaching molecular biology (Rundgren & Tibell, 2010).

2.2.2 Adaptation of visual models in learning molecular biology

Visual learning is characterised by the process of building knowledge through visual representations (Seels, 1994; Sedig & Parsons, 2013). As illustrated in Figure 2.1, Seels provides four possibilities for depicting the relationship between these different areas in visual learning. Additionally, Figure 2.1 illustrates a hierarchy of subcategories. The main question here is how teachers can organise and utilise visual models to assist learners to enhance their performance in biology. Thus, Aisami (2014) defines visual communication as a type of communication that does not use words. For instance, visuals can consist of pictures or any other illustration that appeal to the visual acuity. Figure 2.1 demonstrates how visuals have an effect on the sense of sight.

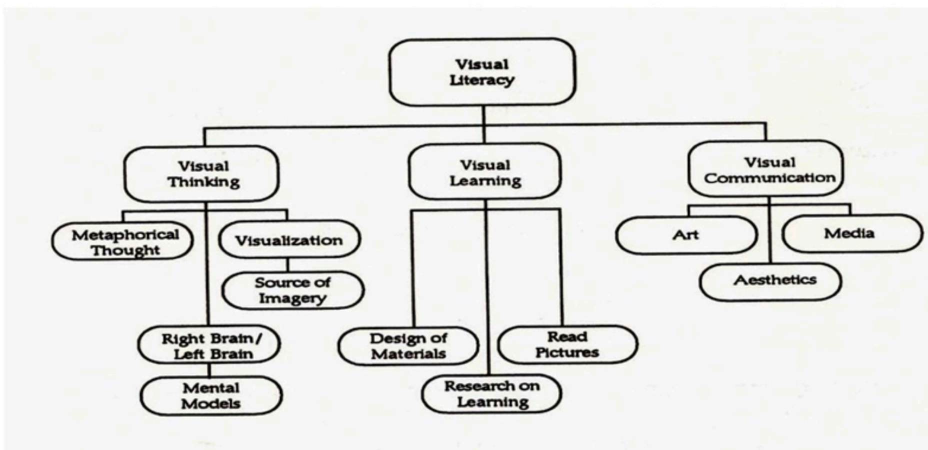

Figure 2.1: The relationship among the different areas of the study in visual learning (Seels, 1994)

Overall, in molecular biology, visuals can encompass diagrams, pictures, charts, symbols, and models. Researchers have examined five visual categories: semiotic and film-video conventions; symbols, signs, and icons; images and illustration; graphical representation; and multi-images (Branden, 1996, as cited in Lohr, 2008: 13). In support of the above, Kouyoumdjian (2012) argues for the positive effect that visuals have on learners' performance. Furthermore, in Figure 2.2 visuals have been demonstrated to motivate and engage learners in the learning process, and images can encourage their creative thinking.

Figure2.2.: An illustration of the appeal of visual images to the sense of sight (*Seels*, 1994)

Literature shows that the utilisation of multiple visual models can be beneficial for learning, firstly by mutually aligning with each other, secondly by achieving the constraint and explanation of unfamiliar representations through familiar representations, and thirdly, by assisting learners in acquiring a deeper conceptual understanding of the molecular biology topics through a combination of models (Ainsworth *et al*., 2015). Moreover, Tasker and Dalton (2008) argue that comprehension can be improved only by visualising learning content which is presented in a task-appropriate manner. The researchers mentioned above assert that video models can be advantageous for learners in demonstrating how to transform a 2D model into a 3D model. By using molecular dynamics animations in the teaching setup, learners can gain a better understanding of the states of matter and how they relate to particle interactions (Rundgren & Tibell, 2010). Visualising the complex and intricate structures of biological molecules can be a challenge for learners. In the high school science class, textbook pictures are used to depict proteins, which make it difficult for learners to observe, interpret, and comprehend their features (Aisami, 2014). According to Bucchi and Saricino (2016), individuals who are taught about protein structures and their roles in molecular biology may encounter difficulties in visualising these molecules. In this scenario, it is crucial for learners to be able to visualise and mentally manipulate proteins to help them create a sophisticated understanding of the relationship between molecular structures and their role within the cells.

2.3 THE IMPORTANCE OF USING VISUAL LITERACY AND VISUALISATION IN TEACHING

It is important for learners and teachers to understand and comprehend the vital role of visual literacy within the context, in order to be able to develop their own skills in visual literacy. According to Grant (2018), visualisation is the learning process through the gathering of skills visually which a learner can develop by keen-sight, understanding and incorporating other sensual experiences. Kovalik and King (2011) add that visual literacy denotes a person having the ability to connect their views using various visual models. To improve teaching and learning, models like charts, diagrams and animations are used to characterise these molecular concepts (Dori & Barak, 2001). Visual literacy assists learners and teachers to develop skills and the ability to understand and use molecular concepts with diagrams and pictures (Branden, 1996, as cited in Lohr, 2008). Due to a lack of consistency and the added complexity of the visualisation tool itself, learners may fail to interpret models in the way instructors or the textbook intended. In this regard, Schönborn and Anderson (2006) suggest that a world-wide discussion is needed so that molecular science can be implemented and standardised.

According to Schönborn and Anderson (2006), learners develop a way in which they process things during visualisation, and they should be exposed to various visual models that will develop their visual literacy skills. In order to comprehend the importance of utilising visual models by teaching and learning science, it is important that teachers should not only concentrate on designing visual models, but should also take into consideration the way in which various learners learn, interpret, and comprehend the models. Therefore, animation and simulations, using video or computer technology, could also enhance conceptual change through visualisation (Lowe, 2003). Similarly, some teachers advocate for the use of analogies when teaching molecular biology topics that appear to be complex. Despite the widespread acceptance of Schönborn and Anderson’s (2006) viewpoints in higher education, the utilisation of visual models in Life Sciences classes, which is essential for all fields of molecular biology, raises doubts. According to the researcher determining the nature of visual literacy is vital in the high school biology classroom.

Visualisation, alongside speaking or verbal teaching enables learners to externalise their thoughts. Thus, it aids in clarifying learners' own ideas when they are struggling to find words to convey them to others. As pictures and diagrams speak volumes, it can be concluded that visual models can assist learners to overcome the language barrier (Taukobong, 2017). According to Aisami (2014), visual literacy is a necessary competency in science, and teachers must be capable of organising, manipulating, and utilising it to teach molecular biology. In this regard, visual literacy can be utilised by learners to enhance their learning and understanding of molecular biology topics. Taukobong (2017) suggests that learners can improve their learning efficiency and foster critical and creative thinking by visualising learning concepts and having the motivation to learn.

In order to enhance visual literacy skills, it is necessary for learners and teachers to have a clear understanding of what visual literacy is (Jenkinso, 2018). Visualisation and visual literacy are based on learners, and teachers often neglect this aspect because it is documented that using visual literacy ideas enhances learning and teaching (Stokes, 2002). Schönborn and Anderson (2006); Rundgren and Tibell (2010); and Emanuel and Challons-Lipton(2013) emphasise that the ability to read and create visual representations is what most definitions compare it to when comparing it to general verbal literacy. According to Bamford (2003), visual literacy encompasses both visual perception and mental observation, while Romero and Bobking (2021) define visual literacy as the acquired skills of accurately interpreting visual messages and creating them. Hence, visual literacy involves being able to understand, create, and use visual biological concepts through interpretation and creation. A visual image is a mental construct that aids the visualiser in comprehending and conveying what they have seen to others. In this regard, the mind must process the vast visual stimuli that learners encounter in today's world. To produce effective visual images, the learner must acquire a range of visual skills that enable them to read and understand images in a meaningful way (Bamford, 2003).

Adding to the above paragraph, in order to understand the meaning of representations, visual literacy requires one to become familiar with the elements and symbols contained in the visual language of a specific discipline (Airey & Linder, 2009). Visual literacy is a core competency that rarely becomes an explicit learning outcome for learners. It is no surprise that the advancement of visual comprehension is now a focus, particularly in biochemistry and molecular biology (Rundgren & Tibell, 2010). Cochran (1976) was among the first to advocate for the importance of visual literacy. Through her work, we are reminded that visual literacy is not something that we add on in the classroom, but rather an essential part of constructing meaning. Educators need to emphasise the inclusion of visuals in our learners' work and provide them with information on how and when to use visuals when teaching molecular biology topics. Airey and Linder (2009) describe semiotic resources as a disciplinary discourse that represents disciplinary ways of knowing through symbols and signs; thus their suggestion is that learning is defined as acquiring knowledge. To perform activities like decoding and interpreting visual models, encoding and creating visual models, and generating mental models, scientists require discursive fluency in their disciplinary discourse (Bamford, 2003).

2.3.1 Similarities and variety of visualisation, models and representation

Visualisation is essential for science because all scientific disciplines utilise visual models such as graphs and chemical formulae. Therefore, connecting the distinction between unobservable molecular processes, scientific theories, and the observable world through visual models, leads to improved comprehension (Rundgren & Tibell, 2010). In science, it is possible to create a visual model to simplify a phenomenon and then use it in an inquiry to explain it for a specific purpose (Gilbert, 2010). According to Reiner (2021), representation is the portrayal of anything and can be divided into the categories, external and internal representation. In addition, it is easy to recognise that visualisation, visual model, and representation are based on the same principles (see part (a) in Figure 2.3). However, variations in visualisation, visual model, and representation (see part (b), (c) and (d) in Figure 2.3) can be observed when there are parts that do not completely overlap. According to Gilbert (2008), researchers need to be aware of the differences and similarities while using visualisation, visual model and representation in the study. The following are some of the differences.

- Some representations are not models, but rather visualisations (refer to (b) in Figure 2.3).

- The scientific community's recognition and agreement on a model is essential, which means that a model can be created in both visual and auditory modes. In this sense, part (c) of Figure 2.3 can be seen as auditory mode that is not visible.
- A representation can be anything from a model or visualisation to an auditory sense that conveys meaning to learners. For instance, if someone hears a bell ringing, they might perceive it as a school bell, which would serve as a reminder to teachers and learners of the start or end of a lesson. However, some individuals in another culture have distinct experiences with the same bell sound and different interpretations of it. This bell sound is not a model that can be generalised, but rather an individualised one. Part (d) in Figure 2.3 could be a metaphor that conveys some kind of meaning, but rather it is not clear if it is a model or even visible.

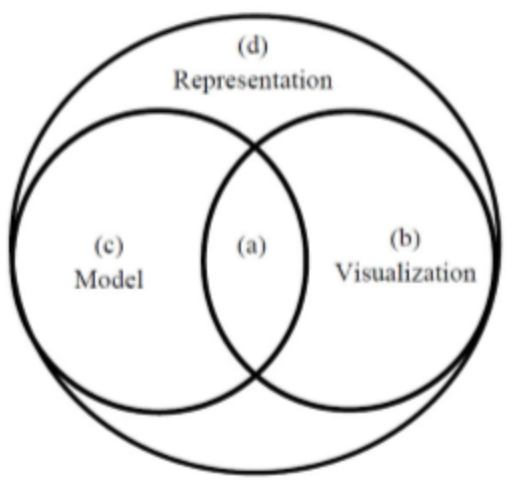

Figure2.3: Relationship between visualisation, visual model and representation

Scientific concepts can be represented more effectively through visualisation, particularly through images and models (Rundgren & Tibell, 2010). The use of the modelling process and visualisation has increased in scientific research. Thus, these mental skills are essential for learners to develop while learning science. According to Gilbert (2008) learners must acquire the abilities to explain and comprehend science models, including contemporary models.

2.3.2 Visual perception

The importance of science education lies in the process of visual perception, visual information processing, and the subsequent creation of adequate concepts for learners. By using visualisation, molecular biology concepts in science education can be applied in new contexts and associated with high cognitive activities (Wiebe *et al*., 2001). According to Seifert (2004, in Machkova and Bilek, 2013), visualisation cannot always replace spoken words, but it can be directed towards specific objectives, such as:

- Minimising the burden placed on teachers.
- The listener's attention is focused on the essence of the presented content.
- To make it easier to comprehend the information being presented.
- The ability to view the contents of personal documents.
- To promote the development of opinions regarding the presented content.

Overall, Gilbert (2008) asserts that visualisation has a positive impact on learners, and it can be utilised in biology. This involves the understanding of the molecular structures and processes in molecular biology topics. Visual perception may appear to be too selective, but this selectivity is the cause of the differences in any subsequently produced visual images (Gilbert, 2008). Basically, visual models are an effective and concrete way to express complex or abstract knowledge and ideas that can make it easier for learners to encode and recall their knowledge. For example, visualisation (Figure 2.4) can make it easy to demonstrate the mechanisms of molecular transport through the cell membrane instead of verbal representation. Furthermore, it has the potential to help learners overcome the common problems they are facing. Although visualisation is associated with what we see, research has shown that learners can create an image without relying on visuals (Reiner, 2021). Furthermore, visualisation processes can be improved by integrating visual information with sensory modalities. An arrangement of various visuals is beneficial to learning (Schönborn *et al*., 2011).

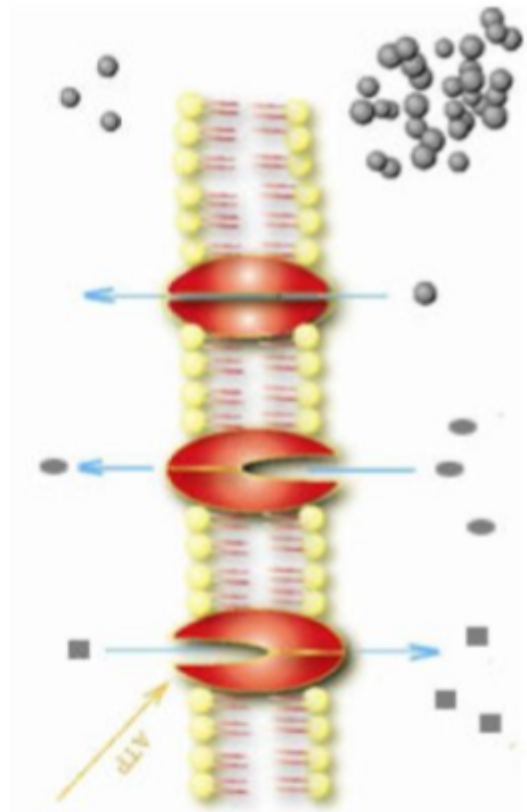

Figure2.4.: The mechanisms of molecular transporting through the cell membrane (Rundgren et al., 2012)

2.4 LEARNING DIFFICULTIES RELATED TO VISUAL MODELS

2.4.1 Learning difficulties associated with internalisation of visual information

According to Mnguni (2014), the complexity linked with visualisation found in the study; is the way learners understand the scientific learning of the role of visual models. Learning difficulties stem from different theoretical cognitive processes of visualisation, thus it is obvious that a lack of visual skills can be caused by the communication of new knowledge (Mnguni, 2014, 2019). Thus, internalisation of visual models is defined as the process whereby sense organs work to absorb information from the world, while conceptualisation visual models are said to be the process where images or pictures are interpreted cognitively in order to give meaning to their depiction (Mnguni & Moyo, 2021). Hence, Schönborn and Anderson (2009) mention that teachers who are teaching science think that learners can create visual literacy on their own without being taught. However, not only learners experience this problem, even teachers find it difficult to teach some components (Luke, 2003). Kirschner (2017) argues that relatively abstract phenomena dealing with the chemistry of life could be depicted, however, their interpretation of various diagrams of the same phenomena could be cognitively demanding.

One of the recommended problem solving strategies is to use visual models, which include, pictures, drawings, videos, and diagrams, as they are significant for learners' understanding of molecular biology problems. The use of a visual model to illustrate the relationship between the elements of the problem can enhance learners' conceptual learning (Serpil *et al*., 2006). Using different visual models is necessary for learners to learn how to translate the results of their thinking into symbolic representations. Mayer (2014), states that for learners to be successful in learning biology, they must be capable of transitioning between problem representation and problem execution. However, the difficulty of visual perception is that of grasping the scientific significance of the visual model that surrounds objects that are foregrounding (Mnguni, 2017). Negative results have been observed in molecular biology due to inadequate visual skills, as evidenced by literature. According to Wu and Shah (2004), there are a few problems in the field of chemistry, and the most significant ones are:

- Despite the fact that chemical phenomena can be represented at a macroscopic level, it is not easy for learners to do so at the sub-micro and symbolic level.
- The concepts represented in a given sub-mode at the sub-micro and symbolic level prove to be difficult for learners to comprehend. The most common obstacle they encounter is interpreting the micro level of a reaction that is represented at the symbolic level.

Thus, to make progress in learning molecular biology, visualising skills are necessary. Basically, visual models can effectively and concretely express difficult or abstract knowledge and ideas, which can assist learners to encode and recall their knowledge more easily (Rundgren *et al*., 2012). Phillips *et al*., (2010) mention that visual models have proven to be effective in learning. Despite this, it is important to highlight the limitations of using visual models for science teachers. Using visual models in science teaching and learning requires awareness of the following points:

- The interpretation of visuals in linked to prior scientific knowledge due to the complexity and symbolism utilised in the visualisation. Kozma (2003) suggests that experienced chemists have the freedom to move between multiple representations of a phenomenon, but learners have constraints on their interpretations due to features displayed in the representations. According to researchers, different visual models in science can be employed for different purposes (Rundgren *et al*., 2012). It is important for teachers to be mindful of the effects of utilising different visuals in learning science.

2.4.2 Learning difficulties associated with conceptualisation of visual information

Although they share a theoretical foundation, existing research has divergent conclusions about how visuals are used in textbooks. According to Guo *et al*., (2017), visual models are generally beneficial for learners' reading comprehension. Despite this, it remains unclear what readers gain from the use of visuals. The United States textbooks were criticised as artefacts that reflect compromises from molecular biology (Roberts & Brugar, 2014). Complex influences cause visuals to be selected without rigorous testing, which results in texts that make it difficult for learners to interpret. In molecular biology, learners were found to have difficulty identifying vital graphical elements, as found by Roberts and Brugar (2014). Certainly, molecular biology is cognitively demanding, which presents learning challenges of varying degrees. Some concepts may be understood easily while others with symbolism and visual language tend to pose greater difficulties (Noble, 2021). Different forms of symbols in molecular biology convey a wealth of information which must be learnt meaningfully. Often the ability to re-call such information from memory characterises the learner's interpretation skill. Hence, memory is linked to knowledge conceptualisation (Weber, 2016)

Codification tools, such as words, pictures, numbers, and videos, can be used to help a learner understand and reproduce their written sign systems, which are commonly referred to as literacy (Bickhard, 2013). Depicting many properties of the cellular environment is a challenge due to the many changes molecules undergo on multiple scales, ranging from autonomic to non-autonomic levels to the random movement of molecular entities. Thus, for learners it is a challenge to understand the sizes of cells, molecules, and atoms in relation to each other (Rundgren & Tibell, 2010). Despite the aforementioned, visual models can achieve certain learning objectives or serve as editorial tools in molecular biology. According to Gilbert (2008), visual models can be influenced by data through predictive or explanatory simulations in biology. Although it is possible to learn about the molecular structures of complex proteins and how structures impact protein functions, learning directly from textbooks can be challenging for learners (Robic, 2010). According to Rundgren and Tibell (2010), learners are tasked with comprehending the relationship between these biological concepts when they conceptualise the spatial attributes of molecular structures. The movement of proteins is constant, both in relation to their interaction partners in their environments and within the protein chain itself. The concept can pose a challenge for learners who want to perceive molecules as stiff structures and molecular interactions as directed linear movements (Robic, 2010).

The understanding of molecular processes is made easier by teachers conveying phenomena that occur at various levels in molecular biology through the use of visual language that utilises multiple representations (O’Nell, 2011). Structures can be represented in different ways, including using various techniques, structural models, and a variation of a symbolic element of a process or pictorial convention. As a result, learners are required to move between various visual models, including abstract diagrams and pictures. Furthermore, they use their own understanding of complex phenomena despite not having prior comprehension of the subject matter (Coleman & Dantzler, 2016). It is not always possible for learners to have the essential skills required to read visuals in the same manner they would learn them. The skills of thinking, learning, and communicating through images is known as visual literacy (Braden, 1982 as cited in Lohr, 2008), are a subdued aspect of biology education. In order to comprehend the visual language of biology, learners need to have a previous understanding of molecular structures and functions, which are often, not present (Robic, 2010). Rundgren and Tibell (2010) point out that individual learners who do not possess important skills to properly interpret visual models often interpret visuals in a literal manner. The representations can have a significant impact on how learners understand molecular biology. Grouping visual types, patterns of use, and the integration between visuals and text is advantageous to understand visual complexity, as there are few systematic attempts to quantify visuals in text (Coleman & Dantzler, 2016).

2.4.3 Learning difficulties associated with externalisation of visual information

The use of multiple visual models that involve visual representations has been empirically proven to be a useful aid to construct knowledge, and comprehend and transfer represented information under specific conditions (Mayer, 2005). Ramulumo (2020) describes externalisation of visual models as a stage where knowledge existing in cognitive structures is externalised through different forms of communication. According to Cartier *et al.* (2001), visual models are used to represent and visualise structures, systems and processes and are often externalised on the screen or page.

Accordingly, such learning involves external visuals, a stimulus perceived from multiple visual models. Memory and knowledge representations that are beyond simple descriptions of perceived stimuli, such as mental or visual images, are internal mental models and incorporate an individual's prior knowledge about the represented data (Hegarty, 2011). According to Liu *et al*., (2023), retaining internal representations in memory to be used at later stage and application are what make them valuable. Although visual models are reported to have advantages, visual models' complex learning environment may have adverse effects on learners' learning (Noble, 2021). One or more of these four sources is commonly believed to be the main cause of complexity:

(a) The *characteristics of the learner* are reflected in the content presented, along with the specific visuals and technologies employed, and are influenced by their cognition, prior knowledge, and abilities (Molinari & Tapiero, 2007).

(b) The *representation's characteristics,* such as the factors of complexity, attention, structures, cognitive load, and arrangement, are all important (Mayer, 2005).

(c) The *characteristics of the pedagogy,* such as the teaching of visual models, involves the use of interactive and passive learning, structural approaches, structural support, training modes, and explicitness (Eysink *et al.*, 2009).

(d) The *contextual characteristics*, such as the difficulty least studied, as difficulties may have an impact on future learning processes, which include learners' sociocultural background and the attitudes and beliefs shared between learners and teachers (Maes *et al*., 2008).

2.4.4 Good practices and challenges

While visualisation in molecular biology has no established best practices, there are certain factors that must be taken into account in the development of visuals (Shahani & Jenkinson, 2012). In this regard, when introducing visual instruction, teachers should consider aspects like the user, the content that is to be shown, the context in which visual models are used, and the objectives to be achieved (Scheiter & Eitel, 2017). Furthermore, when designing the visual models, it is important to take into consideration the limitations of the learners' views and how they affect the amount of changing information that can be used in the classroom. In addition, visual models that are poorly designed can cause confusion for learners. Rundgren and Tibell (2010) point out that a single visual model cannot communicate all the critical issues of knowledge, so teachers should consider which visual models are appropriate for molecular biology.

2.5 INCORPORATION OF THE VISUAL MODELS AND VISUAL LITERACY SKILLS.

According to Schönborn and Anderson (2006), visual skills must aid learners in creating their own charts, diagrams, and pictures, resulting in the development of the scientific concepts and visual literacy skills. The understanding and application of visual communication is supported by visual literacy, and by grasping the fundamental principles of visual literacy, individuals can develop images that they can convey more effectively (Bamford, 2003). Lack of visual skills amongst learners can lead to learning difficulties such as conceptual, visualisation and reasoning difficulties, which could have a serious negative impact on the construction of new knowledge. At this level of molecular biology, processes necessitate the utilisation of visual models and visualisation tools like animations, diagrams and micrographs, and other symbolic language that can assist learners and researchers to develop meaningful knowledge (Schönborn & Anderson, 2006).

According to literature, there is no emphasis placed on explicitly teaching learners how to process visual models, like reading, which is an abstract visual skill. It is important for teachers to encourage learners to take a strategic approach to visual processing, as evidence suggests that in some instance, different abilities are required to interpret various types of visual models in biology (O'Nell, 2011). In order to visualise protein structures, one must possess three-dimensional visual skills, while creating a visual model that represents an upside-down diagram requires 'image flipping' skills. Therefore, to create these skills, learners should be introduced to simple representations and then progress to more complex ones that represent the same phenomenon. The use of visual models in conveying complex messages is mentioned by Tibell and Rundgren (2010). Thus, scientists employ them to model hypotheses, discover mindful patterns in data, and share ideas within the scientific community. In this regard, if the audience of the representation has developed visual literacy, messages contained within visual models can be conveyed. By doing this, learners can create these skills and perform multiple tasks with visual models (Kozma, 2003).

The majority of research on representations has been focused on learners' interpretation of visual models and has not typically emphasised the significance of teachers' graphical literacy as an essential component of pedagogical knowledge. The ability to identify components of images and representations and comprehend the messages being communicated is necessary for teachers (Leu *et al*., 2011). The act of interpreting a given representation, which may seem simple, is influenced by many factors, such as an individual's depth of content knowledge about the idea or concept represented (Schönborn & Anderson, 2009). In addition, molecular biology representations frequently utilise graphical and diagrammatic features, different levels of abstraction, and spatial arrangement of visual models to communicate information (Ainsworth, 2015).

2.5.1 Improved visual literacy skills

Luke (2003) cites that teachers focus on textual, scientific and visual literacy rather than solely focus on textual and scientific literacy when trying to improve visual skills among learners. By promoting visual skills in the classroom, teachers can motivate learners to express and critically respond to ideas (Stokes, 2002). The role of visual literacy in molecular biology requires teachers to explicitly teach learners visual literacy skills to assist them in interpreting and presenting visual models. Taukobong (2017) suggests that teachers should identify the primary factors that impact a learner's ability to visualise models before incorporating them into lesson plans related to visual literacy. Additionally, a learner's general reasoning ability to interpret visual models, and read and make sense of visual content is taken into account. Similarly, teachers are responsible for explaining the purpose of visual models and the conceptual understanding they imply (O'Nell, 2011). Therefore, critical reasoning and thinking are important components of learning visual literacy as a skill, this helps learners in interpreting ideas they perceive.

The principles of backward design should be employed in curriculum design to support visual literacy, with assessments and activities aligned with the learning objectives to provide practice and reinforce the skills underpinning visual literacy, as stated by Wiggins and McTighe (2005). Arneson and Offerdahl (2018) utilise Bloom's Taxonomy to describe the visual learning abilities needed to become familiar with visual models and develop proficiency in extracting meaning from them. Furthermore, Mnguni *et al*. (2016) utilise Bloom's Taxonomy to categorise the cognitive skills related to the visualisation process while attempting to measure learners' visual skills. The ability to understand the scientific meaning of part of a visual model is one of the learning skills associated with internationalising a visual model in biology (Mnguni, 2007).

2.6 IMPACT OF USING VISUAL MODELS IN MOLECULAR BIOLOGY.

The use of visual models and symbolic language is essential for life scientists to research and teach modern biology, particularly at the microscopic level in areas like the chemistry of life (Tsui & Treagust, 2013). Understanding of visualisation of molecular biology components can tend to be more thought-provoking for learners and can result in the misconception of visualisation and difficulties in reasoning ability that can have a negative impact on learners' understanding of molecular and cellular concepts. Crossley *et al.* (1996), show learners' difficulties in reasoning with using the visual models representing the electron transport claim in the mitochondrion. Hull (2003) describes how learners' incorrect interpretation of how the citric acid cycle would look without a cell resulted in them supporting their learning process difficulties with an incorrect explanation. In this regard, models may be advantageous to learners, but some learners find them difficult to explain.

The use of frequently misleading symbolism, along with significant variations in visual model design quality, and subpar methods and strategies for teaching and learning with visual models, can result in conceptual and reasoning difficulties that can impact learners' understanding of biology (Schönborn & Anderson, 2010). Lowe (2003) draws attention to the fact that visual models may be overwhelming and demand high processing skills and comprehension. Conversely, visual models may be underwhelming due to the learners not actively engaging with the visuals. However, the combined use of various models could limit the cognitive load placed on learners as they require strategic knowledge, which promotes reasoning and conceptual change (O'Nell, 2011). According to Nitz *et al*., (2014) interpreting visual models is a common practice reported by most learners. For example, learners were given explicit instructions on how to comprehend graphics through the interpretation of graphics and video. As a result, learners gained more conceptual knowledge of both content and the use of visual models in molecular biology. When learners engaged in the active social construction of knowledge using visual models (Nitz *et al*., 2014), there were positive effects on their content knowledge.

Another significant skill in biology is the ability to communicate visually through drawings. In this way, such modules can include macroscopic, microscopic and symbolic models (Schönborn *et al*., 2010). For a long time, visualisation has been utilised in biology to convey processes. Also, scientists develop visualisations to validate experiments, explore datasets, and other findings. To understand difficult biological processes, learners in biology are heavily dependent on illustrations, interactive simulations, and animations, as stated by Rybarczyk (2011). Molecular structures, including proteins and nucleic acids, have been defined since the discovery of life's chemistry, and methods for describing them have been developed alongside those for determining atomic structures. Visual models are essential for representing these complex structures for solutions and analysis, making this important. An empirical model has been identified by a researcher that identifies seven factors that impact a learner's ability to interpret, visualise, and learn from visual models in the biology context (Schönborn & Anderson, 2009). Figure 6 depicts a Venn diagram that meaningfully expresses the independent nature of the factors.

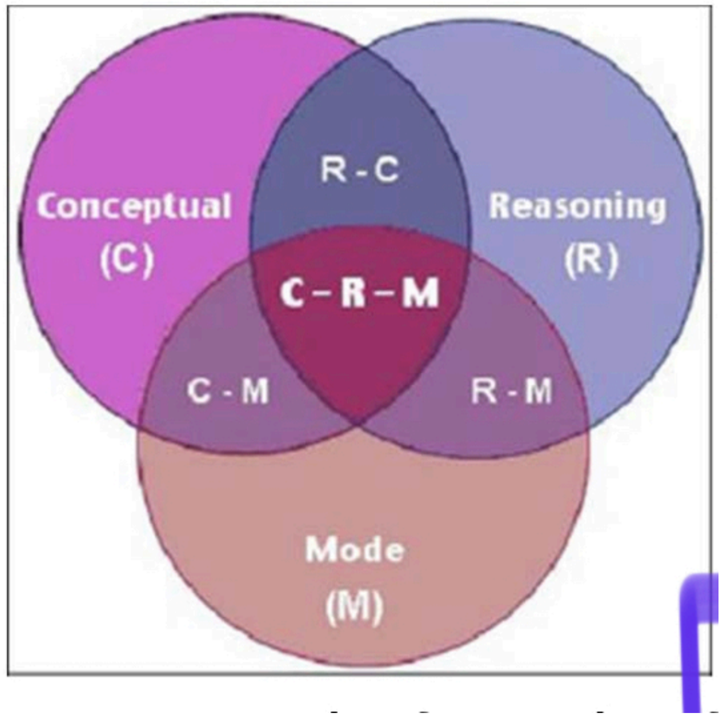

Figure2.5: A Venn diagram representing factors that affect learner's ability to interpret (Schönborn, 2005)

Learners' conceptual knowledge relevant to the visual model is represented by the conceptual factor (C), and all the reasoning skills necessary for visual interpretation are represented by the reasoning factor. The Venn diagram (Figure 6) illustrates how the representation of the mode factor (M) identifies the external nature of external visuals, such as constituent symbolic markings. Tsui and Treagust (2013), state that these three factors are inseparable, which leads to the information of four additional interactive factors. In order to engage their reasoning abilities, a learner must have something to reason with their conceptual knowledge. In molecular biology, the CRM model has been shown to be useful, and it can be utilised to help learners categorise and assess reasoning abilities, as well as to develop problem-solving strategies for interpreting visual models in biology (Scheiter & Eitel, 2017).

2.7 CONCLUSION

The literature discussed in this chapter shows that more emphasis should be placed on visual models and skills, to ensure that good strategies are used by teachers to incorporate visual models when teaching molecular biology in the classroom. The study endeavours to address various approaches to comprehend the teaching and learning of molecular biology, its processes, and the factors that impact learners' behaviour and interaction in the classroom based on the problems identified in the literature. The literature shows that visual literacy and visualisation also improve molecular biology understanding in helping learners perform at their best.

CHAPTER 3: RESEARCH DESIGN AND METHODOLOGY

3.1 INTRODUCTION

This chapter focuses on the research process and how it was performed, with an emphasis on the methods used and research design. After analysing the relevant literature in Chapter 2 of this study, it was essential to select a research design and methods to gather data and respond to the study's research questions. According to Maree and Van der Westhuizen (2009), the research design is determined by the study's goal, while the research methods are determined by the research questions. Therefore, this chapter provides a description of issues involved in selecting a sample, using data collection instruments, and conducting data analysis and its techniques. The discussion includes topics such as reliability, validity, and ethical concerns.

3.2 RESEARCH PARADIGM

The term 'paradigm' has been liberally defined by many academics, allowing it to be used in various settings and academic fields of study. It is necessary to refine these definitions as they are too broad. In order to clarify its new meaning, many new definitions have been generated for the term paradigm. For instance, perceiving and comprehending the world through a paradigm is considered to be a way to make sense of it (Mukherji & Albon, 2015). The behaviour of individuals or groups in a specific community is influenced by a paradigm, which is a group of shared ideas, attitudes, practices, and values (Kamal, 2019). According to these definitions, paradigms are a philosophical approach that individuals or groups employ to comprehend social phenomena. The researcher's decision-making in educational research is guided by a paradigm, which is a philosophical stance that begins with determining what to investigate, how to investigate, and how to collect, analyse, and report data (Khatri, 2020; Kivunja & Kuyini, 2017). According to Khatri (2020); Matta (2021); and Rehman and Alharthi (2016), a research paradigm can be explained as a philosophy's primary belief and expectation system or the foundation for research, which includes assumptions about ontology, axiology, epistemology, and methodology.

In philosophy, ontology is the study of reality's nature (Khatri, 2020). The paradigmatic belief of a researcher that may influence their preconceived notions about truth and understanding (Rehman & Alharthi, 2016). To inform the audience of the objective or subjective nature of the investigated phenomena, researchers must express their ontological position in research (Gruber, 2016). The ontological assumption of a researcher who studies people's experiences and socio-cultural processes is that there are multiple subjective realities instead of objectivity (Khatri, 2020). Furthermore, the researcher has the capacity to discover the concealed meaning in the research data through the utilisation of ontological assumptions (Kivunja & Kuyini, 2017).

Knowledge's nature is the primary focus of epistemology, its acquisition from various sources (Khatri, 2020), and its verification and transmission to others (Rehman & Alharthi, 2016). According to the research paradigm chosen, the researcher will identify the participants, instruments, procedures, and methods utilised in the research study (Greco, 2017). When designing a research study, Kivunja and Kuyini (2017) state that axiology is the term for the ethical considerations that must be considered when designing a research study. By utilising the axiology component of a research paradigm, the researcher can determine, evaluate, and comprehend the concepts of acceptable and unacceptable behaviour during data collection procedures, report findings, data management, and dealing with human participants (Khatri, 2020).

In the literature, there has been the identification of a variety of research paradigms. Research paradigms are divided into three categories by some authors, with positivism, interpretivism/constructivism, and critical theory being the most popular (Rehman & Alharthi, 2016). Shannon-Baker (2016) provides a framework for categorising paradigms, with pragmatism being the fourth paradigm. Positivism, interpretivism, critical theory, postmodernism, and pragmatism are the five paradigms listed by Saunders, Lewis, and Thornhill (2019). The motive, perspective, and worldview of knowledge of each author affects their classification (Okesina, 2020). Rehman and Alharthi (2016) mention that in order to study a phenomenon, it is important to choose a philosophical viewpoint that is aligned with the research needs and requirements rather than imposing a particular worldview.

Positivism proposes that scientific research on human behaviour can be carried out by generating hypotheses. Gathering quantitative data, conducting experiments, and performing statistical analyses to achieve a one-to-one reality that is not dependent on the researcher or the research environment (Kivunja & Kuyini, 2017). In social science research, the positivist view of reality has undergone significant criticism due to its implication that humans are items that are not living and can be utilised in a laboratory setting for experimentation, as reflected by Sheikh and Sultan (2016). Generalising study findings beyond the study environment is not feasible because humans have various values, sentiments, and experiences depending on their situations (Okesina, 2020; Saunders *et al*., 2019).

According to interpretivism, it is better to believe in multiple realities that are socially constructed instead of assuming a truth (Rehman & Alharthi, 2016). The participants are capable of developing their own perspective on social phenomena (Rehman & Alharthi, 2016), and evidence of multiple realities can be found in the words spoken by individual participants (Okesina, 2020). According to this, the interpretivist is a fan of subjective epistemology, relativist ontology, naturalistic methodology, and balanced axiology (Creswell & Poth, 2017). Interpreting data is done by the researcher's subjective epistemology, which is informed by their cognitive processing and interactions with participants (Kivunja & Kuyini, 2017). According to Cropley (2021), each person acquires a distinctive view of the word based on their personal experiences with it. Scholars' perception of reality is largely influenced by the assumptions, impressions, and viewpoints held by individuals (Cropley, 2021).

For this research, interpretivism was the most appropriate approach. The investigation, analysis, and interpretation of the perspectives of individual participants on the investigated phenomenon in their natural settings were necessary for the researcher to address the context of the topic, which is evident. Therefore, the application of a naturalistic methodology was appropriate. The researcher relied on the interpretive paradigm to guide them in their choice of data collection methods. Additionally, it was expected that there would be multiple realities because of the differing experiences of individual teachers in teaching molecular biology. The study is well-suited for the philosophical assumption of relative epistemology, which is interpretivist.

3.3 RESEARCH DESIGN AND APPROACH

For the study, the research design and approach were chosen because they allowed the researcher to design and develop instructional interventions in educational settings. According to Mouton (2007), the research design and approach are responsible for providing the overall structure of how the researcher intends to conduct the study. In this regard, there are two main research approaches that can be used for collecting and analysing data, namely, qualitative and quantitative approaches (Creswell, 2009). The value of these approaches is the source of a great deal of debate among researchers. Within these approaches, there are differences and based on these, it is vital for researchers to use the preferred approach guided by the research questions.

3.3.1 Research design

The research design is utilised to guide data collection and analysis, which is the framework or plan for a study (Pandey & Pandey, 2021). To complete a study and collect, measure, and analyse data, a blueprint is followed. Before collecting data, researchers use their research design, which can be a plan, strategy, logical structure, or mode, to achieve their research objectives and questions (Asenahabi, 2019). A research design, as explained by Mouton (2001), is a strategy for conducting research. The research design which the researcher choice is based on the research questions they intended to answer (Spickard, 2017). There are five approaches for conducting qualitative research: narrative research, phenomenology, grounded theory, ethnography and the case study (Yin, 2003). Thus, this study used case study as the framework for this research. In addition, assessing the interaction between different design components was essential as the study aimed to determine the extent to which teachers utilise visual models when teaching molecular biology.

3.3.1.1 Case study

There are several definitions of a case study design that have been proposed by social science researchers. A case study is the investigation of a social phenomenon in order to comprehend its activities and circumstances (Tomaszewski *et al.*, 2020). A case study is an in-depth of one person, group, or event. In a case study, nearly every aspect of the subject's life and history is analysed to seek patterns and causes of behaviour (Yin, 2017). The point of a case study is to learn as much as possible about individual so that information can be generalised to many others. Case study allows researchers to collect data on why one strategy might be chosen over another (Creswell, 2013).

The researcher involved in a case study gathers a significant amount of information from the individuals they are studying by conducting interviews and analysing documents (Yin, 2017). The use of qualitative case studies allows researchers to study complex phenomena in their context (Creswell, 2013). Due to this, social scientists have proposed multiple definitions for case study design. A definition is given to a case study by Asenahabi (2019) as being comprehensive or rigorous investigation into the unique traits or processes of individuals, and groups of people. In addition, a case study aims to answer specific research design questions by gathering evidence in the case setting and abstracting it to obtain the most accurate answers (Graham, 2000). Nieuwenhuis (2007) backs up the definition above, arguing that the real focus of the case study is particularisation instead of the individual; furthermore, an individual case is examined and studied, with the main focus being on its actions rather than its differences from others.

A researcher uses a case study method to investigate a programme, event, process, activity, or individual in depth. Different data collection techniques are used by researchers over a sustained period to gather detailed information about cases that are bound by time and activity (Creswell, & Poth, 2017). According to Graham (2000), there are two essential qualities of a case study. In case study design, the first thing to do is collect and analyse numerous sources of evidence, each of which has its own weaknesses and strengths. It is necessary to have multiple kinds of data as evidence in a case study to avoid being dependent on a single method of collecting data (Yin, 2017). Moreover, a case study is the result of a researcher who does not rely on prior theoretical viewpoints (Graham, 2000). According to Graham (2000), researchers must participate in the study, gather information, and begin to comprehend the context before determining which theories are most effective. The case study employed in this study allowed for the use of multiple data collection methods to gather information about participants' perspectives and opinions; for instance, interviews and open-ended questionnaires were used to collect the data (Brink, 2018). While there are shortcomings, a case study is a robust design that can accommodate an integrated research study with a clear focus and defined limits. In particular, individuals tend to be biased or selective when sharing or hearing information (Brink, 2018). Despite the drawbacks of a case study design, it was chosen because it was most suitable for this study.

The first, second and third research approach sub-questions were answered through a qualitative research approach that involved a multiple case study. Yin (2017) identified two types of case study designs: single case studies and multiple case studies. Diop and Liu (2020) classified case studies into three types: a single setting case study with a single sub-case, a single setting case study with multiple sub-cases, and multiple cases design. Single and multiple case designs are popular and acceptable (Merriam & Tisdell, 2016). However, a single case study methodology is only appropriate if the study is critical, unusual, revelatory, and longitudinal (Yin, 2017). The multiple case study design was used in this investigation. Schools are complex institutions with diverse educational qualities. In these scenarios, Heale and Twycross (2017) assert that researching “several, similar cases will provide a better answer to a research question than if only one case is examined; hence a multiple case study was deemed appropriate Like any other research design, a multiple-case study has advantages and disadvantages. One significant downside is that implementation can be costly and time consuming (Brink, 2018). This was seen in this study when the researcher had to visit various schools on different days to collect data. However, based on an examination of the alternative research designs that the researcher could have employed, the multiple case study design was the most appropriate research design to explore the research topic. It may be claimed that multiple case studies have more benefits than drawbacks (Gustafsson, 2017).

3.4 RESEARCH APPROACH

3.4.1 Qualitative approach

Taking the study into account holistically, the main research question and objectives of the study were addressed using a qualitative research approach. Through this approach, the researcher wanted to address the wider question of how participants utilise visual models when teaching molecular biology in Grade 10. Qualitative research approach was chosen as the methodology for this study because this approach reinforces an understanding and interpretation of meaning. Qualitative approach is rich, holistic and offers more than a snapshot; it provides understanding of a sustained process (Tracy, 2019). According to Babbie and Mouton (2011), a qualitative approach is a method that gathers data through words and observations rather than numbers. The researcher can comprehend the participant’s thoughts, feelings, and viewpoints on certain topics related to the study through this approach (Struwig & Stead, 2001). In this instance, a qualitative approach helps the researcher to develop an understanding of social or human issues from different perspectives. Zucker (2001) further explains that a qualitative approach is often used in educational studies with the aim of describing and discovering the proceedings, and understanding the theoretical importance of the study. Nonetheless, most qualitative approaches have a sample size that is smaller and more dependent on the subjectivity of the study. Mohajan (2018) states that qualitative approach findings cannot be objectively verified because they cannot be repeated because of the context and interactions. A qualitative approach provides better classification when a researcher needs to explain a specific area of study by examining individual cases of information (Orb, 2001).

There are various advantages to using a qualitative research approach. It enables the researcher to collect rich and extensive data that provides a comprehensive account of the participants' feelings, views, values, experiences, attitudes, and beliefs (Rahman, 2017). Furthermore, unlike quantitative research approaches, individual people's views are recognised, recorded and reported rather than being disguised by majority opinions (Rahman, 2017). Qualitative research methods are adaptable, allowing the researcher to adjust and revise the direction of the investigation while collecting data (Mohajan, 2018). For example, the use of open-ended interviews allows for the emergence of fresh evidence that was not previously considered, as the interviewer can "probe respondents for underlying values, beliefs, and assumptions" (Mohajan, 2018). This provides additional data for analysis and allows the researcher to investigate complex issues that quantitative methods typically overlook (Rahman, 2017). A variety of qualitative research methods might be used in a single study to obtain a holistic picture of the research phenomenon (Mohajan, 2018; Rahman, 2017). Thus, triangulation is easier to achieve in qualitative research than in quantitative research. Moreover, qualitative research typically involves a small sample of individuals, implying that the study can be conducted at a low cost (Mohajan, 2018). In terms of the above, a qualitative approach allows the researcher to gather a wide range of data using different data collection instruments, like interviews, observations, documents, past records, and audio-visual material (Leedy & Ormrod, 2001). This approach is adaptable, as demonstrated by Mohajan (2018), and the researcher can adjust and revise the study's direction while collecting data. Babbie (2010) recommends using a qualitative research approach to determine how participants feel about their involvement in research.

3.5 POPULATION AND SAMPLING

3.5.1 Population

According to Merriam-Webster (2009), study population refers to all elements (objects, groups, events and individuals) that fulfil the sample requirements for being included in a study. The study boundaries are described to aid the reader in understanding and grasping the context in which the study was conducted. Additionally, the study population allows the researcher to utilise an approach that is universal (Casteel & Bridier. 2021). The study's population consists of the individuals, groups, or organisations to which the study's findings may be generalised or transferred (Casteel & Bridier, 2021). It describes the scope or bounds of the study to assist the reader in understanding the context in which the investigation was conducted. It also assists the researcher in avoiding an one size-fits-all approach to data presentation (Casteel & Bridier, 2021). After defining the study's population, the researcher can explicitly specify the study's sample and sampling processes. Kendall (2003), states that there are some qualities which need to be considered for the purpose of inclusion in an accessible population. It was the responsibility of the researcher to choose who takes part, the status of the participants, the nature of the participants and the role that participants' play in the study. The population of this study consisted of the secondary schools in Malegale circuit, Limpopo province. Malegale circuit has seven secondary schools with about 2300 learners and 106 teachers. The researcher has chosen to focus the research on Life Sciences teachers in seven secondary schools offering Life Sciences subject in grade 10. The selection of participants was based on the grounds that they would share relevant information, their interest in the study, and they would be able to help answer and understand the research problem and questions.

3.5.2 Sampling

According to Rahi (2017), sampling entails making a selection from the population in order to find the participants who will be addressed in the study. The process of selecting a certain number of individuals or groups from the target population in a systematic manner is known as sampling (Sharma, 2017). Choosing the correct sample makes the collection of data more effective than when the whole population participates. De Vos, *et al*., (2011) mention that researchers study samples in order to gain more knowledge and understanding of the population from which the sample was taken. In the study, there were a few non-probability sampling procedures that could be utilised, namely, purposive sampling, snowball sampling, quota sampling, and convenience sampling (Sharma, 2017). This study utilised purposive sampling, which helped the researcher to select participants with specific desired traits (Higginbottom, 2004) allowing the researcher to describe the major impact the findings had on the population (Vogt, Gardner & Haeffele, 2015).

In qualitative research, samples are often small in order to support in-depth case-oriented analysis central to this form of inquiry (Vasileiou *et al*., 2018). Furthermore, qualitative samples are purposeful since they are chosen based on their propensity to deliver rich information (Vasileiou *et al*., 2018). The selection of participants in qualitative research is deliberate and not random (Moser & Korstjens, 2018). In qualitative data, purposeful sampling is used, so that participants are chosen without bias (Creswell, 2009). DeCarlos (2018) defines purposive sampling as a strategy that is mostly used to choose the participants from the target population who have the desired characteristics. The aim of purposive sampling is to select persons, things and places that provide detailed data to assist in answering the research questions (Lodico *et al*., 2010). It is necessary to identify relevant cases prior to doing the research (Barglowski, 2018). Furthermore, individuals or groups chosen should be well-informed about the topic of interest and be available and willing to participate (Etikan et al., 2016). Purposive sampling uses less time and is less expensive than other sampling methods; however, it has the disadvantage of being difficult and ineffective when the sample size is large (Regoli, 2019). Nonetheless, purposive sampling was chosen as the best sampling method for this study, since the generalisation of findings beyond the scope of the study was not a priority.

The sample size was based on the fact that Malegale circuit has seven secondary schools that offer Life Sciences; therefore, the chosen population had an equal chance of being included in the sample. Moreover, both the participants and setting of the research were chosen because the traits and attributes of participants and settings were appropriate for the context and purpose of the study. The schools selected from the sampling were selected due to the reason that they are offering Life Sciences subjects. Thus, the participants selected from the schools should be rich of source of information to be utilised in the study, which involved the characteristics such as:

- Participants teaching Grade 10
- Participants teaching Life Sciences in Grade 10
- Participants have two or more year’s experience in teaching life sciences
- Participants having a degree Education.

Seven participants were chosen based on the fact that they could give information that was relevant to the research question and the problem statement. Furthermore, participants were chosen based upon the idea that they meet the requirements stated in the research questions. The use of purposive sampling was used to teachers with appropriate qualifications and experiences in teaching Life Sciences were selected to participate in order to achieve the purpose of this study. The participants’ qualifications and experiences were essential since teachers with suitable qualifications and experience in teaching Life Sciences would provide a better understanding of how teachers utilise visual models when teaching molecular biology topics in Grade 10 Life Sciences in the classroom. Grade 10 Life Sciences teachers who obtained Bachelor of Education (B.Ed.) or Post Graduate Certificate in Education (PGCE) with Life Sciences as a major subject and had been teaching the subject for at least two years were considered as experienced and relevant teachers for this study. in this regard, experience teachers will best inform the research questions The sampled grade 10 Life Sciences teachers in all the seven schools met the criteria of this study and agreed to participate. In this regard, the selection of teachers was based on their interest and participation was voluntary for every teacher from the circuit who was invited. However, gender and age of teachers for this study was not taken into consideration, since the focus of the study was on teaching and learning using visual models. Furthermore, participants were familiar with subject content and the issues faced in the classroom.

3.6 DATA COLLECTION INSTRUMENT AND PROCEDURES

Data collection is a process of collecting data specifically on variables of interest that enables the researcher to answer the proposed research questions (Neuman, 2016). According to Walliman (2017), there are two types of data collection; that is primary and secondary data. Hence, data that is collected at first-hand by researcher is known as primary data. Primary data can be collected by surveys, interviews, focus group, and is considered to be most reliable methods of data collection (Rosenthal, 2016). Secondary data is data that has been previously collected and compiled by someone else and is made accessible to the public (Johnson, 2017). Thus, data collected from the study was primary data from interviews and open-ended questionnaires. The types of data collection instruments and procedures utilised in the study were determined by the selection of research design and research questions, as per Creswell (2009) and Henning (2007). Huberman and Miles (2002) utilise multiple data collection methods (interviews, questionnaires and document review) to ensure triangulation of evidence and correlation of findings from various methods. By combining different approaches to build a more complex picture of methods, methodological perspectives, and theoretical points of view, triangulation can confirm and improve research findings' clarity or precision (Flick, 2004). Additionally, triangulation verifies the outcomes and validates their accuracy, which can be an opposing view that holds that flaws in one method can be mitigated by use of other methods (Cohen & Crabtree, 2006).

Triangulation comes in four different types: (1) data triangulation that utilises multiple source of data across space, time, and participants; (2) the use of multiple investigators for investigator triangulation; (3) approaching data from multiple perspectives and hypotheses is triangulation of theories; (4) using both with-method and between-method triangulation for methodological triangulation (Denzen, 2009). Triangulation is not only about combining data in different ways, but also about capturing a more difficult dimension of an issue, as suggested by Perone and Tucker (2003). In spite of its usefulness, triangulation is not obligatory in every study (Flick, 2004). The study used interviews (face-to-face) and open-ended questionnaires with the teachers so as to promote the quality of the study and gather knowledge. The above instruments were used to address the following research questions: What pedagogical principles inform teachers' use of visual models when teaching molecular biology topics in Grade 10 Life Sciences? How do teachers incorporate visual models when teaching molecular biology topics in Grade 10 Life Sciences? What is the perceived impact of using visual models on learners' content understanding of molecular biology topics in Grade 10 Life Sciences?

3.6.1 Interviews

By conducting interviews, data can be collected using a multi-sensory approach that includes verbal, non-verbal, spoken, and heard information (Cohen, *et al*., 2011). A qualitative research interview is an interview that is intended to gather and collect information about the interviewee's life-world. Ary *et al*., (2006), further explain that the interview can be regarded as one of the methods used to collect qualitative data. Similarly, Yates (2004) supports the statement above, that an interview means creating shared views and understanding between two or more people; meaning the participants and the researcher develop a shared understanding of the study. Interviews assist the researcher to understand how participants interpret knowledge and they ensure that the data collected is valid (Nieuwenhuis, 2007). According to Seidman (2006), an interview allows the researcher to communicate naturally or face-to-face with the participants and allow participants to be comfortable and express their feelings. Dornyei (2007) states that a qualitative interview has two primary characteristics: it is spontaneous and filled with specific traits that allow the interviewee to understand the participants' responses. However, researchers must remember that they are there to listen, not to talk.

As described by Hopf (2004), an interview is a flexible method of communication between the researcher and participants to obtain comprehensive data in the study that can be analysed based on the meanings imparted by interviewees. Researchers collect qualitative data more frequently through interviews and questionnaires. Compared to questionnaires, interviews are more effective at narrative data and allowing researchers to obtain participants' views (Cohen *et al*., 2007). The use of interviewing is not only based on the fact that it builds efficient data, but it also allows the interviewee to speak their mind in their own voice. Nonetheless, Hopf (2004) argues that interviewing is one of the simplest methodologies to use; and interviewing challenges are enough to call them to the researcher's attention. In this regard, interviews should not only be illustrative, but efficient and critical.

Interviews are available in different forms, including structured, semi-structured, unstructured, and focus group interviews. This study used semi-structured interviews, and the interviews were conducted with seven teachers, which helped to supplement and compliment the information gathered. The researcher directed a pre-set flexible interview protocol for a semi-structured interview that is a qualitative data collection method that includes a discussion or dialogue between participants and the researcher, with follow-up questions and comments (DeJonckheere & Vaughn, 2019). An interview guide is used by the researcher to include key questions that should be asked during a semi-structured interview. The interview guide is designed to keep the interviewer focused on the study topic (Alamri, 2019).

Semi-structured interviews are considered to be very versatile in collecting data. Face-to-face interviews are the most commonly used in these interviews. Thus, it allows participants to freely express their feelings and thoughts, and also enables the researcher to observe the body language of the participants (Maphosa & Shumba, 2010). Besides face-to-face interviews, there is the focus group interview which is also popular (Marshall & Rossman, 2014). However, interviews are time-consuming, exhausting, and expensive because the researcher must prepare and plan time to interview individual participants, as well as organise recordings, transcriptions, and coding of the collected data (Alamri, 2019). As a result, the method's transferability in the study is reduced because it can only be applied to a small number of individuals. Although there were some setbacks, semi-structured interviews were chosen as the primary mode of data collection due to their many advantages.

The study used face-to-face interviews to collect data descriptions, among other methods. As previously stated, face-to-face interviews are characterised by synchronous communication in time and location (Opdenakker, 2006). An interviewer's presence enables them to explain complex questions to interviewees, if required. Additionally, visual aids are able to be employed in face-to-face interviews (Cohen *et al*., 2007). The use of face-to-face interview as a method of gathering data has its drawbacks as the reliability of the responses may suffer from the introduction of bias in face-to-face interviews. Phellas *et al*., (2011) suggest that bias could be influenced by the researchers questioning style.

The study's interview guide was created using the five stages proposed by the National Oceanic and Atmospheric Administration, (2015), which include thinking about the research topic, generating a preliminary list of questions, receiving feedback on the preliminary list of questions, modifying the preliminary list of questions, piloting the preliminary list of questions and making additional changes. The supervisor and teachers who participated in the study were given a preliminary list of interview questions to pilot, and amendments were made in response to their feedback. Firstly, pilot interviews were conducted to make sure that there was clarity and the arrangement of the research question and sub-research questions were clearly clarified. Pilot testing helped to iron out any uncertainties in the questions and to estimate how long each interview session would take (Adam, 2015). Participants who were asked to be part of this included teachers in chosen secondary schools who were involved in the initial interview process before the revision. According to Cohen *et al*., (2000), pilot testing assists in increasing the reliability, validity and practicability of interview questions.

The individual interviews were conducted with teachers in selected schools from the Malegale circuit; a total number of seven individual interviews were conducted. These interviews took place at the time given by schools to avoid disturbing lessons in the schools. These interviews had a limited time of 30 minutes and were recorded with the consent of the participants, and notes were also taken. In addition, when all the interviews were done, the recording tapes were transcribed. Transcribed conversations and patterns of experiences were listed as well as identifying items of potential interest. This gave participants time to express and apply their limitations, experience and knowledge acquired in the Life Sciences class when teaching molecular biology. This was done to make sure that the authenticity of the data was maintained and misinterpretations were limited (Doody & Noonan, 2013). Cohen *et al*., (2011) suggest that recording the interview is an imperative aspect as it assists in eliminating mistakes, and the misrepresentation of the data. Section 3.7 will detail the process for coding and classifying data from the interviews.

3.6.2 Open-ended questionnaires

Maree (2007) describes a questionnaire "as a systematic gathering of questions that is used as a sample of population from which data is wanted". In this instance, questionnaires are a popular means of data collection for all types of data, by choosing the required participants for answering questionnaires, which should be developed to address the research objective. The purpose of questionnaires is to gather various kinds of data as it is through this medium that data is created (Smith, 2018). According to Mitchell and Jolley (2007), questionnaires must be designed to fulfil the research objectives and offer relevant data to the study. The questionnaires were short, simple to see and read, and allowed participants to respond and organise their own views.

Open-ended and closed-ended questionnaires vary in many characteristics, more especially as regards to the function of participants when answering the questions. Closed-ended questions limit the participants to the set of different questions given, while an open-ended question gives the respondent time to express their views without being influenced by the researcher (Semyonov-Tal & Lewin-Epstein, 2021). The study focused on open-ended questionnaires, which required participants to express their perception of the impact of using visual models when teaching molecular biology. Answering open-ended questions (response) can be beneficial for the researcher, as they allow participants to select their responses and create various ones that reflect their opinions (Marshall & Rossman, 2014). Using open-ended questionnaires allowed for greater depth of positive responses as the participants were given freedom to reveal their views and experiences (Cohen *et al*., 2000). While there are advantages to open-ended questions, criticisms have been made against it. This is because participants fail to respond to these types of questions, not because they do not have opinions on the questions but because questions are not well addressed (Maree, 2007). Other disadvantages include complexity in coding and analysis of the questions, as it is time consuming for participants and varying amounts of details are given by participants. Besides these drawbacks, an open-ended questionnaire discovers the responses that participants give and this assists in limiting the bias in the study (Adam, 2015).

All these factors were taken into consideration during the development of the open-ended questionnaires. The questionnaires were given to the study supervisor, who was required to give input on the contents, instruction and layout of the questionnaires. The responses from the supervisor resulted in improvements being made to the questionnaire. The questionnaires were then given to seven Grade 10 Life Sciences teachers within selected secondary schools in the Malegale circuit. A questionnaire as one of the research instruments was designed by looking at all aspects and relevant factors. The questionnaires were employed to acquire a comprehensive understanding of the research questions. Participants were given a week to complete the open-ended questionnaires and the questionnaires were distributed personally by the researcher to the selected schools. All the questionnaires were submitted in time; however some participants were reluctant to submit. The questionnaires were short, easy to read and simple to answer, allowing the participants to express their own views. Using open-ended questions allowed teachers to respond freely and to reveal their views and experiences (Cohen *et al*., 2000).

3.7 DATA ANALYSIS AND INTERPRETATIONS

After all the data had been collected, the next rational step was to analyse it, which involved preparing the data for analysis, making sense of the data and getting constructive meaning (Creswell, 2009). According to Mason (2007), data analysis is not a once-off activity but a continuous process of making sense of the data and reflecting on it. According to Mayan (cited in Maree, 2007), data analysis involves observing patterns in the data, asking relevant questions, and adding additional questions, which is followed by sorting, questioning, thinking, constructing, and testing conjecture. Jaspal (2020) explains data analysis as breaking the data down into small units and understanding the views participants have expressed. In mixed methods research, data analysis is dependent on the type of research strategy chosen for the procedures. Therefore, analysis takes place in quantitative (descriptive and analysis) and qualitative (description and thematic text or image analysis) approaches (Creswell, 2009)). Data analysis is employed in mixed methods research to illustrate the sequence of steps necessary to verify the validity of both quantitative and qualitative data. The data collected through questionnaires and interviews was categorised and coded into specific categories (Morse, 1994). Coding, classifying, and categorising the qualitative data was done to ensure trustworthiness, validity, and reliability of the study (Maree, 2007), and triangulation was used to collect, process, and interpret the data. The data from this study was analysed using both thematic and descriptive analysis.

3.7.1 Thematic analysis

According to Cohen *et al*. (2011), qualitative data analysis involves arranging, recording, and presenting the data; basically, interpreting the data according to the participants' understanding of the situation and observing patterns, categories, themes, and irregularities. Qualitative data analysis occurs when data is collected, which is vital in design-based research where the data collected from the study is used to improve the design and refine and adjust the design principles (Henning,2007). Analysing qualitative data can be done using various methods such as content analysis, thematic analysis, narrative analysis, grounded theory, and discourse analysis (Jaspal, 2020). To analyse the data in this study, thematic analysis was utilised. Thematic analysis was used to deal with the first and second research questions, while also partially addressing the third sub-question.

Thematic analysis, as explained by Fereday and Muir-Cochrane (2006), involves recognising patterns in the data being analysed and recognising themes that emerge and become the categories for analysis. One of the most frequently used qualitative data analysis methodologies in the social, behavioural, and health sciences is thematic analysis. Hence, the process is characterised by a careful, focused rereading and review of the data. By analysing the chosen data and constructing coding and category structures based on its traits, the researcher was able to uncover themes related to a phenomenon (Guest *et al*., 2013). Caulfield (2019) explains that thematic analysis is a method that is both rigorous and inductive, designed to select and examine themes from textual data in a transparent and credible way. In a standard thematic analysis, the analysis may consist of a few sentences of text, and the objective is to identify themes within that text segment. Thematic analysis has its shortcomings, such as the tedious comparison of smaller text units, such as lines or words, which are not typically included in most applied thematic analyses due to its time-consuming nature, especially for larger data sets (Guest *et al*., 2013). Although it has its downsides, thematic analysis is adaptable and applied to different sample sizes; additionally, it is a recursive process in which the researcher can revisit previous steps when new themes emerge that necessitate additional investigation (Terry *et al*., 2017). Thematic analysis involves steps that can be both deductive and inductive.

The data collection process began with data analysis in order to discover emergent themes, patterns, and practices. By transcription and analysis of the recorded data, the researcher was able to identify relevant themes. The study used themes that were derived from research questions to analyse the qualitative data collected. De Vos *et al*., (2011) used line-by-line analysis of each interview transcript to identify and code various themes. In order to familiarise themselves with the recordings, the researcher transcribed the data by playing and replaying them. Furthermore, the researcher listened attentively to words and phrases in the participants own vocabularies that captured the meaning of what they do or say. After transcribing the data, coding was introduced to break down the large amount of data into manageable parts. Furthermore, after coding all the data, the researcher grouped all the codes sharing the same meaning together into sub-themes which were eventually grouped together into themes (Creswell, 2009). The researcher used the identified sub-themes to refine the design of the different interventions. Saldana (2011) warns against using too many themes and suggests between three and seven as ideal.

3.8 TRUSTWORTHINESS

Nowell *et al*., (2017) assert that it is imperative for researchers to be regarded as valid by policy makers, professionals, scholars, and the general public. According to Creswell (2011) trustworthiness refers to the consistency in the way a researcher collects data in various settings. Trustworthiness is defined by Connelly (2016), as how confidently one trusts data analyses, collection, and interpretation to be credible, dependable, transferable, and conformable. To ensure that the data collection process is thoroughly examined and analysed, the researcher must ensure that the findings are accurate (De Vos *et al*., 2011). Stahl and King (2020) state that trustworthiness involves a deliberate and meticulous review of various aspects of an inquiry, which is established through techniques that establish truth value, consistency, applicability, and impartiality. To evaluate the validity, and generalisability of quantitative research, reliability, the scientific triad of validity, reliability, and generalisability is utilised. In addition, the validity and reliability guide the study findings to establish the use of large randomised samples and numerical data (Ahmad *et al*., 2019). As qualitative research lacks a unified organisational structure, terms such as validity, reliability, and generalisability become inappropriate (Noble & Smith, 2015). Instead, the term 'trustworthiness' is employed to assess the rigour of the qualitative inquiry. In contrast, qualitative research is not practical or applicable for measuring validity and reliability indices because it uses small non-random samples and non-numerical data (Noble & Smith, 2015). Trustworthiness refers to the level of confidence in the credibility, transferability, dependability, and confirmability of the data, data interpretation, and data collection procedures (Connelly, 2016). According to Nowell *et al*. (2017), this is crucial so that readers can accept or reject the findings. In addition, researchers can use trustworthiness to persuade themselves and their readers that their research findings are significant. Thus, the following sub-sections outline the criteria for sustaining trustworthiness in qualitative research, their significant, and the steps followed in this study to meet the requirements.

3.8.1 Credibility

Creswell (2005) defines credibility as the measure of the researcher’s confidence in the findings. Qualitative researchers might use different techniques to ensure that readers find the study legitimate. In this regard, triangulation is regarded as an approved method that ensures credibility of the study and limits the impact of bias on the data. The study's focus was conveyed to all participants and they all expressed their willingness to participate (Stahl & King, 2020). Triangulation is the use of using multiple sources of data to examine the same phenomenon and identify identifiable patterns in the data (Korstjens & Moser, 2018). Triangulation of data types is a primary method that was used to support the principle in this study where education was viewed and explored from multiple views. Therefore, the collection and comparison of this data improved the data quality based on the principles of data convergence and confirmation of findings (Deggs & Hernandez, 2018).

For credibility, accuracy and authenticity of the data collected, interviews, and open-ended questionnaires from teachers were used to assess for completeness and ascertain the correct content that fit the conceptual framework of the study. Concerning credibility aims to link between the way participants perceive constructivism and the way the researcher portrays their viewpoints (Gunawan, 2015).

3.8.2 Transferability

Transferability is the ability to apply the findings to other settings and contexts or use them in a situation other than the one where they were collected (De Vos *et al*., 2011). The study's transferability necessitates a comprehensive and detailed description of the research methodology. In addition, the study was consistent by using available voice recordings and summaries which served as a database (Crawford *et al.*, 2000). Stahl and King (2020) suggest that transferability can be established by selecting a sample, comparing it to demographic data, and providing detailed descriptions. Transferability was improved by enhancing data description and maximising the ways in which data can be obtained from participants.

3.8.3 Dependability

The term dependability is used to describe whether the study's results would be consistent if repeated with the same subjects in a similar environment (Bisschof & Koebe, 2005). In addition, dependability is comparable to reliability and is measured by how well the findings correspond to the data collected and the appropriateness of the study processes. The study's consistency was demonstrated by describing the research methodology and accessibility of audio recordings in detail. The storage of recorded and transcribed data from interviews, and open-ended questionnaires was conducted safely. Hence, they could be made available to all parties for auditing and review. To improve dependability, an audit trail of processes was utilised, including data collection that was done using multiple sources and methods (Nowell *et al*., 2017).

3.8.4 Conformability

Nowell *et al*., (2017) point out that in analysing the validity of conformability attributes, the researcher must determine if the data and interpretations are figments of their chain of evidence that can be used to support their imagination. Moon *et al*., (2016) describe conformability as being equivalent to objectivity, and all data interpretations and inquiries are made in context and reflect the views of the participants. Conformability was improved by neutrality, which resulted in results that were influenced by the participant's views rather than research bias. According to Korstjens and Moser (2018), conformability guarantees that the research and the researcher's bias is not a factor in the interpretation that reflects the viewpoints of the participants. The researcher maintained a record of raw data collected and the data analysis to ensure consistency, and a supervisor assisted the researcher in validating the findings. Furthermore, it enabled the development of a theoretical framework that was in accordance with the study's purpose and the research questions posed.

3.9 RELIABILITY AND VALIDITY

To establish trust and confidence in the research methodology and findings, it is essential to determine their reliability and validity. The estimated probability of consistency of a particular measurement over time can be described as this (Libarkin & Kurdziel, 2002). According to Morse *et al*. (2002), validity and reliability of the research methods affect the effectiveness of a research study. Moreover, since quantitative and qualitative research methods have different characteristics, each paradigm should use its own criteria to evaluate the validity and reliability of the study. By using triangulation, data collection techniques can be made more effective and weaknesses can be mitigated. Therefore, to ensure the reliability and validity, multiple methods of data collection were used.

3.9.1 Reliability

To have confidence in the research methodology and its findings, it is essential to measure reliability, which is the estimated probability of consistency of given measurements over time (Libarkin & Kurdziel, 2002). To ensure the reliability of the data, various steps were used and documented, by checking for mistakes in the transcripts and ensuring that the meaning of the codes stayed consistent throughout the study (Creswell, 2009). Therefore, reliability of the data collected was ensured by using a tape recorder and note taking during the interviews applying related questions during the interviews.

3.9.2 Validity

According to Creswell (2009), validity refers to the accuracy of findings that can be ensured by the researcher following validation steps. There are certain criteria the study should meet in order to make sure that the results are valid. In addition, validity is a term used to describe how well an instrument measures what it was intended to measure (Maree, 2007). There are various classifications of validity, such as content validity, criterion-related validity, face validity, and concurrent validity. According to Libarkin and Kurdziel (2002), content validity is a measure of how appropriate the items appear to an expected group on the subject matter. Face validity is concerned with the way an instrument or procedure appears, which tells the researcher if the instrument used was well-designed (Golafshani, 2003).

- According to Hyrkäs,*et al*. (2003), triangulation involves using multiple methods to guarantee data validity in the study. A few approaches can used in triangulation to eliminate the bias that may be caused by the use of only one method. According to Maree and Van der Westhuizen (2009), triangulation is required to ensure validity, but they differentiate between the types of triangulation. While in their view triangulation is used when qualitative data is validated by quantitative data. In this regard, with qualitative research; there are a variety of tools that can be utilised to collect and analyse data. In this study, different types of observation, interviews and questionnaires were used to triangulate and make sure that the data was valid. Creswell (2009) mentions that triangulation in data generation uses various data collection methods, so that researcher can gain comprehensive opinions and ensure that the data interpreted was valid.

- The use of open-ended questionnaires were validated during the study. Thus, another way to ensure the data was valid was to use various instruments (Creswell, 2009). In addition, open-ended questionnaires were validated by allowing participants to interpret and respond to questions in the same way. It is necessary to ensure that the data collected is valid; by making sure that during face-to-face interviews, where the researcher did not infringe on the space of the participants. Questionnaires were reviewed to avoid ambiguity, leading or stressful questions. Furthermore, interviews were recorded and the same questions were asked to all participants. The validity in the data collection ensured that detailed notes were taken during the interviews, a good quality tape recording was done and that there was also transparency in the note taking. Cohen *et al.*, (2007) suggest that the design stage can help reduce threats to validity by choosing the required instruments for collecting the required data. Creswell and Hirose (2019) recommend that there must be an alignment of the relationship between the research design and the methodology, findings, and research questions. In order to get more valid data it is necessary to align data generation and data analysis. In this instance, using the strategies described above for this study, the collection of the data and the results indicated that it can be viewed as a reasonably valid study.

3.10 RESEARCH ETHICS

When considering ethics, the researcher must consider whether conducting the study is appropriate, which means that ethics is about the question of what is right or wrong (Leedy & Ormrod, 2005). Ethical considerations are relevant throughout the entire research process, not just when data is collected (Creswell, 2009). Effective and meaningful research requires ethical consideration, therefore, the ethical conduct of an individual researcher is scrutinised to an unprecedented level (Field & Behrman, 2004). Therefore, ethical considerations are important to the study process and the researcher is accountable for conducting the study in a way that positively impacts science and human welfare. The researcher took into account the following for the, protection of participants, research integrity and protection of the institution. Permission for the project or research was given by the Ethical Research Committee at the University of South Africa and the Limpopo Department of Education. An informed consent form was created by the researcher to be signed by the participants prior to engaging in the study. The consent form acknowledged that data collection was done in a way that protected the participant's rights. According to Creswell (2013), the following were included in the consent form:

- The participants identification
- Identifying the institution (organisation)
- Determining the purpose of the study
- Identification of the advantages of the study
- Confidentiality is given as a guarantee
- Notation of risks to the participants

Both quantitative and qualitative aspects are taken into consideration during data collection and interpretation. Respecting the anonymity of participants was a priority for the researcher. Neumann (2000) stresses the importance of the researcher disclosing research details, such as the readers assessing the study's credibility by evaluating the study's design credibility for themselves. Another ethical issue that needed to be considered when collecting and interpreting data was the possibility of bias. The theory of the researcher was articulated during this study, and the use of purposive sampling minimised any possible bias in selecting participants. It is important to consider the researcher's relationship with the participants when conducting the study.

3.11 CHAPTER SUMMARY

This chapter's aim was to provide a summary of the research methodology and data collection processes, to provide a response to the research questions of the study. The utilisation of a mixed methods approach and design-based research methodology was validated through the presentation of various arguments and facts. Furthermore, the discussion revolved around the process of selecting a study sample and developing instruments and procedures for collecting data, along with measures to ensure reliability, validity, and trustworthiness. The ethical considerations that were considered before and during the research were also discussed.

CHAPTER 4: PRESENTATION, ANALYSIS AND INTERPRETATION OF THE RESEARCH RESULTS

4.1 INTRODUCTION

The purpose of this chapter is to present the results and analyse the data gathered through interviews, open-ended questionnaires, and document review. Data presentation forms an important part of research and adding visual aspects to the data makes the data collected easier to understand. As mentioned previously, the aim of the research was to determine the extent to which teachers utilise visual models when teaching molecular biology topics in Grade 10 Life Sciences, as well as the impact of using such visual models. The findings were based on the study objectives as well as answering the study's research questions. The data that was obtained is presented in the form of tables while the interpretation is given in statements. Before providing the outcomes of the interviews and open-ended questionnaire, it may be useful to repeat the study research questions, as any data presented aims to answer these questions. Considering the above discourse, the study seeks to respond to the following research questions:

- What pedagogical principles inform teachers' use of visual models when teaching molecular biology topics in Grade 10 Life Sciences?
- How do teachers incorporate visual models when teaching molecular biology topics in Grade 10 Life Sciences?
- What is the perceived impact of using visual models on learners' content understanding of molecular biology topics in Grade 10 Life Sciences?

The interviews and open-ended questionnaires results presentation were analysed using thematic analysis, and emerging themes and sub-themes are analysed and discussed. Descriptive, statistical analysis is used to identify frequencies and percentages to answer all the questions in the open-ended questionnaire.

4.2 PROFILING OF THE PARTICIPANTS

This section presents the teachers' profiles showing insightful cross-teacher analysis indicating age, gender and qualifications in Life Sciences or related fields, and teaching experience as shown in Table 1. Also, the study uses pseudonyms for participants. The sample for the study was based on Grade 10 Life Sciences teachers, where seven teachers were purposively selected, both males and females of any age. Most teachers were middle aged, with experience in teaching molecular biology topics. However, the study did not focus on the teachers' experience and their ages, hence, the selections of participants was based on the grounds that they were able to share relevant information and were interested in participating in the study, which helped in answering and understanding the research problem and research questions.

As shown in Table 4.1, there were seven participants in this research from diverse age groups, ranging from 25 to 44 years old, with a gender distribution of four males and three females. Participants' experience in the educational field varied between 2 and 15 years, while qualifications included Bachelor of Education (B.Ed.), Postgraduate Certificate in Education (PGCE), and B.Ed. Honours. The pseudonyms used for the participants were Sello, Lindelani, Thabang, Lerato, Phuti, Jane, and Karabo, reflecting a balanced mixture of expertise and educational backgrounds, allowing for a comprehensive analysis within the research context

Table4.1: Biography information

Participants	Pseudonyms	Age	Gender	Experience	Qualification
Participant 1	Sello	34	Male	9 years	B.Ed.
Participant 2	Lindelani	31	Male	6 years	PGCE
Participant 3	Thabang	31	Male	7 years	B.Ed. (Hons)
Participant 4	Lerato	25	Female	2 years	PGCE
Participant 5	Phuti	44	Female	15 years	B.Ed.
Participant 6	Jane	41	Male	12 years	PGCE
Participant 7	Karabo	26	Female	4 years	B.Ed.

4.3 THE EMERGING THEMES FOR RESEARCH QUESTION 1

In this section, results demonstrating the pedagogical principles that inform teachers' use of visual models when teaching molecular biology topics in Grade 10 Life Sciences will be presented.

4.3.1 Perceived importance of visual models in teaching molecular biology topics in Grade 10 Life Sciences

Visual models is defined in literature in Chapters 1 and 2, and in molecular biology topics there are many visual models which teachers can use when they are teaching molecular biology. Such visual models can be very simple to use during a lesson, while others are more complicated. The data from Table 4.2 elucidates the perspectives of Life Sciences teachers in South Africa on the significance of employing visual models for teaching molecular biology topics in Grade 10. Four overarching themes emerged: Enhancing Understanding, Increasing Engagement, Importance of Representation, and Facilitation of Memory.

With regards to, Enhancing Understanding, interviewees such as Sello and Lindelani attest that visual aids simplify the teaching of complex concepts, facilitating better comprehension for both teachers and students. Furthermore, Thabang highlights the tangible aspects of learning through hands-on engagement. The theme of Increasing Engagement suggests that visual models can serve as motivational tools, stimulating interest in science, as suggested by Lerato. They also cater to visual learners, thereby increasing overall student engagement in the subject matter. The theme, Importance of Representation underscores the necessity of models for rendering abstract concepts, such as molecules, more accessible and understandable, a viewpoint reinforced by both Phuti and Jane. Such representational tools are deemed essential, especially for subjects that involve microscopic or otherwise unobservable entities. The Facilitation of Memory theme indicates that visual models aid in information recall and real-world application.

Collectively, these responses present a multifaceted appreciation for the utilisation of visual models, signifying their importance as pedagogical tools for effective teaching and learning in molecular biology.

Table 4.1: Perceived importance of visual models in teaching molecular biology topics in Grade 10 life sciences.

Themes	**Sub-themes**	**Evidence from the interviews**
Enhancing Understanding	Facilitation of Complex Concepts	"It assists teachers to illustrate, diagrams that are in colour and it also makes learning quite easier for learners because they can see." (Sello)
		"Visual models are very important, they assist teacher in communicating biological ideas [...] it also helps learners interpret difficult concepts from the topic." (Lindelani)
	Hands-on Engagement	"Visual cannot only be through maybe videos and pictures, but visual is also mainly on the demonstration by giving learners an opportunity to see and touch get to see what is going to be explains." (Thabang)
Increasing Engagement	Motivating Interest in Science	"So most of the learners are encouraged to do science when they learn through the model." (Lerato)
	Visual Learning Preference	"So they also support the learners which learn through the visual [...] they memorise everything they teach through the models." (Karabo)
Importance of Representation	Models as Essential Tools	"Because molecules are impossible to see with the naked eye You need to have models to represent those. Concepts so that it enhances understanding." (Phuti)
		"For example, a DNA molecule cannot be taught without model or seen visually." (Jane)
Facilitation of Memory	Aiding in Recall	"It also plays a vital role in helping learners remember what they have been taught during exams." (Phuti)

	Real-world Application	"So when I was marking scripts I was able to see some of the learners where referring to a particular picture from videos that they saw, this helps learners to answer critical questions." (Phuti)

4.3.2 Do you use visual models when teaching molecular biology topics in Grade 10 Life Sciences? If yes how regularly or If NO specify why?

Data from Table 4.3 reflects a unanimous agreement among the educators on the importance of using visual models to teach molecular biology to Grade 10 learners. The frequency of use ranged from "often" to "always", emphasising the reliance on visual aids for teaching complex concepts. The timing of implementation varied, with some educators preferring to use visuals after the lesson to consolidate understanding and others integrating them during the lesson to maintain engagement and clarity. The purpose of these models was multifaceted, serving to clarify, engage, illustrate, emphasise, and prevent misconceptions. The availability of resources also influenced the use of visual models, with some educators more fortunate than others in terms of access to educational materials. This thematic analysis highlights the critical role of visual aids in facilitating comprehension in science education.

Table4.3: Use visual models when teaching molecular biology topics in Grade 10 life sciences.

Themes	Categories	Evidence (Verbatim Quotes)
Frequency of Use	Often	"Yes, often especially when teaching diagrams with labels and functions, illustrations..." (Sello)
	Always	"Yes, I always include visuals when the topic required diagrams and processes to be explained..." (Lindelani)
	Mostly often/ Regularly	"Yes, mostly often after each topic or two times in a month when is time to emphasis or explain concepts better..." (Phuti)

		"Yes, most of the time molecular biology topics like chemistry of life and cells require visual models so I always use visuals..." (Thabang)
	Every Time/ Consistently	"Yes, I show them videos every time after lesson sometimes I use models during lesson..." (Lerato) "At the end of every lesson to avoid confusion to learners..." (Karabo)
Timing of Use	After Lesson	"...Videos every time after lesson..." (Lerato) "At the end of every lesson to avoid confusion to learners..." (Karabo)
	During Lesson	"Yes, during lesson while am teaching I use slides or models..." (Jane) : "Yes, use of visual models more often, most of the time and during lesson." (Sello
Purpose of Visual Models	Clarification	"Sometimes I include visual after lesson to clarify some misconception." (Lindelani)
	Engagement	"...This allows my learners to engage." (Lerato)
	Illustration/ Explanation	"...Especially when teaching diagrams with labels and functions, illustrations..." (Sello) "...I always use visuals to illustrate for learners to understand." (Thabang)
	Emphasise/ Explain Concepts	"...When is time to emphasis or explain concepts better..." (Phuti)
	Avoid Misconception	"...To show understanding and there is no misconception." (Karabo)
Availability of Resources	Resource-Dependent	"But it depends on whether models are available in my situation our school has enough resources to help me in teaching molecular biology topic." (Phuti)
	Resource-Sufficient	"Molecular biology topics like chemistry of life and cells require visual models so I always use visuals to illustrate for learners to understand." (Thabang)

4.3.3 Types of visual models preferred for teaching molecular biology topics

Table 4.4 presents varied preferences the participants had regarding the types of visual models utilised in teaching molecular biology topics. Notably, these preferences can be grouped into three major themes: Multimedia Utilisation, Learner-Centred Approach, and Resource Limitations.

Under Multimedia Utilisation, slides and videos emerged as commonly used visual aids. Interestingly, the employment of slides is particularly favoured for showcasing diagrams, whereas videos serve to elucidate processes. Overhead projectors, models, charts, and pictures are also cited, albeit less frequently. This indicates a multimodal approach to instruction, where diverse visual aids are strategically selected to cater to the specific content being covered. The Learner-Centred Approach is underscored by sub-themes like Hands-On Learning and Multiple Voices/ Explanations. Teachers like Lerato and Karabo advocate for experiential learning, asserting its lasting impact on mastery. The use of multiple voices, as Phuti suggests, allows for a more comprehensive understanding, possibly addressing different learning styles. "Resource Limitations" is a crucial theme, with teachers such as Thabang pointing out that many schools fall into quintals 1 and 3, thereby suffering from inadequate resources. This theme casts a shadow on the other themes, as resource constraints could potentially limit the application of preferred teaching methods.

The document review showed that each molecular biology topic provided a specific aim on the use of visual models such as, "knowing life sciences, investigating phenomena in life sciences, and understanding the importance and application of life sciences". Thus, it outlined good strategies to select the best visuals, looking at learners' learning needs and goals. The document showed pedagogical principles that informed teachers to use visual models in their lessons when teaching molecular biology topics, for example, the use of constructivism learning and inquiry-based learning. The document gave a few examples of various visual models that a teacher could use when teaching molecular biology topics in Grade 10 Life Sciences such as the use of pictures to demonstrate organic and inorganic compounds. Therefore, this shows that leaners learn best when they are taught by various visuals. Overall, the table sheds light on a pedagogical landscape that is both diverse in its approaches yet constrained by resources, emphasising the need for strategies that are not only effective, but also feasible within the given context

Table 4.: Types of visual models preferred for teaching molecular biology topics

Themes	**Sub-themes**	**Evidence from the interviews**
Multimedia Utilisation	Slides	"I prefer using slides, especially for diagrams." (Sello); "Sometimes I use slides to show the pictures of the cells or the structures or the molecules." (Lindelani)
	Videos	"Then for processes I use videos." (Sello); "Normally Depending from the topic, I use videos." (Lindelani); "Sometimes using video so they can how molecules and plant tissues looks like" (Karabo); "myself I always prefers to use different kinds of videos" (Jane)
	Overhead Projector	"In my school, I'm using an overhead projector with my laptop that has got a PowerPoint presentation lesson." (Thabang)
	Models	"Sometimes I even use the model of the models like in chemistry there's sometimes where we talk about the atoms." (Lindelani); "Like if I did the plan self, I can ask them to use different types of the molecules for making these two structures." (Lerato)
	Charts	"The first one that is very easy to use our charts." (Karabo)
	Pictures	"another type of visual that I use is the pictures to aid my lesson" (Lindelani); "here is a picture create a model of what you see on this picture" (Karabo)
Learner-Centred Approach	Hands-On Learning	"Like if you let them do it themselves, the master you, they'll never forget about it." (Lerato); "giving learners projects" (Karabo)

	Multiple Voices/ Explanations	"So, hearing different voice also helps, because the person the video might explain better than the way as a teacher I explain." (Phuti)
Resource Limitations	Resource Constraints	"We are lacking resources because our schools mainly are quintal 1 & 3 whereby we also have In adequate resources" (Thabang)
	Pedagogical Principle	The document reviewed outlines strategies for selecting visuals, focusing on learners' needs and goals, and highlights principles like constructivism learning and inquiry-based learning. It provides examples of visuals for teaching molecular biology topics in Grade 10 Life Sciences, such as pictures demonstrating organic and inorganic compounds

4.3.4 Strategies used to select visual models for teaching molecular biology topics

The data outlined in Table 4.5, demonstrates strategies employed by Life Sciences teachers in South Africa for selecting visual models in teaching molecular biology. As shown in Table 4.5, there are four overarching themes that emerged, namely, Topic-Centric Approach, Pedagogy, Learner-Centric Approach, and Resource Availability.

The Topic-Centric Approach highlights the importance of aligning visual models with the specific topic and its learning outcomes. Teachers like Sello, Thabang, and Lindelani suggest that the topic in focus largely dictates the choice of visual models, with learning outcomes serving as guiding factors for selection. Pedagogy is another significant theme, wherein teaching methods and technology are considered. Thabang, for instance, highlights the role of pedagogical methods in choosing visual aids, also mentioning the inclusion of technology. The Learner-Centric Approach highlights the tailoring of instructional materials according to the learning preferences and involvement of students. Lerato emphasises a more participative approach, allowing learners to create their own models if their learning style aligns with hands-on activities. Jane also mentions the choice of visual aids based on learners' understanding. Karabo cites a lack of resources at the school level, while Phuti leans towards using diagrams from textbooks or similar models. The last theme, Type of Visuals, considers whether pictures or videos are more suitable depending on the complexity of topics, like DNA or mitosis.

The data offers a comprehensive overview of multiple factors influencing teachers' choices, each contributing to a richer, more contextual understanding of the pedagogical decisions involved in teaching molecular biology.

Table 4.5: Strategies used to select visual models for teaching molecular biology topics

Themes	**Sub-themes**	**Evidence from the interviews**
Topic-Centric Approach	Topic Consideration	"It will depend on the topics that I'll be preparing for them." (Sello) "That is determined by the topic I'm teaching." (Thabang) "For me to decide I look at the type of topic that I'm teaching." (Lindelani)
	Learning Outcomes	"Normally in every lesson before you start a lesson, you go through the learning outcomes." (Lindelani)
Pedagogy	Teaching Methods	"The pedagogy. I mean the method of teaching." (Thabang)
	Technology Use	"Use of cell phones is another visual model" (Thabang)
Learner-Centric Approach	Learning Preferences	"I start by investigating my learners learning needs." (Lerato) "Always chose pictures and videos based on learners understanding." (Jane)
	Learner Involvement	"If the learners they learn through doing then I will decide that learners should create their own models." (Lerato)
Resource Availability	School Resources	"In this case we don't have much resource at my school" (Karabo)
	External Resources	"Look at the diagrams that are in there and then create modules or look for models that are similar or the same as the ones those that are in their textbooks." (Phuti)
Type of Visuals	Visual Types	"If I am teaching about the DNA or the mitosis, then this is where I check If I should use the pictures or videos." (Lindelani)

		"For something that they cannot do on their own, then I have to teach it through the overhead projector, demonstrate it." (Thabang)

4.3.5 Strategies for incorporating visual models into assessments of learners' learning in molecular biology topics

Assessment is defined as the systematic process of collecting information about what a learner knows, can do, and is learning to do (Carlson *et al.*, 2019). In the Life Sciences classroom, assessment is an integral part of science. Data in Table 4.6 provides a multi-faceted examination of strategies employed by Life Sciences teachers in South Africa for incorporating visual models into assessments focusing on molecular biology topics. Several themes emerged from the data as shown in Table 4.6.

In terms of theme 1, Assessment Format, the data shows a dichotomy between formal and informal assessments, with the former generally involving written evaluations and the latter incorporating visual elements, like pictures. Various types of visual models are deployed, including pictures, videos, and diagrams. Each format appears to serve distinct pedagogical purposes, such as labelling for pictures and structural understanding for diagrams. Pedagogical strategies include activities like labelling structures, drawing them, or using quizzes, and these methods are often intertwined with the chosen visual model. These strategies reportedly lead to enhanced student understanding and are resource-efficient. However, the downside includes concerns over the authenticity of visual-based assessments and potential misconceptions among learners. Lastly, teachers emphasise the need for assessments to have real-life applications, thereby making the learning contextually relevant.

The document revealed the vitality of the assessment of learners, which was well outlined with each assessment having learning outcomes when using visual models in teaching molecular biology topics, meaning learners must be able to understand, comprehend and create connections between ideas and concepts to make meaning in molecular biology topics. In addition, the assessments used to test learners' understanding are visual tests, verbal assessment, and written assessment. Hence, the document provided suggestions to evaluate the usefulness of visual models to learners when they are taught molecular biology topics, such as through formative assessment or a learner's feedback. The document provided clarity on the depth and scope of the content to be assessed in Life Sciences Grade 10; this guides the philosophy underlying the teaching and assessment of molecular biology using visual models in Grade 10. These findings present an intricate landscape that speaks to the nuanced strategies teachers employ, along with the challenges they face, in visual model-based assessments in molecular biology.

Table 4.2: Strategies for incorporating visual models into assessments of learners' learning in molecular biology topics

Themes	**Sub-themes**	**Evidence from the interviews**
Assessment Format	Formal Assessment	"Assessment must be in line with what is written when they're writing formal assessment, they have just to write on the paper" (Sello)
	Informal Assessment	"During the informal assessment... normally I use pictures" (Sello); "Formal or informal test I always make sure that include pictures" (Lindelani); "You can decide if the quiz is going to be formal or informal" (Karabo)
Type of Visual Models	Pictures	"I normally use pictures in the class activities" (Sello); "I always make sure that include pictures" (Lindelani); "Use of pictures in classwork is what I do mostly" (Karabo)
	Videos	"And when they're looking at the video, I can stop the video" (Lindelani); "You can make them watch a video" (Karabo); "I will choose the correct type of visual model like videos" (Jane)
	Diagrams	"Draw structures" (Thabang); "Diagrams in molecular biology requires to be drawn and labelled" (Lerato); "You can take a picture insert it in test" (Karabo)

Pedagogical Strategies	Labelling	"Require learners to identify and label the structures from the pictures" (Sello); "Ask them to label if there's a structure" (Lindelani); "Ask learners to identify molecules from or structures from the videos" (Lerato)
	Drawing	"I can tell them to draw structures" (Lindelani); "I normally advise them to try to draw structures" (Lerato); "Requires learners to draw some plant and animal structure" (Jane)
	Quizzes	"Use of quiz during lesson" (Karabo); "Then after you give them a short quiz for them to answer" (Karabo)
Advantages	Enhances Understanding	"The results are becoming better and better from our learners because of these visual models" (Sello); "You're able to achieve more when using videos" (Karabo)
	Resource Efficiency	"It do save us sometimes and also it save us a resources" (Sello)
Disadvantages	Authenticity Concerns	"Their disadvantage on the assessment is that their authenticity… is not guaranteed" (Thabang); "assessment does not work for me visually because the authenticity part of it, it is not guaranteed" (Phuti)
	Misconceptions	"We are realising that learners has got misconceptions" (Phuti)
Contextual Relevance	Real-life Application	"Learners need to relate what they are doing in classroom with real life experience" (Karabo)
	Pedagogical Principle	The document revealed the vitality of assessment to learners, which was well outlined with each assessment having learning outcomes when using visual models in teaching molecular biology topics.

4.3.6 How do you assess whether learners have understood the molecular biology topics presented through visual models?

The thematic analysis reveals a cohesive approach to assessing learners' understanding of molecular biology through visual models. The predominant theme centres on the use of diagrams and visual representations, which are integral in both formative and summative assessments, as shown in Table 4.7. Instructors tend to use diagrams not only as a teaching tool but also as a means of evaluation, asking students to label or redraw structures and identify phases or components. This method allows for the assessment of both recall and comprehension. Questions posed during or after visual presentations such as videos, are common, promoting an interactive learning environment. The evidence suggests that this visual-centric approach supports the facilitation of spatial and relational understanding crucial in molecular biology.

Table4.3: How do you assess whether learners have understood the molecular biology topics presented through visual models?

Themes	Categories	Evidence from Verbatim Statements
Use of Diagrams	Labelling and Function	"Ask them to explain some concepts and processes from lesson" (Sello)
		"Which requires learners to label and give functions of those organelles" (Lindelani)
	Identification	"Ask them to identify molecules like water molecule" (Phuti)
	Drawing and Redrawing	"Ask them to draw plant cell or give them diagrams of mitosis phases" (Thabang)
Interactive Visual Assessment	Video-Based Questions	"I pause the video and ask questions like learners to label the structures" (Lerato)
	Diagram Interpretation	"In formal tests I always make sure that there are diagrams included which requires learners to label and interpret" (Karabo)
	Visual Model Questions	"I use WhatsApp to send activities that have visual models question" (Jane)

Use of Technology	Digital Assignments	"Assess through diagrams, which required to be labelled, redraw and identify" (Karabo)

4.3.7 Do your learners provide visual solutions in their classwork books? If yes, provide examples

The thematic analysis of the qualitative responses provided by the participants highlights a variety of ways in which learners engage with visual solutions in their classwork. The data represented in Table 4.8 indicates that visual solutions are not only prevalent but also diverse across different scientific concepts. Participants report that learners are capable of drawing detailed scientific structures, graphs, and carrying out experiments with visual aids. This suggests a high level of engagement and comprehension when visual elements are incorporated into learning activities. Learners' abilities to translate theoretical concepts into visual representations may be indicative of their understanding and mastery of the material. The use of visuals seems to assist in tackling complex topics, such as molecular biology, and in enhancing the identification of specific biological tissues, suggesting a practical comprehension that extends beyond rote memorisation. It is evident that visual solutions are an integral part of the learning process for these students, aiding both in understanding and in the ability to convey complex information effectively.

Table 4.4: Learners provide visual solutions in their classwork

Themes	**Categories**	**Evidence from Verbatim Statements**
Graphical Representation	Drawing Graphs	Lindelani: "...Able to draw graphs..." "...learners are able to draw graphs..." (Karabo) Jane: "...Drawing graphs..."
Scientific Structures	Diagrams and Models	Lindelani: "...Structures of mitochondria even cells or phases of mitosis." "...Learners to label and illustration of nucleic acids..." (Phuti)

Visual Experimentation	Conducting Experiments	Lindelani: "...Able to do their experiment on their own" Jane: "...Performing experiments with aid visual models..."
Visual Aids in Learning	Use of Visuals	Thabang: "...Present information visually to other learners." "...Since I used visuals they are able to identify tissues..." (Lerato)
Comprehension of Complexity	Linking Complex Concepts	"...Describe processes that are complicated and they can even link molecular biology lessons" (Karabo)
Identification and Labelling	Recognising Components	"...Being able to draw diagrams, identifying diagrams..." (Sello) "...Able to identify tissues like parenchyma and collenchyma..." (Lerato)

4.4 THE EMERGING THEMES FOR RESEARCH QUESTION 2

In this section, the results represent the ways teachers incorporate visual models when teaching molecular biology topics in Grade 10 Life Sciences.

4.4.1 Strategies for integrating visual models into teaching molecular biology topics

Choosing the correct types of visual models assists teachers to integrate and modify visual models effectively in molecular biology topics. Data concerning strategies that the participating Life Sciences teachers in employ for incorporating visual models in teaching molecular biology generated five overarching themes, namely, Accessibility, Instructional Preparation, Real-world Connection, Time Efficiency, and Resource Utilisation. Under Accessibility, the emphasis is on visual clarity and auditory support, signifying the importance of catering to diverse learning needs (Sello). In the theme, Instructional Preparation, teachers prioritise the structured sequencing of topics and active learner engagement. These methods align with pedagogical best practices that encourage scaffolding and student-centred learning. Real-world Connection is crucial for effective teaching, as evidenced by strategies like relating theory to familiar concepts (Thabang).

Such connections facilitate a deeper understanding and retention of complex topics. Time Efficiency is another focal area; quick preparation and supplemental aids benefit both teachers and learners (Lerato). Resource Utilisation indicates a blend of traditional and modern teaching aids. Teachers rely on multimedia resources and integrate textbooks with visual aids for a more holistic teaching approach (Karabo, Phuti). The use of various resources suggests an adaptive teaching style responsive to resource availability and curricular demands.

Table4. 5: Strategies for integrating visual models into teaching molecular biology topics

Themes	Sub-themes	Evidence from the interviews
Accessibility	Visual Clarity	"Everyone who is having maybe some visual defects will be able to see and gain knowledge" (Sello).
	Auditory Support	"If I'm playing a video it has to have sound and that sound has to be quality" (Sello).
Instructional Preparation	Structure and Sequence	"I would check the topic and teach learners first about the structures of plants and animal cell" (Lindelani).
	Active Learning	"I will then engage the learners, allowing them individually to take part in creating the models" (Lindelani).
Real-world Connection	Relating Theory to Familiar Concepts	"Sometimes you need to relate it to either something that they know or something that they have heard of" (Thabang).
	Integration of Theory and Models	"They relate to the theory to that particular model" (Thabang).
Time Efficiency	Quick Preparation	"Preparation is easy and quicker" (Lerato).
	Supplemental Aid for Teachers	"As a teacher some of the topics I don't understand them and unable to teach, so using some visual models really come in handy" (Lerato).
Resource Utilisation	Multimedia Resources	"I also have multiple videos of the same topics which gives learners opportunity to understand and see molecules differently" (Karabo).

	Textbook and Visual Integration	"I start my lesson by teaching in class first using textbook methods" (Phuti).
	Resource Availability	"Sometimes I check the type of visual resources I have in school after I choose the best visual and teach" (Phuti).

4.4.2 How do you ensure that visual models are integrated effectively with other teaching materials and approaches when teaching molecular biology topics?

The thematic analysis of participant responses regarding the integration of visual models with other teaching materials and approaches in molecular biology topics reveals several themes. These themes encompass strategies for enhancing student understanding, tailoring to cognitive levels, associating with effective teaching methods, the use of multimedia, challenges with integration, and the importance of alignment with topics (Table 4.10). Participants highlighted various approaches, from ensuring comprehension across different cognitive levels to struggling with integrating engaging methods within the curriculum scope.

Table 4.6: How do you ensure that visual models are integrated effectively with other teaching materials and approaches when teaching molecular biology topics?

Themes	**Categories**	**Evidence (Quotations)**
Differentiated Learning	Understanding and Cognitive Levels	"By ensuring that all learners with different learning abilities understand and ensuring that all cognitive level are met on low, middle or high order questions" (Sello)
Effective Teaching Methods	Matching Methods to Topics	"I check what the topic requires and associate with good teaching methods" (Lindelani)
Use of Multimedia	Audio-Visual Aids	"Provide learners with video or audio of scientist explaining about molecular biology topics, sometimes I bring models during lesson to demonstrate for better comprehension of the topic" (Phuti)

Integration Challenges	Curriculum Scope and Engagement	"Interacting with other teaching approaches is sometimes difficult, as sometimes I struggle to finish scope in an engaging question and answers" (Thabang)
Visual and Explanatory Aids	Slides and Explanation	"Most of the time I use slides that explains the chemistry of life better and also use explaining methods to the videos" (Lerato)
Topic-Visual Alignment	Visuals Matching Topic Needs	"Is important to know what topic requires and also check the type of visuals to teach so it explains molecular biology topics very well" (Karabo)

4.4.3 Perceived impact of using visual models on learners' development of critical thinking skills

As shown in Table 4.11, a comprehensive overview of Life Sciences teachers' perspectives on the perceived impact of using visual models for learners' development of critical thinking skills in a South African context was explored and the following themes were identified, Enhanced Conceptual Understanding, Enhanced Critical Thinking Skills, Technological Advantages, Memorisation and Retention, and Engagement and Motivation.

The first theme, Enhanced Conceptual Understanding, includes sub-themes such as Imagery and Imagination, Real-world Application, and Clarity and Discrimination of Concepts. Teachers like Sello and Thabang emphasise how visual models offer learners an enriched, multi-sensory experience that improves their understanding of abstract concepts, such as molecular biology. The second theme centres on Enhanced Critical Thinking Skills, emphasising the role of visual models in fostering problem-solving and interpretation. Lindelani and Phuti note how these tools enable learners to engage in inquiry-based learning, thereby enhancing their curiosity and deepening their understanding. Technological Advantages, the third theme, is pertinent given the context of the fourth industrial revolution. Sello mentions that visual models are aligned with technological advancements, and learners can create their content, thus gaining skills relevant to future learning environments. Memorisation and Retention are also crucial benefits of using visual models. Lerato highlights how visual models make it easier for learners to memorise complex structures, thereby aiding in academic success. The theme of Engagement and Motivation discusses how visual models capture learners' interest and facilitate meaningful learning experiences. Phuti and Lindelani point out that the interactive nature of visual models fosters curiosity and engagement, thereby making the learning process more effective. Generally, the data corroborates the manifold advantages of incorporating visual models in pedagogical practice, particularly in the context of enhancing learners' critical thinking skills.

The document explains the important skills that learners will acquire when visuals are used. It further mentions the process skills in Life Sciences as it is about building evidence in Life Sciences which is diverse. The most fundamental skills which learners will acquire are as follows:

- Observation - observation means learners have the skills to look at living systems in detail with a scientific eye. Drawing is one of the biological skill observations learners will acquire. Written descriptions capture observations that cannot be recorded in drawings.
- Designing and conducting an investigation - scientific investigation provides a sequence of steps for learners. Learners will acquire skills in making observations and asking questions.
- Working in a Life Sciences classroom - learners will learn to follow the teacher’s instructions whenever they are in Life Sciences classroom. There are certain rules to follow when learners work in a classroom that has specialised apparatus.

Table 4.7: Perceived impact of using visual models on learners’ development of critical thinking skills

Themes	**Sub-themes**	**Evidence from the interviews**
Enhanced Conceptual Understanding	Imagery and Imagination	"So, it increases their imaginary abilities because [...] you're also able to see it and hear other presenters presenting better than me." (Sello)
	Real-world Application	"Now we say that the science becomes insignificant because it will not apply to our daily lives." (Karabo)

	Clarity and Discrimination of Concepts	"To understand or draw a line between the DNA and they are in a, but the minute you show them to say, this is a DNA and his double stranded structure and this is an RNA and it's a single stranded structure as part of molecular biology, learners realise that oh by mere looking they understand." (Thabang)
Enhanced Critical Thinking Skills	Problem Solving and Interpretation	"Sometimes you can give them complicated experiment and that experiment requires them to interpret it using the different type of chemicals given using the type of molecules given using the type of." (Lindelani)
	Inquiry and Curiosity	"Learners start to ask questions on different structures used to represent cell, if it was a textbook only they would understand better and ask deep questions and think out of the box." (Phuti)
Technological Advantages	Fourth Industrial Revolution	"Since now we are in the fourth industrial revolution then we use visual models to teach biology." (Sello)
	Learner-Generated Content	"Learners can also learn to design those videos and models that in future we can have access to this models that will be a teaching aid well that will be using when we are teaching molecular biology then it's going to be easier for us." (Sello)
Memorisation and Retention	Easier to Memorise	"But then using the structure from the videos and pictures could help learners realise how epidermis and tissues looks like so it become easier for them to memorise such kind of the structures and excel." (Lerato)
Engagement and Motivation	Interest and Attention	"Visual models help learners to be interested in the topics, they become more curious and start asking questions." (Phuti)
	Meaningful Learning	"That look likes exactly the DNA structure or sometimes I ask them to. Develop model of plant or animal cell on their own." (Lindelani)

Process Skills in Life Sciences		The document provides the skills that learners will develop when they are taught molecular biology through the use of visual models: which are observation, designing and conducting investigations, and working in a Life Sciences classroom

4.4.4 Do you think learners understand better when they are taught using visual models in molecular biology topics? If YES/NO provide explanation?

Thematic analysis of participants' responses revealed an overarching theme of enhanced comprehension and retention when visual models are employed in molecular biology education (Table 4.12). The themes suggest that visual models not only facilitate the visualisation of complex structures but also engage students, thereby improving their ability to describe, memorise, and understand processes. A notable increase in learner interactivity was observed, with students asking pertinent questions and demonstrating creativity in model development. Furthermore, evidence indicates improved performance and retention of information, highlighting the importance of visual aids in supporting diverse learning needs and fostering a deeper grasp of scientific concepts.

Table 4.8: Learners understand better when they are taught using visual models in molecular biology topics

Themes	Categories	Evidence
Visualisation	Structure and Process Visualisation	Sello: "Able to visualise structures and diagrams."
Engagement	Active Participation	Lindelani: "Start to engage and get bigger picture of the topics."
Comprehension	Improved Understanding	Phuti: "Memorise and understanding has improved."
Questioning	Critical Thinking	Thabang: "Learners often ask questions related to lesson that shows understanding."
Creativity	Model Development	Phuti: "Learners always get a chance to develop their own models actually they creativity is increased."

Retention	Long-Term Memory	Thabang: "Learners seem not to forget what they saw, unlike what they heard."
Interactivity	Interactive Learning	Lerato: "Able to answer critical questions and ask questions that require more understanding and information."
Performance	Academic Improvement	Karabo: "Their performance on the topic of chemistry of life has positively improved even struggling learners show some understanding."
Assessment Comprehension	High-Order Thinking	Jane: "I saw learners understanding when they are able to answer questions related to the topic, which sometimes they are high order questions."
Conceptual Linking	Relational Understanding	Sello "Being able to relate or link topic, answering questions."

4.4.5 Strategies for adapting the use of visual models to meet the needs of different learners

Concerning strategies for adapting the use of visual models to meet the needs of different learners, four overarching themes were identified, namely, Accessibility, Multi-Modality, Critical Thinking, and Adaptability (Table 4.13). Accessibility is defined in terms of adaptations for visual and hearing defects, involving tactile models and audio-visual aids. The theme of Multi-Modality is well-articulated by Lindelani, who emphasises the need for visual, auditory, and tactile teaching methods to address varied learning preferences. This is particularly significant for making abstract concepts in molecular biology, more comprehensible. Critical Thinking is promoted through visual aids, and a nuanced approach to question-setting is informed by Bloom's Taxonomy (Thabang). The adaptability of teaching styles and the customisation of learning aids to individual needs demonstrate an inclusive pedagogy (Lerato). Moreover, the data points out the role of Practicality and Relatability in teaching. Hands-on learning opportunities and the incorporation of indigenous knowledge foster a more contextual and relatable learning experience (Karabo). Lastly, the focus on Inclusivity is evident in efforts to address special needs and encourage active participation in model creation (Phuti).

This data (Table 4.13) offers valuable insights into the diversity of methods and philosophies in play, highlighting the nuanced approach required to cater to a broad spectrum of learning needs and styles in Life Sciences education.

Table 4.9: Strategies for adapting the use of visual models to meet the needs of different learners

Themes	**Sub-themes**	**Evidence from the interviews**
Accessibility	Visual Defects	"I do ask in the class if we have anyone who is having problems with visual defects, I normally use models to feel them and audios from the videos." (Sello)
	Hearing Defects	"Again those who are having some hearing defects, I'll be using videos and slides." (Sello)
Multi-Modality	Learning by Seeing	"They learn best by seeing and others they learn through hearing others they learn through touching." (Lindelani)
	Learning by Hearing	"For those who learn through hearing I can use audio but the audio goes on with the video." (Lindelani)
	Learning by Touching	"I prefer to have the structure, the model of the plant cell that they can touch for those learners who learn best by touching." (Lindelani)
Critical Thinking	Development Through Visuals	"The visual model in the teaching profession of molecular biology can help learners to develop critical thinking skill." (Thabang)
	Bloom's Taxonomy	"Remember, as we assess we use the blooms taxonomy, the different cognitive levels as far as the setting of questions is concerned." (Thabang)
Adaptability	Tailored Teaching Styles	"In my classroom, I normally use different teaching styles." (Lerato)
	Accommodating Individual Needs	"We accommodate each and every learner using visual models." (Lerato)
Practicality and relatability	Hands-On Learning	"Some learners are more hands-on than minds-on." (Karabo)

	Indigenous Knowledge	"That's where we now integrate indigenous knowledge within science." (Karabo)
Inclusivity	Addressing Special Needs	"I have this learner in class who has a hearing problem so I always try to let him watch slides or videos." (Phuti)
	Active Creation of Models	"I always allow them to create their own cell models which influence their understanding of the concepts." (Phuti)
	Adaptability	The document shows outlines the best methods for incorporating visuals during lessons within the instructional material. As most classes have various learners who have different learning needs. The document suggested ways to adapt visual models to meet the needs of diverse learners in the classroom. In addition, it shows that lessons can be taught using pictures, videos, and audios, to accommodate learners learning needs and different models, for example show picture of foods that contain fats.

4.5 THE EMERGING THEMES FOR RESEARCH QUESTION 3

In this section, results demonstrating the perceived impact of using visual models on learners' content understanding of molecular biology topics in Grade 10 Life Sciences will be presented

4.5.1 Challenges faced when using visual models to teach molecular biology topics

The data was analysed to determine the challenges encountered by Life Sciences teachers in South Africa when employing visual models to elucidate molecular biology topics. The challenges are organised into four major themes, namely, Resource Limitations, Learner Engagement, Language Barriers, and Remote Learning.

Resource Limitations was further divided into two sub-themes, namely, Availability and Preparation Time. Teachers like Sello and Karabo explicitly note that acquiring suitable visual models is a primary hurdle, while Jane mentions the time-intensive nature of downloading videos. Moreover, Sello, Lerato, and Phuti all emphasise that effective utilisation of visual models requires substantial preparation time. The second theme, Learner Engagement, is divided into sub-themes of Attention and Behaviour, as well as conceptual understanding. Lindelani and Thabang point to attention lapses and misuse of gadgets as problems. More critically, teachers like Lindelani, Lerato, and Karabo indicate that learners sometimes struggle to connect the visual models to the underlying molecular concepts. Language barriers, specifically English proficiency, is another significant challenge. Lindelani and Phuti mention that learners often fail to comprehend the English language used in videos or slides, leading to instructional inefficacy. Lastly, Remote Learning challenges include issues related to monitoring and attendance. Teachers like Thabang and Jane find it difficult to track learner engagement in a remote setting, as physical presence does not necessarily translate to active participation.

Based on the data, it is clear that the challenges are multifaceted, encompassing both logistical constraints and pedagogical issues that impede the effective use of visual models in teaching molecular biology topics.

Table 4.10: Challenges faced when using visual models to teach molecular biology topics

Themes	Sub-themes	Evidence (Verbatim Statements)
Resource Limitations	Availability of Visual Models	"I don't find the suitable ones, so that's the main challenge" (Sello)
		"The main challenge is getting models" (Karabo)
		"Downloading videos can be sometimes time consuming" (Jane)
	Time and Preparation	"Needs good preparations, not something that you are just going to do in the last minutes" (Sello)
		"Use of visual models also use lot of time to prepare" (Lerato)
		"This sometimes waste time" (Phuti)
Learner Engagement	Attention and Behaviour	"Sometimes when am using visuals some learners they turn not to listen" (Lindelani)
		"Learners can misuse their gadgets" (Thabang)
		"My learners are sometimes so naughty that would disturb lesson" (Jane)
	Conceptual Understanding	"Some learners fail to relate concepts with the videos" (Lindelani)
		"Most of my learners always find it difficult to explain some of structures" (Lerato)
		"They experience misconceptions to some of the molecules displayed which require more to explain" (Karabo)
Language Barriers	English Proficiency	"Language become problem since most fail English" (Lindelani)
		"Use of English by presenters sometimes become a problem" (Phuti)
		"So it becomes problem to some of my learners as they do not understand some words written from the slides" (Jane)
		"There is no one to monitor the progress" (Thabang)

Remote Learning	Monitoring and Attendance	"You think they are attending while they are just present" (Jane)
	Negative impact	The document outlined a few strategies to solve the language barrier as it influences teachers to use learner's mother language to emphasis the concepts. In addition, the document shows less solutions to improve time management and other ways to solve the language barrier. The document provides strategies to integrate visual models in molecular biology but provides less solutions to purchasing or getting the equipment models.

4.5.2 Perceived benefits of using visual models in teaching molecular biology topics

With regards to the perceived benefits of using visual models in teaching molecular biology topics (Table 4.15), data shows the benefits are categorised into three overarching themes, namely, Enhanced Learning Experience, Efficiency in Teaching, and Modernisation and Professionalism. The theme of Enhanced Learning Experience is further divided into sub-themes such as Ease of Understanding, Depth of Understanding, Engagement and Enjoyment, and Recall and Retention. Responses highlight that visual models facilitate not just surface-level comprehension but also deepen the understanding of intricate molecular structures. This duality supports engagement and aids in information retention. Efficiency in Teaching is manifested in terms of both time and resource savings. Visual models expedite the teaching process while minimising material costs, making them a cost-effective teaching strategy. The theme of Modernisation and Professionalism underscores how the use of visual models aligns with technological trends, such as the fourth industrial revolution, thus contributing to pedagogical professionalism. Additionally, visual models enhance remote learning capabilities, making them a versatile tool in the contemporary educational landscape. Overall, the data advocates for the multifaceted utility of visual models, extending from pedagogical effectiveness to logistical efficiency and modern-day relevance.

Table 4.11: Perceived benefits of using visual models in teaching molecular biology topics

Themes	Sub-themes	Evidence from the interviews
Enhanced Learning Experience	Ease of Understanding	"Let learners learn fast and best" (Sello) "My learners get to understand the topic and they never forget what I taught them." (Lindelani) "Understand what you are explaining" (Thabang)
	Depth of Understanding	"Visuals give depth view of the concepts." (Lerato) "Develop deeper understanding of concepts that are complicated." (Jane)
	Engagement and Enjoyment	"It makes learning fun and enjoyable." (Thabang) "Encourage mood of the learners to love science" (Karabo)
	Recall and Retention	"They never forget what I taught them" (Lindelani) "Able to relate to it easily to recall facts on that particular model" (Phuti)
Efficiency in Teaching	Time-Saving	"It saves times." (Sello) "It saves time." (Thabang)
	Resource-Saving	"It also saves material from the school" (Sello) "The work that you teach in the class you are able to send it to your learners at the end of the lesson" (Thabang)
Modernisation and Professionalism	Adaptation to Technology	"We are living in the fourth industrial revolution" (Thabang) "Professionalism in the education sector, it makes work to be clean" (Thabang)
	Remote Learning Capabilities	"Send them through a cell phone with visuals" (Thabang) "Wherever in in the world where I will be, as long as there's an Internet connectivity." (Thabang)

4.5.3 Perceived impact using visual models in teaching molecular biology topics on learner's engagement and motivation

Table 4.16 provides a comprehensive view of the perceived impact of utilising visual models in teaching molecular biology topics among Life Sciences teachers in South Africa. The data is organised into four major themes, namely, Positive Impact on Performance, Enhanced Engagement, Motivation, and Addressing Diverse Learning Styles, with each theme subdivided into relevant sub-themes. The first theme, Positive Impact on Performance, indicates a marked improvement in assessment scores and enhanced understanding of the subject matter. Teachers, such as Sello and Lindelani, report a "drastic" improvement in learner performance, suggesting the efficacy of visual models in facilitating academic achievement. The second theme, Enhanced Engagement, delineates an increase in learner curiosity and active participation in class. Teachers, like Lindelani and Karabo, observe that the learners are "always curious" and "hungry to learn," thereby suggesting that visual models capture and sustain attention (Lindelani; Karabo). Motivation as a theme highlights the intrinsic motivation and peer learning catalysed using visual models. Thabang and Karabo note a positive shift in learners' attitudes toward the subject, with Phuti and Jane pointing out that learners are capable of peer-directed learning sessions, even in the teacher's absence. Finally, the theme, Addressing Diverse Learning Styles, indicates the versatility of visual models in catering to both visual and kinaesthetic learners. Teachers, like Thabang, elaborate on the diversity of learning styles, underscoring the adaptability of visual aids (Thabang).

The document is clear on describing the use of visual models to improve learners' engagement and motivation when learning about molecular biology. Providing examples of how learners can be engaged and motivated, for example, the use of group discussions, allowing maximum participation during lessons and using words to motivate learners. The document details ways to support and engage learners for success, and further explains the importance of working in groups, which provides good training for learners and encourages learners to work in teams to share molecular biology ideas. The document shows that using visual models assists learners to communicate with each other to complete the task and this also helps learners to keep motivated.

Table 4.12: Perceived impact using visual models in teaching molecular biology topics on learner's engagement and motivation

Themes	Sub-themes	Evidence from the interviews
Positive Impact on Performance	Improved Assessment Scores	"Their performance has improved drastically" (Sello); "My learners have improved their performance in class since visual models were used in the lessons." (Lindelani)
	Better Understanding	"They are having a better understanding of naming and identifying structures and also giving functions" (Sello); "It also has improved their learning capacity" (Lindelani)
Enhanced Engagement	Increased Curiosity	"They always curious" (Lindelani); "My learners are always hungry to learn" (Karabo)
	Active Participation	"Learners have love of the visual" (Thabang); "They start to pay attention" (Lerato)
Motivation	Intrinsic Motivation	"Learners have love of the visual" (Thabang); "My learners attitudes towards the subject or molecular biology topics has changed in a positive way" (Karabo)
	Peer Learning	"They're able to help each other with they had misconceptions and clear those misconceptions" (Phuti); "Most of my learners even if am absent they are able to create groups" (Jane)
Addressing Diverse Learning Styles	Catering for Visual and Kinaesthetic Learners	"We have got type of learners, kinaesthetic and visualization visualised learners" (Thabang); "They kind of static, they learn by touching auditor, they learn. I listening, but someday learned by watching the process as it unfold" (Thabang)
Classroom Management	Easier Class Control	"So using the model also help in managing the class" (Lerato)
Perceived Impact		The document provides examples of how learners can be engaged and motivated e.g., the use of group

		discussions, allowing maximum participation during lessons and using words to motivate learners

4.5.4 Can you share an example of a successful lesson where you used visual models to teach molecular biology topics to your learners?

It is evident from the data that visual models play a pivotal role in enhancing the understanding and engagement of learners in molecular biology. The themes identified reflect the multifaceted impact of visual aids, which include improved learner performance, increased interest in the subject matter, enhanced ability to compare and contrast biological structures, and a greater propensity for learners to engage in critical thinking and active participation (Table 4.17). Notably, the use of visual models fosters a deeper comprehension of complex concepts, as evidenced by the learners' ability to draw intricate molecular structures and their success in performing experiments. The thematic analysis further highlights the importance of visual models in facilitating effective communication of scientific information, thereby bolstering the educational process.

Table 4.13: Example of a successful lesson where you used visual models to teach molecular biology topics to your learners

Themes	**Categories**	**Evidence from Verbatim Statements**
Enhanced Comprehension	Comparison and Identification Skills	"Compare plant and animal cells differences and similarities" (Sello)
Improved Academic Performance	Learner Assessment and Interest	"Performance increases, even their interest" (Lindelani)
Engagement and Participation	Active Learning and Experimentation	"Learners are always arguing... their engagement is out of this world." (Karabo)
Visualisation Skills	Drawing and Structural Recognition	"Learners these days are able to draw molecular biology structures very clear." (Phuti)
Critical Thinking	Inquisitiveness and Complex Questioning	"My learners ask critical questions which are related to visuals" (Lerato)

Conceptual Understanding	Utilisation of Visual Aids	"I used a chart that showed the two cells" (Thabang)
Learning Reinforcement	Post-Lesson Comprehension	"Learners after class they seem to understand the topic." (Jane)
Active Learning	Participation and Performance	"learners being able to draw structures, participation increased, answering complex questions" (Karabo

4.5.5 Have you noticed any difference in learners' engagement and motivation when using visual models to teach molecular biology topics compared to other teaching methods? Give examples

The use of visual models in teaching molecular biology appears to significantly enhance learner engagement and motivation, according to educators' observations. Themes identified include Increased Participation, Improved Understanding, and Heightened Interest. The data from Table 4.18 elucidates that educators' note that visual aids such as videos and microscopes not only encourage group discussions and peer consultations but also enable learners to relate concepts to real-life situations. The tangible experience of constructing models seems to foster a deeper grasp of the subject matter, leading to improved attention and retention of information. Furthermore, visual models have contributed to a lively classroom atmosphere and even spurred students to successfully compete in Life Sciences contests. The evidence presented in the table below underscores the vital role of visual teaching aids in making molecular biology more accessible and stimulating for learners.

Table 4.14: Difference in learners' engagement and motivation when using visual models to teach molecular biology topics compared to other teaching methods

Themes	**Categories**	**Evidence (Verbatim Statements)**
Enhanced Participation	Group Discussions	"Yes, they form groups for discussion..." (Lindelani)
	Peer Consultation	"Others even become comfortable to consult about what I taught using visuals" (Sello)
	Class Participation	"Participation was always at maximum..." (Phuti)
Improved Understanding	Questioning and Responses	"There were always asking and answering questions which shows that they understand" (Phuti)
	Practical Application	"Learners are very eager to participate and even relate real life situations..." (Thabang)
	Information Retention	"Learners attention is also improved as well as increased information retention" (Thabang)
Increased Interest	Autonomous Learning	"My learners...are able to engage in groups or each other" (Lerato)
	Anticipation for Lessons	"They are always interested to attend the next lesson" (Lerato)
	Interaction and Relatability	"My learners participate better and good interaction to each other and again most of the time they are able to relate the structures" (Karabo)
Positive Classroom Atmosphere	Enjoyment and Motivation	"Yes, my class this day is so jolly since I introduced the use of visual models..." (Jane)
	Competitive Engagement	"Learners even entered competitions (for life sciences) which they performed very well" (Jane)
Enhanced Learning Experience	Active Engagement	"yes there's difference, participation in class, formation of group discussion, learners interest to lesson" Phuti)

4.5.6 Can you give an example of how you have seen visual models positively impact learners' understanding of molecular biology topics?

The integration of visual models in teaching molecular biology has significantly enhanced learner engagement and comprehension. Participants report a marked improvement in academic performance and a heightened interest in the subject matter (Table 4.19). Visual models facilitate a deeper understanding of complex concepts, as evidenced by improved test results and class participation. The transition from traditional teaching methods to visual aids has bridged the gap in learners' grasp of intricate structures and processes. This pedagogical shift underscores the pivotal role of visual learning tools in fostering a conducive learning environment for complex scientific topics.

Table 4.15: Examples of how you have seen visual models positively impact learners understanding of molecular biology topics.

Themes	Categories	Evidence
Engagement	Class Participation	"Learners engaging in class" (Lindelani)
	Interest in Subject	"Learners are always interested to attend my class" (Lerato)
Comprehension	Understanding Complex Concepts	"Learners learn best when they see or hear. Especially with the topic filled with complex concepts" (Phuti)
	Interpretation of Structures	"My learners are now able to interpret difficult structures" (Karabo)
Academic Performance	Improvement in Test Scores	"During test my learners show good results" (Thabang)
	Improved Answering of Questions	"Performance has improved, good improvement to learners answering questions" (Jane)
Skill Development	Identification and Labelling	"Learners were able to identify various structures, draw graphs, label structures and give functions" (Sello)
	Drawing and Diagramming Skills	"Even being able to label and drawing diagrams" (Lindelani)

	Describing Processes	"Learners were also able to explain and describe processes" (Sello)

4.5.7 Advice for novice teachers on the use of visual models to teach molecular biology topics in Grade 10

The data also provided insightful perspectives from the participants regarding the use of visual models for teaching molecular biology topics in Grade 10. Four main themes were identified, namely, Engaging Learners, Educational Outcomes, Teaching Strategies, and Resourcefulness.

Under Engaging Learners, teachers recognise the power of visual models to motivate and cater to diverse learning styles. Motivation is identified as a pivotal factor, and visual models are seen as instrumental in sustaining learner interest (Lindelani). Notably, Thabang emphasises the relevance of visual models in the context of the fourth industrial revolution, linking pedagogical tools to contemporary societal transformations. In terms of Educational Outcomes, improved learning and exam success are underscored as tangible benefits. Sello advocates for the use of visual models as they have a positive impact on learning and academic performance. Thabang elaborates that these models help in "unpacking" complex processes in DNA, thereby aiding in exam performance. The Teaching Strategies theme offers a fresh perspective against traditional methods. Lerato advises educators to steer away from conventional teaching styles and encourages hands-on learning. Jane's narrative echoes this, asserting that modern methods fend off learner disinterest more effectively than traditional means. Lastly, Resourcefulness is highlighted as an essential trait for teachers. Phuti suggests that a lack of resources should not deter educational quality; rather, educators should be innovative in creating their own teaching materials. Karabo adds that institutional support has been beneficial for creating models.

Table 4.16: Advice for novice teachers on the use of visual models to teach molecular biology topics in Grade 10

Themes	**Sub-themes**	**Evidence from the interviews**
Engaging Learners	Motivation	"So using the visuals really will help learners to get motivated and to make them get interested to the subject." (Lindelani) "Learners are not motivated, learners are not engaged..." (Thabang)
	Diverse Learning Styles	"Accommodate different learners in the class..." (Lerato) "Since some of the learners since our learners learn differently..." (Lindelani)
	Fourth Industrial Revolution Relevance	"First and foremost, we are in the fourth industrial revolution and visual model is one of the equipment in the fourth industrial revolution." (Thabang)
Educational Outcomes	Improved Learning	"It's what I'm advising them to stick to these visual models when teaching molecular biology because it improves the learning for learners and it also improves our results..." (Sello)
	Exam Success	"...Ours. It is to unpack the processes in the DNA for them to understand and implement them in the exam. At the end of the day so that they could pass..." (Thabang)
Teaching Strategies	Innovative Approaches	"I will advise them not to use traditional methods of teaching..." (Lerato) "I have seen with myself when I started teaching I was so afraid to use any slide, hence I saw my learners that sometimes they get bored of the old fashion in teaching molecular biology." (Jane)
	Hands-On Learning	"In most of the cases when they use the model they should also allow the learners to take part." (Lerato)
Resourcefulness	Self-made Materials	"I will tell them that as a teacher they shouldn't be stopped by lack of resources at school rather they become clever and create their own resources." (Phuti)

	Institutional Support	"So I think that the institution has played a part of which was a good one, but they have played a part in helping us to be able to create models and in science." (Karabo)

4.6 CHAPTER CONCLUSION

This chapter presented, examined and discussed the study findings. Questionnaires were analysed, interpreted and reported. Findings from the interviews that were conducted with teachers were discussed and emerging themes were also highlighted. In addition, the document was reviewed and the open-ended questionnaires were discussed. The next chapter will summarise the research findings, draw conclusions pertaining to the research questions, limitations and make recommendations for future research based on the data collected.

CHAPTER 5: SUMMARY OF FINDINGS, RECOMMENDATIONS AND CONCLUSIONS

5.1 INTRODUCTION

In this study, the researcher intended to determine the extent to which teachers utilise visual models when teaching molecular biology topics in Grade 10 Life Sciences, as well as the impact of using such visual models. In the previous chapter, the results of the study were presented and the findings of the research study were discussed in detail. This chapter serves as a summary of the findings, highlights some limitations, and presents the main findings of the study. The findings in this chapter will be correlated with the problem statement from Chapter 1, and the recommendations from the findings will show that the research questions have been effectively addressed. Finally, the chapter concludes with suggestions for future research.

5.2 SUMMARY OF THE STUDY

This study considered the literature from other researchers, guided by different methodologies and theoretical frameworks as presented in Chapters 1 and 2. Based on these, the findings of the current research are discussed with the view of responding to the following research questions:

- What pedagogical principles inform teachers' use of visual models when teaching molecular biology topics in Grade 10 Life Sciences?
- How do teachers incorporate visual models when teaching molecular biology topics in Grade 10 Life Sciences?
- What is the perceived impact of using visual models on learners' content understanding of molecular biology topics in Grade 10 Life Sciences?

5.3 DISCUSSION OF THE FINDINGS

5.3.1 Pedagogical principles that inform teachers' use of visual models when teaching molecular biology topics in Grade 10 Life Sciences

In Chapter 2, a comprehensive discussion was held on the significance of visual models in molecular biology topics. Visual models in molecular biology often incorporate various components "including diagrammatic features, discipline specific graphical, spatial arrangements of visual elements to convey information, and varied levels of abstraction" (Offerdahl *et al*., 2017). The results present a multifaceted appreciation for the utilisation of visual models, signifying their importance in teaching molecular biology using visual models. The findings of the study further indicate those visual models, Enhance Learners' Understanding, Increase Learners' Engagement, the Importance of Representation, and the Facilitation of Memory. Parthasarathy and Premalatha (2022) add that visual models in biology serve as a tool for conceptual change for learners. Further study indicates that visual models are vital in teaching molecular biology as they facilitate complex concepts in molecular biology topics and aids learners in recalling the concepts taught. Jenkison (2018) emphasises the importance of visual models in biology education, especially when it comes to conveying difficult concepts. In addition, it has a significant impact on the way they perceive molecular biology. In this regard, Ealy (2018) stresses that molecular biology processes are not easily observed, and teachers depend on visual models to convey concepts in biology. Teachers' views reported in this study suggest that visual aids simplify the teaching of complex concepts, facilitating better comprehension for both teachers and students.

The study findings show that a teacher's time in teaching visual models frequently ranged from "often" to "always", emphasising the reliance on visual aids for teaching complex concepts. Furthermore, the study found that teachers timing of implementation varied, with some teachers preferring to use visuals after the lesson to consolidate understanding and others integrating them into the lesson to maintain engagement and clarity. According to Bodsworth & Goodyear (2017) teachers should see themselves as facilitators in learners' learning and identify learning and experiences with learners when using visual models. Teachers agreed that their learners are providing visual solutions whenever they are given assessments. Thus, Musakhonovna (2022) stresses that there are scientific foundations for good pedagogical practices when using visual models in teaching molecular biology topics. It was shown in the study that teachers should be familiar with how to evaluate learners understanding of targeted concepts, and understands what prior knowledge is absent and what knowledge can be acquired in molecular biology. Tasker and Dalton (2008), argue that from the design perspective, the effective design of visual models needs to focus on how to facilitate a deep understanding of science concepts for learners.

Teachers' views reported in this study suggest that a comprehensive overview of multiple factors influences teachers' choices of visual models, and each contributed to a richer, more contextual understanding of the pedagogical decisions involved in teaching molecular biology. Hence, the findings from the study indicate that teachers used a topic-centric approach, pedagogy, and resource availability to choose the best visual models to teach molecular biology. According to Lee and Gail (2018), teachers tend to select visual models based on the availability and rationale for images to be used in the lesson. In this regard the selection is also based on models that are aesthetically pleasing, simply designed and illustrate specific concepts in molecular biology (Lee & Gail, 2018). Hence, the findings show that teachers prefer to utilise multiple visual models like videos, slides, overhead projector, models and charts to teach molecular biology topics. When information is delivered through images, graphics, or illustrations, as well as verbal presentations, learners tend to process it more effectively and respond better to words (Mahmoudi *et al*., 2015). The findings suggest that multiple visual models are useful in clarifying molecular biology topics. Data proved that the use of visuals assists learners to recall and answer questions, also various voices from the videos help learners to understand better and these assist learners in retaining memory or remembering lessons very well. The use of diagrams, charts, graphs and videos in molecular biology helps learners to understand and interpret concepts related to the content; this is confirmed by the findings of Parthasarathy and Premalatha (2022).

In addition to the above results, Offerdahl and Arneson (2017) indicate that the use of videos enhances learner's interactions with teachers and improves their understanding of the molecular images. The study indicates that the use of videos, slides, pictures and models further assists in assessing learners' knowledge during lessons. In certain conditions, learning with multiple visual models involving visual representations can help learners construct knowledge, understand, and transfer represented information, as empirically proven (Mayer, 2005). The data shows that teachers used constructivism and inquiry-based learning when teaching molecular biology using visual models. Meaning teachers observed that learners are able to understand, comprehend and create connections between ideas and concepts to make meaning in molecular biology when they are assessed and taught.

These findings present an intricate landscape that speaks to the nuanced strategies teachers employ, along with the challenges they face, in visual model-based assessments in molecular biology. The findings show that teachers use formal/informal assessment like tests/classwork/class activities to assess their learners' understanding of molecular biology. According to Neumann *et al*., (2023), assessing learners using visual models improves learners' visual literacy, which effectively helps learners to identify, interpret, and create images in science. Hence, results show that teachers mostly use pedagogical strategies asking learners to label, draw, identify and interpret, as well as answer questions to assess learners understanding when they are taught biology through visuals. The predominant data centres on the use of diagrams and visual representations, which are integral in both formative and summative assessments. According to Neumann (2023), the ability of learners to interpret and organise these diagrams in assessment is linked to the fundamental understanding of molecular biology and their skills in visual literacy. The data indicates that visual solutions are not only prevalent but also diverse across different scientific concepts. Teachers' views reported in this study are that learners are capable of drawing detailed scientific structures, graphs, and carrying out experiments with visual aids.

5.3.2 Teachers' incorporation of visual models when teaching molecular biology topics in Grade 10 Life Sciences

The study shows that teachers are able to choose the correct type of visual models which assists them in integrating and modifying visual models effectively when they are teaching molecular biology topics. Kenyon (2011) support that when choosing the visuals in teaching biology, it is important to take into account the nature and direction of the educational and cognitive activity of learners. The findings show that teachers' influence on choosing is influenced by Accessibility, Instructional Preparation, Real-world Connection, Time Efficiency, and Resource Utilisation. Thus, the study's findings emphasise the best strategies teachers use to integrate visual models enhancing student understanding, tailoring to cognitive levels, associating with effective teaching methods, the use of multimedia, challenges with integration, and the importance of alignment with topics. Hence, the use of various resources suggests an adaptive teaching style responsive to resource availability and curriculum demands. Although visual models have been used extensively in specialised lessons, only recently did they become affordable, reaching more teachers. With increased availability, their use has become vital and can improve most learners' understanding of biology (Garcia-Bonete *et al.*, 2019).

The findings from the study corroborate the manifold advantages of incorporating visual models in pedagogical practice, more especially in the context of enhancing learners' critical thinking skills. Thus, the results show that integration of visual models into molecular biology contribute to learners developing skills for self-acquisition of knowledge. Hence, the level of knowledge and skills of learners within the framework of the topic prove that it depends on teachers using quality visual models when teaching molecular biology (Schönborn & Anderson, 2006). According to Nitz *et al*. (2014), keeping the attention of learners involves reasonable visuals to help maintain the attention and cognitive activity of learners at the level necessary for effective incorporation. It is important for teachers to structure the presentations of material in a way that activates learners thinking skills in science (Fan & Zhong, 2022). The study reveals that proper planning of lessons is beneficial to teachers in terms of time to select the necessary visuals which assist in accomplishing their objectives and developing effective lesson presentation. Taukobong (2017) cites that visualisation of learning concepts along with the motivation to learn, have been found to help learners learn concepts more efficiently and foster critical and creative thinking skills, in order to create visualisation skills. The study presents the evidence on the effectiveness of using visual models in promoting learners' understanding, critical thinking skills, engagement, motivation and memory retention in molecular biology topics. According to Rini *et al*., (2020) there is a significant effect of visual models on learner's critical thinking skills, motivation and improvement of learners' thinking skills.

According to Lantolf & Pavienko (2014) using various visual models in the classroom contributes, not only to the success of normal learners, but also to the learners with special needs, which further assists those learners to comprehend molecular biology concepts. The findings of the study reveal that visual models offer valuable insights into the diversity of methods and philosophies in play which highlight the best approach to cater to a broad spectrum of learning needs and styles in Life Sciences education. Taukobong (2017) and Schönborn and Anderson (2009) support the findings of this study by stating that visual models can accommodate different learning styles, resulting in an increase in learners' understanding of the molecular biology concepts. The study further shows that teachers use multi-modality and tailor their teaching styles to accommodate learners' needs. The use of visual models in teaching molecular biology concepts results in learners performing better on the task, as found by Neumann *et al*., (2023). Therefore, the mediation entails using visual models and demonstrations to support teaching of complex concepts in molecular biology topics and facilitate learners understanding of the content. In addition, complex scientific and biological phenomena can be presented to learners through well-illustrated diagrams (Musakhononva, 2022). The study found that there is a notable increase in learner interactivity in class, with learners asking pertinent questions and demonstrating creativity in model development. Furthermore, data indicates improvement of learner's performance and retention of information, highlighting the importance of visual aids in supporting diverse learning needs and fostering a deeper grasp of scientific concepts.

5.3.3 Perceived impact of using visual models on learners' content understanding of molecular biology topics in Grade 10 Life Sciences

The study shows that visual models enhance remote learning capabilities, making them a versatile tool in the contemporary educational landscape. Overall, the data advocates for the multifaceted utility of visual models, extending from pedagogical effectiveness to logistical efficiency and modern-day relevance. With regards to the benefits of using visual models in teaching molecular biology topics, study findings show that visual models are beneficial by Enhancing Learning Experience, Efficiency in Teaching, and Modernisation and Professionalism. The data highlights that visual models facilitate not just surface-level comprehension but also deepened understanding of intricate molecular structures and the duality supports engagement and aids in information retention. Therefore, the study clearly suggests that using visual models enhances learners' understanding and increases learners' engagement in class. Literature revealed that visual models arouses the interest and engagement of learners and also assists teachers to explain the concepts easily, thus visuals are vital in molecular biology (Ahmed & Odewumi, 2020). In addition, Burgin *et al.,* (2019) cite that visuals provide an avenue for learners in classroom engagement and build great knowledge about biological processes and structures.

The results provide a comprehensive view of the impact of utilising visual models in teaching molecular biology topics. In this instance the data shows that visual models have a positive impact on academic performance, indicate a marked improvement in assessment scores and enhance understanding of the subject matter. This was in agreement with Moursi's (2013) study, which demonstrates the effectiveness of various visual models in learners' achievement. Thus, the data shows that there is a drastic improvement in learner performance, suggesting the efficacy of visual models in facilitating academic achievement. Eilam & Gilbert, (2014) conducted a study on the effect of visual teaching on the performance of science students, and their findings revealed that visuals had a positive effect on their performance. These findings are consistent with existing research. Odewumi *et al.,* (2019) reveal that there is a significant difference between the performance of learners in their classes taught with graphics and without graphics. The current study agrees with Clark's (2007) study, which shows that visual learning with diagrams and videos assists learners to understand complex concepts in biology.

The study emphasises the significance of visual models in academic success of learners who are taught molecular biology topics with visual models, but teachers encounter barriers when utilising visual models to explain molecular biology topics. The results show that teachers observe some challenges in teaching and learning molecular biology using visual models, namely, resource limitations, learner engagement, language barriers, and remote learning. Data shows that acquiring suitable visual models is a primary hurdle for teachers, and the time-intensive nature of downloading videos explicitly affects their teaching time. Moreover, data emphasises that effective utilisation of visual models requires substantial preparation time. Results show that learner engagement intentionally lapses and learners' misuse of gadgets affects teaching and learning. More critically, data indicates that learners sometimes struggle to connect the visual models to the underlying molecular concepts.

The study found that a language barrier, specifically English proficiency, is another significant challenge learners are facing when they are taught molecular biology topics. Moreover, the study's findings reveal that learners often fail to comprehend the English language used in videos or slides, leading to instructional inefficacy. According to Omar *et al*. (2015), learners from various linguistic cultures are not familiar with diverse connotative meanings of the words used to construct biological concepts. The data supports the researcher's notion that learners who were not native speakers of a language struggle with molecular biology concepts when videos are used as visual aids. Behrmann *et al*., (2018) support the researcher's position, stating that if learners do not comprehend concepts, they cannot create precise cognitive structures, which has a negative impact on learning. Cimer (2012) suggests several reasons why learners struggle with learning molecular biology in the following statement: how teachers teach biology, learners learning styles, and teachers' choice of visual aids. To ensure effective learning of molecular biology topics, teachers recommend,closely monitoring the selection of appropriate visual models for teaching to ensure successful lessons. Some concepts may be understood easily while others with symbolism and visual language tend to pose greater difficulties (Noble, 2021).

5.4 RECOMMENDATIONS

The study recommends the following aspects based on the study findings. These recommendations are based on molecular biology, Life Sciences curricula, and use of visual models.

- Teachers should ensure that diagrams, models and videos are used effectively to create complex and complicated mental models of knowledge about molecular biology.
- To tackle these issues, it is necessary to enhance teaching methods and models, and have effective teaching strategies that are well developed and technologically advanced.
- The views expressed by teachers in this study are significant for other teachers, policy makers, and schools to take into account when designing curricula and other educational processes.
- As molecular biology is an innovative field, its teaching would be best served by novel pedagogy accustomed to its unique features when teachers use visual models.
- Workshops are needed to improve teachers' knowledge on the use of visual models.

5.4.1 Recommendation for further research

This study recommends the following for further research:

- Other provinces need to conduct similar research to determine the effects of visual models on teaching molecular biology topics.
- Further study might include exploration of how learners interpret the visuals and how their background experience shapes their learning.
- Further studies should examine the utilisation of videos as a teaching tool for molecular biology in Life Sciences.
- Further research is necessary to examine learners performance through tests and lesson observation when teaching molecular biology using visual models.
- Explore the use of videos to teach molecular biology in Life Sciences.

5.5 LIMITATIONS

There were issues that emerged from the data collection process, namely, some questions from the interviews were not answered, and some participants were reluctant to participate. This may be due to participants being scared to answer questions incorrectly. However, the researcher explained to participants that there was no wrong answer. In addition methods of data collection employed to answer the second research question and the third research question which was twofold was limiting. A mixed-methods approach to the research could have addressed this limitation, including classroom observations and document analysis. The study was limited to seven participants since there were only seven schools in the Malegale circuit and each had only one Grade 10 Life Sciences teacher. In addition, the study offers insight into the use of visual models from teachers. However, it did not seek learners' views and perceptions directly. Besides the challenges and limitations faced, and the constraints of the generalisation of the results in particular, the researcher thinks that it is feasible to draw conclusions that make an important impact on the growing body of scientific knowledge of teachers who are using visual models in molecular biology topics.

5.6 CONCLUSION

This study intended to determine the extent to which teachers utilise visual models when teaching molecular biology topics in Grade 10 Life Sciences, as well as the impact of using such visual models. In accordance with the purpose of the present research; the study findings show that using visual models does improve learners' visualisation skills and performance related to molecular biology topics. The general assumptions were confirmed by the study findings that the experience of the teachers in response to the study emphasised the importance of visual strategies in learners' comprehension in molecular biology topics. Teachers can use visual models as a tool to assist learners with diverse learning needs. Molecular biology topics contain many difficult concepts that learners struggle to understand when they are taught by visual models because of language barriers. The results of this study demonstrate that teachers who always use visuals to teach molecular biology stimulate the improvement of visual literacy abilities among learners. The researcher hopes that the study will expand the views of teachers on the use of visual models when teaching molecular biology and also inspire them.

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APPENDIX A: LIMPOPO PROVINCIAL DEPARTMENT OF EDUCATION APPROVAL

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

Makhura SI
P.O.BOX 2712
RADITSHABA
0718

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: **"THE EFFECT OF USING VISUAL MODELS IN TEACHING AND LEARNING MOLECULAR BIOLOGY ON LEARNER PERFORMANCE IN GRADE 10 AT SELECTED SECONDARY SCHOOLS IN MALEGALE CIRCUIT, LIMPOPO.."**

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 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 : MAKHURA SI 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.

Mashaba KM
DDG: CORPORATE SERVICES

14/06/2023
Date

APPENDIX B: REQUEST PERMISSION LETTER TO LIMPOPO DEPARTMENT OF EDUCATION.

Enquiries : Prof. Mnguni L.E

Tell : 0117172764

Email : lindelani.mnguni@wits.ac.za

Ref: 2023/04/12/59859806/29/AM

Department of Education

Sekhukhune East

Private Bag X9041

Burgersfort

1150

Request to conduct research

Dear Sir/Madam

I am MAKHURA S.I (59859806) currently enrolled for a master's degree in Education at the University of South Africa, supervised by Prof. L.E MNGUNI of the Department of Science and Technology. I am engaged in a research study entitled: The effect of using visual models in teaching and learning Molecular Biology on learner performance in Grade 10 at selected secondary schools in Malegale circuit, Limpopo. This study intends to determine the extent to which teachers utilise visual models when teaching molecular biology topics in Grade 10 Life Sciences, as well as the impact of using such visual models. Senior secondary school teachers will form part of the study and their participation is highly important, I therefore ask permission to approach several schools in the Malegale circuit, Sekhukhune East district to conduct this research.

Attached herewith is a copy of the University of South Africa's ethical clearance certificate. For any further information, please feel free to contact me on 0712124438 or email at 59859806@mylife.unisa.ac.za or my supervisor on Tel: 0117172764 or email: lindelani.mnguni@wits.ac.za. Your permission to collect data for this study will be deeply appreciated.

Yours faithful: Makhura S.I UNISA Student

APPENDIX C: REQUEST PERMISSION LETTER TO THE PRINCIPAL

Enquiries : Prof. Mnguni L.E

Tell : 0117172764

Email : lindelani.mnguni@wits.ac.za

Ref: 2023/04/12/59859806/29/AM

Attention: To School Principal

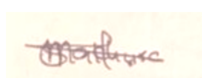
Permission to conduct a research in your school

Dear Principal

I am master's student at the University of South Africa (59859806). The title of the study is: The effect of using visual models in teaching and learning Molecular Biology on learner performance in Grade 10 at selected secondary schools in Malegale circuit, Limpopo. Senior secondary school teachers will form part of the study and their participation is highly important, I therefore ask for permission to approach several teachers in your school in the Malegale circuit, Sekhukhune east district to conduct this research.

I will at all times make sure that teaching programmes are not disturbed, therefore interviews will be conducted out of lesson contact. My supervisor for this study is Prof. L.E MNGUNI in the Department of Science and Technology, he can be contacted on Tel: 0117172764 or email: lindelani.mnguni@wits.ac.za In the event of any enquiries contact myself on 0712124438 or email:59859806@mylife.unisa.ac.za. Thank you for your time and consideration in this matter, hoping to hear from you.

Yours faithful

Makhura S.I.  UNISA Student

APPENDIX D: CONSENT LETTER TO TEACHER

Consent Form and Confidentiality Agreement

The following are the conditions that will be followed throughout the research

- No real names will be used in any report instead pseudonyms and codes will be used in all verbal and written reports.
- The report will be treated in a confidential way and will only be accessed by the participant, the researcher and supervisors
- Participation in this research is voluntary, participants have the right to withdraw at any point of the study, for any reason and without any prejudice, the data collected,records, andreports written will be discussed.
- Findings of the research will be used to improve teaching of Molecular Biology.

I, ___________________ (participant name), confirm that the person asking my consent to take part in this research has told me about the nature, procedure, potential benefits and anticipated inconvenience of participation.

I have read (or had explained to me) and understood the study as explained in the information sheet.

I have had sufficient opportunity to ask questions and am prepared to participate in the study.

I understand that my participation is voluntary and that I am free to withdraw at any time without penalty (if applicable).

I am aware that the findings of this study will be processed into a research report, journal publications and/or conference proceedings, but that my participation will be kept confidential unless otherwise specified.

I agree to the recording of the interviews________________

I have received a signed copy of the informed consent agreement.

Participant Name & Surname (please print)

____

Participant Signature Date

Researcher's Name & Surname (please print)

Researcher's signature Date

APPENDIX E: TEACHERS INTERVIEW GUIDE

Opening Section

(a) Engagement: Ask a general question to make participants feel comfortable, and to build rapport.

- When you think about visual models, what comes to your mind? Please take your time to think about it. You have five minutes to do this.
- Ok, five minutes has elapsed. I would love to hear your views. You can tell us your response (Give the participant a chance to speak and remember to say 'thank you' when they are done.)

Thank you very much for your contribution. It was quite interesting to hear your views. Now, let us proceed to our next set of questions.

(b) **Exploration**: Ask specific questions focusing on the topic of discussion

- **In your opinion, how important are visual models in teaching molecular biology topics in Grade 10 Life Sciences?**
- **What types of visual models do you prefer to use when teaching molecular biology topics and why?**
- **How do you decide which visual models to use when teaching molecular biology topics to your learners?**
- **How do you integrate visual models into your teaching approach for molecular biology topics?**
- **What do you think are the benefits of using visual models in teaching molecular biology topics?**
- **What are some challenges you face when using visual models to teach molecular biology topics?**

- **How do you incorporate the use of visual models into assessments of learners learning in molecular biology topics?**
- **Do you think the use of visual models in teaching molecular biology topics can help learners develop critical thinking skills? If so, how?**
- **How do you adapt your use of visual models to meet the needs of different learners in your classroom?**
- **Do you think that the use of visual models in teaching molecular biology topics has an impact on learner's engagement and motivation? If so, how?**

(c) **Exit:** Ask a follow-up question to determine if there is anything else related to the topic that needs to be discussed.

Before we end the discussion, is there anything you wanted to add that you did not get a chance to bring up earlier? (Give participants time to speak)

Closure

Thank you so much for your time and sharing your opinions and emotions with us. Your feedback is valuable to our research and this has been a very successful discussion. We hope you found this discussion interesting. If there is anything you are unhappy with or wish to complain about, please feel free to talk to me at the following number: 0712124438. I see our time is up and we have to come to the end of our discussion. Once again, thank you very much for your participation.

Good bye!

APPENDIX F: OPEN-ENDED QUESTIONNAIRES

Instructions

- Please answer the following questions, include relevant answers and examples whenever possible.
- Remember there is no 'right' or 'wrong' answer to the questions. Remember the researcher is interested in your views on the questions asked.
- Where options are given **TICK (√) ONE ONLY**

Q1: Do you use visual models when teaching molecular biology topics in Grade 10 Life Sciences?

YES	NO

If yes, how regularly or if NO, specify why?

Q2: Can you share an example of a successful lesson where you used visual models to teach molecular biology topics to your learners?

Q3: Have you noticed any difference in learners' engagement and motivation when using visual models to teach molecular biology topics compared to other teaching methods?

YES	NO

Give examples.

Q4: Do you think learners understand better when they are taught using visual models in molecular biology topics?

YES	NO

If YES/NO provide explanation.

Q5: Do your learners provide visual solutions in their classwork books?

YES	NO

If yes, provide examples.

Q6: How do you assess whether learners have understood the molecular biology topics presented through visual models?

Q7: How do you ensure that visual models are integrated effectively with other teaching materials and approaches when teaching molecular biology topics?

Q8: Have you ever encountered a situation where visual models were not effective in helping learners understand molecular biology topics?

YES	NO

If so, how did you address this?

Q9: In your experience have ever seen a positive correlation between use of visual models and learners performance?

YES	NO

Q10: Can you give an example of how you have seen visual models positively impact learners' understanding of molecular biology topics?

Q11: How would you rate your teaching performance using visual models in molecular biology topics?

POOR	GOOD	VERY GOOD	NO CHANGE

Q12: How would you rate your learner's performance using visual models in molecular biology topics?

POOR	GOOD	VERY GOOD	NO CHANGE