The effectiveness of an animation on Grade 10 learners' understanding of Mitosis in Tembisa, South Africa.

by

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ABSTRACT

Science education has seen an increase in the use of computer-based models for improving learners' conceptual understanding. However, the effectiveness of these models remains a subject for much debate, particularly given the multiple factors that affect learning. There is also a dearth of research regarding the effectiveness of these in previously-disadvantaged school contexts where access to computer-based infrastructure is minimal. Countries such as South Africa are currently adopting teaching methods that integrate information technology. This includes the distribution of smart boards, mobile computers, and tablets in school to support teaching and learning. The extent to which these resources have a positive impact on learning is a subject of ongoing research. In addition, researchers are still exploring the role that computer-based teaching could have on learners in light of a relatively poor socio-economic context.

In light of the increasing use of computer-based teaching in South African schools, the primary purpose of the current research was to investigate the effectiveness of virtual realities such as computer-based animations on students' content understanding in Life Sciences. This research, conducted as a mixed-method approach in a High school in Tembisa, outside of Johannesburg in South Africa, involved Grade 10 Life Science learners (n = 67). These learners were selected using non-random purposive sampling. A quasi experimental design was adopted in which traditional textbook-based teaching was used to teach mitosis, while the experimental group was taught using an animation. Pre- and post-test learner performances were then compared within and between groups. Interviews were also conducted to determine potential learning difficulties associated with the use of the animation.

Results indicated that learners' performance improved when being taught through an animation. Results also reflected that some learners experienced learning difficulties when using the animation. The integration of sounds and pictures on the animation was shown to assist learners create visual mental models. Learners were able to build their own mental model based on the observations and accompanying sound. Results also demonstrated that visual information presented through the animation is retained in the memory structure for a longer period and learners were encouraged to develop an understanding of learnt concepts and support their memory retention which improved their achievement in the post-intervention test.

KEY WORDS

Virtual Reality, Animation, Conceptualization, Visualization, Life Sciences, Mitosis, Learning Difficulties, Teaching Strategy, Cognitive Theory of Multimedia Learning.

DECLARATION

Title: The effectiveness of an animation on Grade 10 learners' understanding of Mitosis in Tembisa, South Africa.

I Dudrah Martha Nokuthula Moyo, declare that this dissertation mentioned above my own work except as indicated in the references and acknowledgements. It is submitted in the fulfillment of the requirements for the degree of ***MAGISTER EDUCATIONIS*** in the University of South Africa, Pretoria. It has not been submitted before for any degree or examination in this or any other university.

Dudrah .M N. Moyo :

Signed at Pretoria, South Africa on the 29th July 2019.

DEDICATION

This dissertation is dedicated to Atlas Combined School for always keeping the researcher grounded in achieving this milestone, through the school's unwavering support from staff members and learners.

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CHAPTER 1: INTRODUCTION AND BACKGROUND OF CURRENT RESEARCH

1.1 Introduction

The performance of South African learners in the National Senior Certificate (NCS) examinations in science subjects including Life Sciences has been a cause for concern for several decades. In biology-related subjects such as Life Sciences, learning challenges are often associated with the microscopic nature of various processes and phenomena such as cell structure and cell division (Anderson, Schönborn, du Plessis, Gupthar & Hull, 2013). They further assert that most of Life Sciences concepts are abstract and complex in nature. The complexity and abstractness of most of Life Sciences concepts demand teachers to be innovative in their teaching approaches and use of teaching and learning media. These innovations are part of what Lederman (2013) refers to as reforms in science education.

Science education reforms and related research advocate for the use of practical investigations in the science classroom in order to improve learners' concept understanding (Lederman, Lederman & Antik, 2013). As observed by Vhurumuku (2015), practical investigations expose science learners to the processes that scientists employ in scientific research and could improve content understanding among learners. However, owing to lack of equitable distribution of educational resources in South African schools, some schools lack the basic equipment to facilitate hands-on practical investigations. It is on these bases that the present researcher explored the use of animations as alternative to practical investigations in under-resourced schools. For example, the learners could be taught mitosis practically through the use of microscopes in the laboratory but due to challenges in obtaining adequate resources animations could prove as a possible solution to this challenge. Mayer and Moreno (2002) define animations for educational purposes as ways of representing processes or concepts by using a series of computer-based drawings, graphics, or photographs of objects (such as puppets models). Similarly, Zahra (2016) defines animations as a technical process that produces motion illusions to the viewer by sequencing still images in analogue or digital environment. Buckley (2013) proclaims that modern technological advancements have enabled the use of animation packages as learning media and facilitate practical investigations virtually.

Flavo (2008) and Bryson (2013) assert that animations are a component of VRs that also include visual models and visual representations, all collectively known visio-semiotic modes (VSM). Bryson (2013) defines VR as the use of computer-based multimedia to create the effect of an interactive three-dimensional world in which the objects have a sense of spatial presence. He further asserts that VR comes along with custom designed, three-dimensional environments allowing intuitive transparent interfaces in the sense that the computer interface is not visible to the user. In the teaching and learning of science virtual, reality enables the use of a computer to create visual images that aid in the understanding of abstract and complex scientific concepts (Bryson, 2013). Advanced emerging computer hardware and software such as smart-boards, PowerPoint programs, E-learning, or animations are examples of visual reality programs for teaching and learning situations (Potkonjak, Gardner, Callaghan, et al., 2016).

Mnguni (2018) defines VSMs as visual models that use discipline specific semiotics to represent scientific phenomena for research, teaching and learning. These include written language, static multidimensional images, animations, and symbols. Kozma and Russell (2005) define visual modelling as the graphic representation of concepts or processes as learning media. In contrast, visual representation refers to the techniques used to represent processes or concepts by encoding it as visual graphics. The main aim of visual representations is communicate information or ideas clearly and effectively through graphical means (Evagorou, Erduran, & Mäntylä, 2015). They also assert that visual representations are essential for communicating ideas in the science classroom; however, the design of such representations is not always beneficial for learners. The uses of VRs of all forms are meant to enhance learning in the science classroom. Therefore, the current research investigated the effectiveness of an animation on learners' concept understanding on mitosis in a Life Sciences classroom.

Virtual reality enables the representation of complex scientific phenomenon in a fascinating manner to learners while promoting effective teaching and learning of science. The implementation of VR multimedia in the teaching and learning of science can improve learning and retention of material presented in a classroom situation as compared to traditional teaching (Kozma & Russell, 2005; Mayer, 2001). These authorities further assert that visual models accompanied by audio lead to increased comprehension of the material and improved retention of the material as demonstrated by results in assessments. In line with this observation therefore, the present research intended to explore the effectiveness of an animation in the Life Science classroom in the South African context. Cross and Adam (2007) declare that there is greater availability of computers, data projectors and smart-boards in schools as a result of the Department of Basic Education(DBE) in 2003 advocating for the integration of information and communication technologies (ICT) for learning and teaching. These technologies enable facilitation of the employment of animations in the Life Sciences classrooms.

According to Azer and Azer (2016), animations are computer programs that temporarily create a set of images or apparatus that represent real life situations to enable learners to bridge the gap between reality and abstract scientific knowledge. In addition, Azer and Azer (2016) maintain that animations present a number of benefits in the teaching and learning of science such as enhanced learning by active learner participation and the creation of a risk-free learning environment. The integration of animations in science has the potential to improve higher learning outcomes in ways not previously possible with traditional instructional strategies (Rutten, Joolingen, & Veen, 2014). For example, these entail learners being able to know, use, and interpret scientific explanations of the natural world; generate and evaluate scientific evidence and explanations; and enhanced skills in an array of multimedia, including computers, and have effective techniques for implementing them in the classroom. Furthermore, animations display the potential to reinforce other skills indirectly.

Educational animations are hence representations of real life experiences or natural phenomena. Dilshad et al.'s (2016) definition suggests that simulations are models of a theoretical physical system display on a digital computer. Howie and Blignaut (2009) assert that animations support learning and are useful in developing high-order skills of critical thinking, analysis and scientific inquiry. Besides representing real life situations, animations also expose learners to forms of Information and Communications Technologies (ICT), which are relevant skills that are required in the 21st century and 4th industrial revolution such as critical thinking, problem solving, ICT literacy as well as scientific reasoning and methods.

1.2 Virtual realities in science education

According to the South African DBE (2011) while there is a slight improvement in the performance in the overall NSC examinations, the majority of learners in Life Sciences have not managed to attain 60-70% in the 2018 examination (DBE , 2019). As observed earlier, the complexity and abstractness of concepts in cytology and molecular processes and structures are a challenge to learners. Çimer (2011) proclaims that the nature of science itself and its teaching methods are among the reasons for the difficulties in learning some scientific concepts. Designing learning environments while ignoring learners' interests and expectations causes several learning problems in science classrooms (Zeidan & Jayosi 2015). Pehlivan and Köseoğlu (2010) argue that computers, the Internet, online resources, and instantaneous access to information are part of learners' social world. Any learning environment that totally excludes these forms of technologies negates the contextual settings of this generation of learners. The present research considers non-employment of computers, online resources and VRs in the Life Sciences classrooms as compounding the challenges that learners meet.

DBE (2011) emphasises the need for the adoption of teaching strategies that promote inquiry-based learning through hands-on practical investigations. According to Ramnarain (2014) and (Mokiwa & Nkopodi, 2013), inquiry-based science learning is the idea that science learning should be authentic to science practice. They assert that inquiry-based learning comes from research in cognitive science that provides evidence that science effective inquiry occurs when learners imitate scientists in the process of inquiry. However, this recommendation might be considered improbable in schools that teach science in under-resourced classroom settings. According to the Department of Education White Paper (Department of Education, 2003) about 70% of South African schools have become better resourced with learning materials including advanced multimedia although some rural and township schools still lack conventional teaching apparatus that support the implementation of practical investigations.

The Life Science Curriculum and Assessment Policy Statement (CAPS) also advocates for inquiry-based science teaching and learning. CAPS advocates for the creation of classroom situations that allow learners to be active in the construction of scientific knowledge. In this regard, Ramnarain (2015) asserts that direct instruction alone cannot replace in-depth experience with science concepts that inquiry-based strategies provide. In the same vein, Donnelly, Linn and Ludvigsen (2014) argue that effective learning requires learners to create mental models that connect their learning experiences to the scientific concepts. Such assertions while seemingly feasible in the science classrooms that support hands-on practical activities, under-resourced rural and township schools might lack the capacity for the provision of hands-on practical activities (lack of experimental equipment and materials).

In some cases, schools possess equipment and materials for practical investigations. However, teachers might lack the skills and knowledge of using such equipment and materials in teaching (Englund, Olofsson & Price, 2017). Therefore, the current researcher investigated the effectiveness of VRs (animations) as alternatives to hands-on practical activities in the learning of the NOS in Life Sciences in under-resourced schools. This is because there is a dearth of knowledge regarding the use of animations as an alternative to hands-on practical activities, particularly in the under-resourced South African contexts. It is this gap therefore that the present study sought to address.

While VRs may prove effective in improving learners' content understanding, there is also a dearth of research regarding teachers' skills for the use of multimedia-based teaching approaches without compromising the authenticity of science. Literature speaks of VRs environments (Merchant, Goetz, Cifuentes, Keeney-Kennicutt, & Davis, 2014). However, there is little or no mention on how teachers create these VR environments for the affordances of application of VRs such as animations in sciences classrooms. For application of virtual realties to be a success in science classrooms, teachers' abilities to adapt to teaching strategies that will blend multimedia and content is essential and key to this study.

As part of the transformation in the South African education system, the DBE advocates for the introduction of 21st century technologies in schools. This has led to an increase in the availability of computers in schools. However, teachers now need to develop both understanding and competency in embedding ICT into teaching by developing their technological, pedagogical and content knowledge (DBE, 2011). The integration of VRs is associated with the integration of ICT in education. The adoption of animations requires specific pedagogical strategies for effective implementation. This study sought to investigate the effectiveness of VR as alternative to hands-on practical activities in under-resourced life sciences classroom. The emphasis placed on the use of VR in teaching and learning of science (Merchant, Goetz, Cifuentes, Keeney-Kennicutt, & Davis, 2014). The new paradigm that this study sought to establish was the issue of VR in enhancing learning through provision of virtual practical activities.

Curriculum reforms in science education as adopted by DBE (2011) realises the importance of learner-centred approaches to learning and teaching. According to Von Glasersfeld (2001), cognitive constructivism assumes that knowledge is personal and subjective; therefore, multiple interpretations of events are valued and acknowledged. In addition, Von Glasersfeld (2001) alludes that constructivism assumes that teachers serve as facilitators who provide learners with an authentic, learner-centred and problem-based learning environment. Driver, Asoko, Leach, Mortimer, and Scott (1994) underscore that social constructivism assumes that individual learners construct knowledge by looking for shared meanings within a particular social context. They stress the importance of looking at each child as an individual who learns distinctively. Driver et al., (2001) further posits that social constructivism describes through zone of proximal development, which posits that human potential is theoretically limitless; but the practical limits of human potential depend upon quality social interactions and residential environment. According to Vygotsky (1978), this zone of proximal development is the distance between the actual developmental level and potential development level. The actual development level is determined by independent problem solving and the potential development level is determined through problem solving under adult guidance or in collaboration with more capable peers. The use of virtual animations in science classroom could promote learner-centeredness and construction of knowledge in the classroom.

The idea of bringing VRs in the science classroom influences the learning environment and learning styles. Virtual realities fall part of visual aids. Visual aids are suitable tools that encourage effective learning and making learning meaningful. While this might be true, learners need to be socialised into a different type of learning style. The use of VRs might shift learners from kinaesthetic-tactile to visual learning (Shabiralyani, Hasan, Hamad & Iqbal, 2015). Kinaesthetic-tactile is where learners tend to learn best through movement and touch (hands-on). Dunn and Dunn (2014) assert that in aesthetic tactile, learners like to engage in practical activities, they may take many notes and learn best when they are allowed to explore and experience their environment. Visual learners prefer to receive information by seeing it. Typically, visual learners pay much attention to detail. Visual learners are less likely to speak in class than their hands-on peers, and generally use few words when they do. Visual learning materials such as pictures and simulations are useful in the learning process (Dunn, 1984). Shifting from one learning style to the other needs special pedagogical strategies, which will create a smooth transition. In-service teachers might not be in possession of such pedagogical strategies. Lack of such pedagogical strategies might impair the efforts of usage of VRs in the science classroom in consequence hinder conceptual understanding (Dunn, 1984).

1.3 Problem Statement

Burns (2013) identifies such skills as blending pedagogy, multimedia and content as critical for teachers to possess for VR application to be a success. While there is a drive to introduce VR in South African schools, in this study it is noted with concern that teachers are not formally equipped with instructional practices and pedagogical techniques for use of VR in the science classrooms. The problems that relate to teachers' readiness for VR application in science classrooms arise from two sources: The first is that teachers might not be familiar with modern technologies for use in the science classrooms. The second is that change from their traditional methods of teaching to one where they have to incorporate multimedia might be cumbersome. Burns (2013) asserts that teachers' under-readiness to use VR in learning situations might owe to lack of on-going professional development.

One other notable problem is teachers' lack of virtual literacy (VL) – a collection of abilities that enable one to select, interpret, analyse, present pictorial or graphic information (Lundy & Stephens, 2015). Teachers struggle to select appropriate VRs (animations) that are adaptable to the specific contexts of their learning environments, while learners lack visualisation skills (VS).

Mnguni (2014) defines visualisation skills as an individual's ability to encode and decode information presented by external representations. In designing online VRs, a "one size fit all" concept is adopted which neglects the diverse contextual factors of its users (Legault, Zhao, Chi, Chen, Klippel, & Li, 2019).). With teachers' notable lack of technological skills, adapting an existing VR might be dreadful (Akçayır & Akçayır, 2017). Lack of adaptation skills of an existing VR might lead to the VR used in the classroom being not compatible to the learning processes. In this study, it is realised that while there is an advocacy for use of VRs in schools to meet the demands of the 4^{th} industrial revolution, there is little attention given on teacher development to equip them with the necessary skills and knowledge (Englund, Olofsson & Price, 2017). It is noted in this study that the slow pace at which the technologisation of the education system is being implemented might owe to lack of appropriate teaching strategies that consequently lead to learners attaining poor results in science.

Gaigher and Lederman (2014) emphasise that engaging learners in practical investigations contributes to improved performance in science. The authors reiterate that practical investigations improve learner performance through elaborate comprehension of scientific concepts and acquisition of scientific skills. As such subjecting science learners to classrooms that lack facilities could compromise their achievement in science. There is limited research conducted on the effectiveness of alternatives to practical investigations in developing countries in the literature. For instance, South Africa was ranked as one of the poorly performing countries in Science, as ranked by the Trends in International Mathematics and Science Study (TIMSS) and high failure rate continues to recur in the science domain (Reddy & Dempster, 2015), perhaps because of a shortage of conventional resources. Given the above discourse, the researcher through this study sought to investigate the effectiveness of VR as being alternatives to practical investigations in the science classroom. Virtual realities (PhET simulations) engage learners in activities that can enhance their scientific knowledge (Shen, Lei, Chang, & Namdar, 2014).

1.4 Research Aim and objectives:

This present research aimed to investigate the extent to which the use of an animation in teaching could improve Grade 10 learners' understanding of mitosis.

The objectives of the present research are:

- To determine the impact of the use of animations in the learning on Grade 10 learners' understanding of mitosis.

- To determine the learning difficulties associated with the use of animations in learning Grade10 mitosis in Life Sciences.

1.5 Main research questions:

The research question being investigated in this study asks:

To what extent could the use of animations in teaching improve Grade 10 learners' understanding of mitosis?

As a result the sub-questions that guide the present research are as follows:

a) What is the impact of the use of animations in learning on Grade 10 learners' understanding of mitosis?
b) What are the learning difficulties associated with the use of animations in learning Life Sciences Grade 10 Mitosis?

1.6 Rationale of the study

The present research observes that we have entered a new cultural era where the use of computers and VRs have entrenched themselves into our everyday lives, as they have into the sciences, and science classrooms and most of the social spaces we inhabit. The present research also observes that VRs are integral to the functioning of all advanced classroom activities. It is a strong and seemingly unavoidable change – one that compares the acquisition of knowledge and skills, competence and mastery of abstract biological concepts. Employment of VRs in the Life Sciences classroom might create affordances of learning such abstract concepts as found in cytology with ease.

Responding to the above research question will be of value to science in relation to teaching and learning. The emphasis on the sciences curricula is on the teaching of nature of science. Nature of Science is pivotal to the existence of humankind, as natural phenomena are observed examined and explained scientifically in the modern world, (Irez, Han-Tosunoglu, Dogan, Cakmakci, Yalaki, & Erdas-Kartal, 2018). Riga, Winterbottom, Harris and Newby (2017) draw from Dewey's (2013) explanations of the purpose of science education in the society. Riga et al. (2017) declare that the aim of science education is to produce scientifically literate citizens; innovative, critical thinkers and agents of transformation in their societies. Science education plays a vital role in producing informed individuals as the desired learning outcomes are highly influenced by educators' pedagogy. The findings of the present research will resonate with the benefits of science education on the society; considering that, education is transforming technologically in order to meet the demands of the society. Schools that could previously not afford their learners practical activities owing to unaffordable costs of equipment would rely on animated practical activities with conviction of VR's benefits.

Empirical studies investigating the integration of VRs in the science classroom have indicated that poor pedagogy negatively influence the implementation of simulations. A study reported that educators underestimate the role of practical investigations in achieving the objectives of the science curriculum (Wei, Chen, & Chen, 2018). These authors further reported that educators are confused of their role in guiding hands-on activities in the classroom, which prevents meaningful learning. The present research sought to contribute to this growing area of research by exploring explicitly how inappropriate pedagogy hinders effective implementation of virtual instructional strategies.

The researcher sought to highlight the significance of VRs as alternatives to practical investigations in high school science teaching and learning. The DBE (2011) advocates for the implementation of practical investigations in science teaching and learning in accordance with the inquiry based approaches. The DBE White Paper Six of 2011 also seeks to employ ICT in the classroom (Donohue & Bornman, 2014). This resonates with what Joshua, Obille, John, and Shuaibu (2016) describe as the 21st essential skills for survival in technological advancing world. Joshua et al. (2016) envisage that the use of VRs addresses the implementation of both inquiry-based learning and ICT in the science classroom (Joshua et al., 2016). An animation teaching approach will also address the demands of the CAPS curriculum, which the present research sought to address issues that relate to equity where learners in under-resourced schools will be afforded the opportunity to construct scientific concepts through animations. Computers and other related gadgets like tablets, which are almost at everyone's disposal, could afford the use of VR at low or no cost.

Recent empirical evidence suggests that disparities in the distribution of learning resources in South African schools. Bowers (2016) highlights that the current variation in the distribution of educational resources has remained the same over the past decades. Model C schools are better resourced compered to school in the townships, as well as, school in urban areas are better resourced compared to schools in rural areas. In spite of the above-mentioned disparities, the educational setting has improved over the decades; there is an increasing availability of computers in schools (Adu & Galloway, 2015). The researcher hopes that the present research has offered some insight into how VRs could assist in the reduction of the gap in achievement of science learners from different social contexts.

A considerable plethora of research literature has been published on the evaluation of the effect of simulations on pedagogy and learners' performance in science. However, much of the research is inconclusive on the substitution of practical activities with virtual activities in the science classroom (De Jong et al. 2013; Sauter et al., 2013; Hofstein & Lunetta, 2003; Roschelle, 2007). Steinberg (2013) asserts that exposing learners to virtual activities requires learners to learn in a manner that fundamentally differs to that of scientists. This assertion illuminates a contested area on the value of VRs as alternatives to hands-on activities. It is evident that there is further need to investigate the effectiveness of VRs as alternative to practical activities in the science classroom. Therefore, the present research provides an opportunity to advance the understanding of the effectiveness of VRs as alternatives to practical investigations in under-resourced schools.

As indicated in the reviewed literature mentioned above, the use of VRs as instructional tools in science teaching is associated with active participation from learners as well as improved learner performance, (Tang & Abraham, 2015). Nonetheless, there is little information on how practical investigations could be conducted at under-resourced schools, more especially in the South African context. The Department of Education has embarked on a programme of introducing electronic learning in schools as means of transforming the education system function in line with the technological demands of the 21st century and fourth industrial revolution (Joshua, Obille, John, & Shuaibu, 2016). In this regard, this study considers use of VRs as alternative to hands-on practical activities to be part of this transformation. Furthermore, E-learning broadens access to the internet that is flooded with VRs though there is limited research conducted on VRs as being alternatives for hands-on practical investigations in the science classroom. For these reasons, it is imperative to examine the efficiency of VR as alternatives to practical investigations. Therefore, this study sought to contribute to the body of knowledge on the relevancy and effectiveness of animations in science teaching and learning.

CHAPTER 2: LITERATURE REVIEW

2.1 Introduction to literature

This chapter explores the key debates in the literature, which are relevant to use of VR such as animations in a classroom environment, and covers four main areas. The first section explores the learning theories and how they influence the use of VRs in the learning and teaching environment. This chapter also reviews literature that addresses teaching and learning in the classroom. Included in the review of literature that addresses learning in the Life Sciences classroom are different learning styles. The chapter also reviews literature that speaks to various teaching strategies such as inquiry-based learning and cooperative learning. The second section explores the effectiveness of virtual learning as an alternative to hands-on practical activities in learning and teaching of biological concepts. The virtual learning environment (VLE) explores its role in relation to managing available resources. The final section examines the use of VLEs for teaching and learning in relation to a broader e-learning context.

2.2 Theories of learning

The present study explores learning theories as means of explaining how learning in the classroom takes place. History of educational psychology has seen the developments of learning theories from behaviourist theories to cognitivist theories and currently to constructivist theories. Virtual learning theory tends to integrate all the mentioned theories in explaining how learning takes place in a virtual learning environmental.

2.2.1 Behaviourism

Behaviourism equates learning with changes in either the form or frequency of observable performance or change in behaviour (Harasim, 2018). Skinner (1985) and Epstein (1991) state that learning is accomplished when a proper response is demonstrated following the presentation of a specific environmental stimulus. The key elements to behaviourism are the stimulus, the response and the association between the two. Sobel (2002) asserts that primary concern in behaviourism is on how the association between the stimulus and response relation is strengthened and maintained. Fletcher (2016) suggests that behaviourism focuses on the importance of the consequences of performances and contends that responses that follow by reinforcement are more likely to recur in the future. There are minimal attempts to determine the structure of a student's knowledge or to assess which mental processes are necessary for them to use (Fletcher, 2016).

According to Gebremeskel, Kebede and Chai (2016), behaviourism and VRs approaches promote the use of multimedia. Gebremeskel et al. (2016) further state that for teachers teaching strategy that employ VR such as simulations and animations. Paraskeva, Mysirlaki and Papagianni (2010) define VR as a mixture of several educational packages powered by multimedia for use in the classrooms. According to Farhan, Aslam, Jabbar, Khalid, and Kim (2017) behavioural theories or associationists draw from on work done by Pavlov and Skinner with the focus being classical and instrumental Behaviourism respectively. They further assert that in a VR lesson the conception of education becomes a multimedia represented by a sequence of mechanical actions consist stimulus - reply – reinforcements (aimed at achieving the behaviourism of the subject's behaviour).

Farhan, et al. (2017) argue that according to Skinner, behaviourism is achieved not only through the response but because of environmental reinforcement; in this regard, they observed that reinforcing behaviourism that interests Skinner is the presentation of the unconditioned stimulus, not the answer that occurs to him. The relationship of behaviourism to VR lessons support the interaction of the subject and external environment. Applied to education, it implies the subject from whom the virtual space is waiting for a response (reply) stimulates the component systems of the areas of information and communication based on the pedagogical and teaching approach used in the virtual environment. The reinforcement received by the subject's behaviour derives from the external world stimuli captured. In this sense, the subject to interact with the virtual training environment receives stimuli (S) contained in the learning space; stimuli are represented by all components of the virtual space. Of course, web pages, learning objects, dynamic images, and micro worlds are educational stimuli received by the trainee, on which the subject must answer (A), and for which, depending on the response, receives a reinforcement (R) (Klašnja-Milićević, Vesin, Ivanović, Budimac, & Jain, 2017).

Conditioning of behaviour by external interactions is an important part of behaviourist theory. In Pavlov's classical conditioning, stimulus leads to response while in Skinner's instrumental conditioning behaviour leads to reinforcement (Ormrod, & Jones, 2014). While such approaches might seem somewhat mechanistic, the concepts of rapid feedback embodied within them are important in helping learners to work at their own pace. The idea of positive reinforcement was outlined by Thorndike, who emphasised how 'satisfaction' could reinforce positive behaviours (Berlyne & Tapp, 1969), while Skinner noted that the ideal of behaviourism is to change the environment to reinforce the kind of behaviour that benefits everyone (Sobel, 1990). Thalheimer (2006) describes how reinforcement of learning relates to Ebbinghaus' spacing effect, where learning is greater when studying spread out over time (Dempster, 1988). *Table 2.1* summarises the key features of the behaviourism theory.

Table 2.1

Key features of behaviourism (*adopted from Ally2004).*

Key features	Explanation
1.An emphasis on producing observable and measurable outcomes in students	Learners should be told the explicit outcomes of the learning so that they can set expectations and can judge for themselves whether they have achieved the outcome of the lesson.
2. Testing learners to determine whether or not they have achieved the learning outcomes	Testing and assessment should be integrated into the learning sequence to check the learner's achievement level and to provide appropriate feedback. This can also include pre-assessment of students to determine where instruction should begin.
3. Appropriate sequencing of learning materials to promote learning	Learning materials must be sequenced appropriately to promote learning. The sequencing could take the form of simple to complex, known to unknown, or knowledge to application. There should be an emphasis on mastering early steps before progressing to more complex levels of performance.
4. Providing feedback to learners	Learners must be provided with feedback so that they can monitor

so they can monitor how they are doing and take corrective action if required	how they are doing and respond to that feedback to change their learning behaviour.
5. Providing reinforcement to positively impact performance (e.g. tangible rewards, informative feedback.)	Use of reinforcement to impact performance. This can take the form of tangible rewards and informative feedback. It may occur in a repeated process, with the reinforcement shaping the response until it is correctly executed.

2.2.2 Cognitivism

Ertmer and Newby (1993) assert that the cognitive theories stress the acquisition of knowledge and internal mental structures and, as such, are closer to the rationalist end of the epistemology continuum. In addition, Bower and Hilgard (1981) emphasise that learning equated with discrete changes between states of knowledge rather than with changes in the probability of response. Jonassen (1991) concurs with the above assertion and states that cognitive theories focus on the conceptualization of students' learning processes and address the issues of how information is processed (received, organized, stored, and retrieved) by the mind. Learning is concerned not so much with what learners do but with what they know and how they come to acquire it (Korpershoek, Harms, de Boer, et al., 2016). As projected in the assertions (Etmer & Newby, 1993; Bower & Hilgrad, 1981; Korpershoek et al., 2016) the point of departure from behaviourist theory of learning is that cognitivist theory describes learning as a mental activity that entails internal coding and structuring by the learner. The learner becomes as an active participant in the learning process. The similarity of the two theories is that they both emphasise the role that environmental conditions play in facilitating learning. The two theories do not describe the involvement of mental processes that bring about the acquisition of knowledge and storage of that knowledge in the memory structures but rather present the product of knowing. The neglecting of learners as active agents in the processes of acquiring knowledge is lacking in the descriptors of the two theories.

Mayer (2005) notes that cognitive theory of multimedia learning (CTML) is based on three main assumptions: there are two separate channels (auditory and visual) for processing information; there is limited channel capacity; and that learning is an active process of filtering, selecting, organizing, and integrating information. Mayer (2005) also discusses the role of three memory stores: sensory (which receives stimuli and stores it for a very short time), working (where we actively process information to create mental constructs also referred to as schema, and long-term (the repository of all things learned. According to Mayer's CTML the idea that the brain does not interpret a multimedia presentation of words, pictures, and auditory information in a mutually exclusive fashion; rather, these elements are selected and organised dynamically to produce logical mental constructs.

Clark and Mayer (2016) distinguish meaningful learning from "no learning" and "rote learning" and describe it as active learning where the learner constructs knowledge. According to Mayer (2005), meaningful learning is demonstrated when the learner can apply what is presented in new situations, and students perform better on problem-solving transfer tests when they learn with words and pictures. Mayer (2008) also identifies two types of transfer: transfer of learning and problem solving transfer. He further asserts transfer of learning occurs when previous learning affects new learning. Mayer (2009) defines learning as a change in knowledge attributable to experience.

Mayer (2005) suggests several principles for multimedia learning such as animation and interactivity principles, which state that people do not necessarily learn better from animation than from static diagrams. The other principle is cognitive aging principle, which states that instructional design principles that effectively expand the capacity of working memory are particularly helpful for older learners. The third principle of learning under cognitive theory proposed by Mayer (2005) is collaboration principle, which observes that people learn better when involved in collaborative online learning activities.

2.2.3 Constructivism

Constructivism is a theory that equates learning with creating meaning from experience (Duffy, & Jonassen, 2013). Although constructivism is considered to be a branch of cognitivism (both conceive of learning as a mental activity), it distinguishes itself from traditional cognitive theories in a number of ways. Most cognitive psychologists think of the mind as a reference tool to the real world. Conversely, constructivists believe that the mind filters input from the world to produce its own unique reality (Jonassen, 1991).

Cognitive constructivism: According to Piaget, people organise their experience into schemes that help them make sense of their experiences and achieve equilibrium (Eggen & Kauchak, 2013). New experiences assimilate with existing schemes (Eggen & Kauchak, 2013). Accommodation and a change in thinking occur with new experiences conflict with existing schemes (Eggen & Kauchak, 2013). Maturation and experiences with the physical and social work advance development, and as children develop, they progress through stages that describe general patterns of thinking, ranging from perceptual dominance in preoperational thinkers to the ability to think logically and hypothetically for formal operational thinkers (Eggen & Kauchak, 2013). Cognitive constructivism proposed that learners proceed through four stages based on maturation and experience (Eggen & Kauchak, 2013). Cognitive constructivism theory makes assumptions of how learners interact with their environment and how they integrate new knowledge and information into existing knowledge.

Social Constructivism: Social constructivism focuses on the role of culture and social intentions (Daniels & Perry, 2003). Social constructivism maintained that speech is a major psychological tool in the child's development of thinking. As children age and develop, their basic speech becomes more complex (Daniels & Perry, 2003). Social constructivism describes cognitive development as the interaction between social interaction, language and culture (Eggen & Kauchak, 2010). Social interaction and language provide the mechanism and tools that help children develop understandings that they would not be able to acquire on their own and advance their development (Eggen & Kauchak, 2010). Social interaction and language exist in a cultural context that uses the language of the culture as the mechanism for promoting development (Eggen & Kauchak, 2010). According to Daniels (2001), six major assumptions guide social constructivism theory.

a) Children develop through informal and formal conversations with adults.

b) The first few years of life are critical for development, as this is where thought and language become increasingly independent.

c) Complex mental activities begin as basic social activities.

d) Children can perform difficult tasks with the help of an expert.

e) Challenging tasks promote cognitive development growth.

f) Play is important and allows children to stretch themselves cognitively.

Social and cognitive constructivists' theories have similarities between their two theories of cognitive development. For example, cognitive constructivists believed that development occurs because the learner is an active learner. In other words, the learner must actively organise new information with existing information to obtain a state of equilibrium (Eggen & Kauchak, 2010). Social constructivism agreed with cognitive constructivism on this account, theorising that children are actively involved in the learning and development process because they provide feedback to the adult or teacher about their level of understanding (Eggen & Kauchak, 2010). Constructivist theories promote inquiry-based learning as an instructional learning strategy.

According to Bransford (2007), a constructivist view of learning focuses on the process of knowledge construction with concept development achieving a comprehensive understanding of the goals. Mahoney (2004) observes that constructivism is characterised by an approach where individuals construct their own understanding and knowledge of the world, through confronting new experiences and reflecting on those experiences. According to the constructivist view, the learning process involves the following two concepts: the first concept describes knowledge as a product of inquiry; and active re construction as the expansion of understanding of mental frameworks (Piaget, 1970; & Bransford et al., 2000; Abbott & Ryan, 2009). The learner's previous knowledge constructions, beliefs and attitudes are considered in the knowledge construction process (Murphy, 1997). In addition, the second concept states that learning is an active process involving deliberate progressive construction and deepening of meaning (Bergen, 1993).

Learning situations, environments, skills, content and tasks are relevant, realistic and authentic representation of the natural complexities of the ‘real world. In contrast to behaviourism, this centres on learners’ efforts to accumulate knowledge of the world and on the teacher’s effort to transmit it, in the constructivist view of learning; teachers play the roles of coordinators. According to Bergen (1993), a subtle difference between behaviourism and constructivism is that behaviourism emphasises observable and external behaviours while constructivism takes a more cognitive approach, have profound implications for all aspects of a theory of learning. Researchers presents different arguments on the constructivist view of learning by emphasising different components, such as the types of knowledge, skills and attitudes, the role of teacher and learner, and how goals are established.

Winn (2005) states that, the educational use of VRs provides compelling evidence of the potential of the emerging 3D virtual worlds to facilitate constructivist-learning activities. One of the main advantages of VR identified is that learners are able to view an object or setting from multiple perspectives (Dunleavy & Dede, 2014). Dunleavy and Dede (2014) point out that virtual environments offer many benefits including opportunities for experimentation without real-world repercussions, opportunities to “learn by doing”, or “experiential learning” and ability to personalise an environment.

Yilmaz and Sahin (2011), define constructive teaching and learning as a process that encompasses individual and cooperative, as well as, self-regulated and interpretive construction of one’s thoughts through actively engaging with social and physical environment. Below ten attributes of constructive teaching and learning:

1. Learning is an active process.

2. Learning is an adaptive activity.

3. Learning is situated in the context in which it occurs.

4. Knowledge is not innate, passively absorbed, or invented but constructed by the learner.

5. All knowledge is personal and idiosyncratic.

6. All knowledge is socially constructed.

7. Learning is essentially a process of making sense of the world.

8. Experience and prior understanding play a role in learning.

9. Social interaction plays a role in learning.

10. Effective learning requires meaningful, open-ended, challenging problems for the learner to solve.

Kozbelt, Beghetto and Runco (2010) posit that in constructivist learning, it is important not only to learn something that is already known (discovered) but to create new knowledge, new information, to create and construct something new. Furthermore, as it is the case in the present research in terms of the question about the role of digital media in learning and teaching, one should begin with questioning the novelty of digital media in classroom instruction compared to traditional media (textbooks). In selecting all possible technological devices and software for classroom purposes, there has to be consideration of the following factors: the digital delivery and presentation of information in multimodal and simultaneous forms; the performance of actions and actions via digital technologies that were until recently performed manually; and computer mediated communication (Pacheco, Cano, Flores, et al., 2018).

According to Winn (2005), VRs enable knowledge construction that is viable through functional and social interaction. Winn (2005) also highlights that based on the social constructivism approach, the world is accessible to us only through our shared interpretations, and the idea of an independent reality is at best an irrelevant abstraction and at worst incoherent. In this regard, Panasan and Nuangchalerm (2010) argue that in order to achieve the best outcome in a VR lesson, constructing a shared goal and an understanding of the given problems are essential for the learners. He further asserts that visual and verbal language provide the shared structure necessary for communicating meaningful ideas and concepts in the design situations. Since meaning is derived from language and language is interdependent between two or more persons, it follows that socio-cultural processes of negotiation, cooperation, conflict, rhetoric, ritual, roles, social scenarios, and the like are crucial factors in the development of meaning and reality.

2.2.4 Social learning theory

While the theories described above are applicable to any learning situation, there is need to explore theories that influence learning in VRs environment. Blisset and Atkins (1993) explain the academic roles of the teacher in classrooms that employ VRs are the same as in traditional classrooms. However, Mayers and de Freitas (2013) propose that the e-learning theory fitfully describes a teacher's role in a VR classroom. They identified the *associationist/empiricist* perspective (learning as activity), the *cognitive* perspective (learning as achieving understanding) and the *situative* perspective (learning as social practice) as possible theories that could influence the roles of teachers in VRs classroom. According to Mayers and de Freitas (2013), associationist perspective learning is the process of connecting the elementary mental or behavioural units through sequences of activities. They describe teachers' role under this e-learning theory as that of analysing the subject matter content and breaking it into specific associations to be expressed as behavioural objectives. As described by the associationist, e-learning theory learning is teacher centred.

2.3 Teaching and learning in a Science classroom

Teaching and learning in a classroom is a process that requires the participation of both teachers and learners. The teaching and learning process in science classrooms is more demanding because of the nature of the subject domain (Kober, 2015). Kober (2015) further declares that continuous instructional reflection is essential for learner achievement in science. According to Obiekwe and Chinwe (2012), teachers desire their learners to acquire knowledge. This aspiration leads to the dilemma faced by teachers in wanting to reach all their learners through the same teaching strategy. Nasri, Yusof, Ramasamy and Halim (2010) claim that teachers resort to drilling strategies as means of enhancing learning in the science classroom. Ebert-May, Derting, Henkel et al., (2015) concur with Nasri et al.'s (2010) assertion and further assert that science teaching should endeavour to afford learners first-hand experience of the scientific inquiry processes and facilitate construction of conceptual knowledge through designed learner-centred activities. This assertion is in line with the cognitive theories of learning. The construction of knowledge is important than the acquisition of factual knowledge in learner-centred methods.

Cognitive theories brought a new paradigm in the learning process, which emphasise that learning is as a result of learners' construction of knowledge rather than acquiring knowledge in the classroom (Perkins, 1991). Driver, Asoko, Leach, and Scot (1994) claim that cognitive learning results in organised storage of information in the learner's schema and this organised complex is referred to as cognitive structure. The desired type of teaching in the life sciences classroom is then that which affords learners to effectively construct knowledge. The duty of the teachers then is to create affordances of knowledge construction in the science classroom. The process of knowledge construction calls for learners to be active participants in the classroom (Toven-Lindsey, Rhoads, & Lozano, 2015). Actively engaging in the classroom could be through dialogues and practical activities. As observed by Vygotsky (1978) learning construction takes place in a social setting. Affordances of knowledge construction that teachers develop should also take into cognizance the social environment of the learners.

2.3.1 Traditional teaching and learning methods

According to Aziz and Hossain, (2010) define traditional teaching as a strategy that is teacher-centred and involves direct interaction between teachers and learners. In this approach the teacher plays the role of a "transmitter" who transmits information to the learners as "receivers". The learners are also regarded as "tabula rasa" (empty vessels) and teachers to fill them with knowledge (Dillon, 2016). Guan and Wang (2012) assert that traditional teaching methods focus on memorization and repetition of the content termed as rote learning. This teaching method hinders meaningful learning, as mental process skills such critical thinking and problem solving are neglected. Rote learning is regarded as motivation for learners to grasp basic knowledge. For example, rote learning is considered to be effective in the mastery of phonics in languages, periodic table and multiplication tables in mathematics (Guan & Wang, 2012). Educational psychologist have also criticised this approach as it neglects 'active learning'. Active-learning observes learners as active participants in the teaching-learning process. This promotes deep-learning as learners meaningfully engage with content (Aziz & Hossain, 2010). Zhang and Chen's study (2012) revealed that traditional teaching methods prove ineffective in promoting deep-learning and enhancing critical cognitive skills especially in the science classroom. Quinnell, May and Lloyd, (2012) reported that when comparing traditional teaching method and ICT teaching method in Life Sciences, learners taught with the ICT teaching method performed improved more than those that were taught through traditional teaching method. Therefore, teachers must be reflective practitioners to ensure achievement in the present digital classroom contexts.

2.3.2 Multimedia teaching and learning methods

The 21st century classroom context has technologically advanced in order to meet societal needs. As a result, educational policies have been revised to promote the implementation of multimedia in the South African education system (Heleta, 2016). The Life Sciences CAPS curriculum calls for 'Doing Science'. This implies that pedagogical strategies that teachers incorporate should include practical activities. In some schools, carrying out practical activities becomes impossible owing to lack of resources. Smetana and Bell (2012) suggest that multimedia such as animations can be used as substitute for practical activities. He argues that forms of multimedia built for experimental learning and observation provide an opportunity to practice and learn within a controlled environment. Various forms of multimedia programs have a clear and important effect on facilitating both teaching and learning of biological processes. For instance, animations for biological dissections and those that provide representations of things that happen and cannot be seen with a naked eye such as gene interaction, cell division, photosynthesis, and cellular respiration can be best dealt with through animations (Merchant et al., 2012). Chen (2010) asserts that simulations can also be used when laboratory experiments are expensive, or when the laboratory experiments cannot be performed in the school laboratory; for example, the experiment that releases toxic substances**.**

According to Yilmaz (2006) and Chen (2010), animations that can be used in a biological classroom are physical simulations. They claim that physical simulation deals with the physical material to be used and to identify its nature, such as the equipment of the scientific laboratory that are used restricts experiments, which in the real laboratory are dangerous. They also identify procedural simulation as appropriate for biological classrooms. Peffer et al. (2015) highlights that, the aim of this type of animation is to learn a series of steps in a process. Procedural simulation suits this study as it is based on the process of mitosis cell division.

Hoffer, Radke and Lord (1992) claim that the decline of inquiry-based learning in the science classroom over the last two decades was owing to the non-availability of support provided by animations. With the advent of the growth in usage of computers in classrooms, Woodrow (1992) indicates that there is a wide gap between the current level of multimedia and the reality of its implementation in classrooms. One such disparity is teachers' lack of knowledge and skills of using computers as teaching tools. Ronen et al. (1992) maintain that most teachers need specialised guidance in the methods that use VRs such as animations in their preparation for teaching. In this regard, Sheingold and Hadley (1990) indicate that teaching with multimedia seems to influence teaching style toward an increasingly learner-centred and active learning orientation. This calls for a change in the traditional teaching methods towards adoption of learner-centred methods. Teachers with progressive beliefs about teaching tend to be drawn toward using multimedia. Honey and Moeller (1990) that teachers with a high level of multimedia inclination tended to concentrate on instilling a sense of curiosity and desire to learn in their learners. They further assert that such teachers tend to reduce the amount of time spent on content and devoted more time to an inquiry-based approach, which helped learners develop critical thinking. Honey and Moeller (1990) indicate that teachers with a low level of multimedia implementation are more heterogeneous. They claimed that when these teachers used various forms of multimedia, their motive would be to reinforce basic skills or to increase motivation rather than to improve the curriculum. Such teachers would revert to traditional methods of teaching science rather than scientific inquiry.

According to Aldrich (2004), animated visualisations that show both structures and processes help teachers convey important scientific concepts in Life Sciences particularly in cytology. He further argues that designers of these animations benefit from knowing how learners perceive and comprehend such visualisations. Aldrich (2004) defines animations as visualisations that allow learners to learn critical concepts and relationships between these concepts. Learners learn cytology concepts and processes such as cell division by attending to, seeing, and understanding all the associated elements and the ways that they change and evolve during the process. On the contrary, Cook (2011) argues that because often animations are too complex to be quickly understood, learners need to establish accurate mental models to assist in their comprehensions. This advocates for appropriate pedagogical strategies for use of animations in the Life Sciences classroom.

According to Gredler (2004), animations much like computer games engage learners in virtual worlds where they apply their knowledge, skills and thinking in virtual situations. Because learning in general, as well as how people learn is multidimensional (Gardner, Kornhaber, & Wake, 2010) animations provide multi-sensory interaction, visualization, and symbols. Tversky, Morrison and Betrancourt (2002) concur with this notion and further argued that visualisations and symbols augment learners' cognitive capacities and help to convey concepts and information. Falvo (2008) asserts that animations are much more effective than tutorials and drills, and enhance motivation, transfer of learning, efficiency, and flexibility while being safe, convenient, and controllable over real experiences. Theories of learning seemingly support the employment of such VRs as animations in the teaching and learning environments.

According to Domalewska (2014), various forms of multimedia used as learning and teaching tools is fixed on improving learning and teaching in schools. Domalewska (2014) further argues that multimedia supported and enriched formal instruction demonstrates positive pedagogical implications for science classrooms. Multimedia-supported learning offers integration of learning with learner needs and cultural experiences and plays a substantive role in developing autonomous life-long learners that possess skills and knowledge necessary for achieving success (Domalewka, 2014).

Multimedia can enhance the practice of learners' and teachers' (Merchant, Goetz, Cifuentes, et al., 2014). Merchant et al. (2014) further explain that the mere use of multimedia in the classroom does not yield good results. This is because pedagogical skills are required in the application of multimedia in learning and teaching situations. The manner in which computers and multimedia are utilised by learners and teachers is what makes the difference in learning and teaching. On a different token, Ndibalema (2014) argues that there is little evidence on how ICT has been successful in schools mainly because there are no clear multimedia educational strategies in place to improve the pedagogical skills for teachers. Ndibalema (2014) also proposes that aspects such as teachers' willingness, confidence, motivation, attitude, thinking, and belief are some of the factors that need to be explored when looking at various forms of multimedia and classrooms. Integrating multimedia into educational practices has proven to be a slow and complex process. In fact, it can take four or more years from the time new technologies are first introduced to the point when changes can be observed in learners. To date, the most prevalent barriers to successful integration include organisational support, teacher attitudes and expectations, and multimedia itself.

Teachers' attitudes and expertise with the use of multimedia have been identified as key factors in the integration of multimedia in classrooms (Inan & Lowther, 2010; Zhoo & Frank, 2003). Zhoo and Frank (2003) further argue that teachers need to hold a positive attitude towards multimedia in order to use it effectively in their teaching. Moreover, their pedagogical beliefs and existing teaching practices will shape how they incorporate multimedia in the classroom (e.g., Honey & Moeller, 1990; Sandholtz, 1997). In order to use multimedia effectively for educational purposes, teachers must not only be familiar with how to operate equipment, but also understand how these tools are effectively used in science classrooms to incorporate inquiry-based learning activities that accomplish important learning goals (Ramnarain, 2015). As stated by Inan and Lowther (2010) while many teachers use multimedia in their private lives and know how to operate it, they often lack some of the other knowledge and skills required to support teaching and learning. Inan and Lowther (2010) argue that teachers need continuous professional development to keep up with how professionals are using multimedia in science classrooms and to understand the essential role that multimedia plays in supporting inquiry-based learning.

Martirosov and Kopecek (2017) define VR as a computer-based form of multimedia that provide visual, aural and tactile stimuli of a virtual world generated in real time. Mayer (2014) asserts that the use of VRs in the classroom was justified not because of its added value as an educational tool but mainly because the use of VR allow testing different situations without putting extremely expensive material and learners in high risk situations like normal school science laboratories. Tracey and Bridget (2007) describe VR as one of the 21st century technologies for enhancing teaching and learning while centred mainly on the merging of education with entertainment. They further assert that enhancement of learning and teaching is achieved by VR through substitution of artificial interfaces by simulated processes. Tracey and Bridget (2007) recognised the power as being the ability to bring about the representations of natural processes in science classrooms. They also claimed that VR enables first person experiences, which are natural, unreflected and personal, generating direct, subjective, and personal knowledge. Barak, Ashkar and Dori (2011) claim that learning through VR provides a less symbolic interaction with the environment.

Different types of VRs include desktop-based VR technologies such as Second Life, which creates replicas of real life places. According to Merchant et al (2012), other Second Life's affordances are 3-D objects to teach abstract concepts. Other forms of VRs are digital and those represented in form of avatars. These actively engage in realistic activities that stimulate learning. Interactive animations are also part of VRs that are widely in use today. The commonly used VRs in the science classrooms are computer simulations and animations (Galas & Ketelhut, 2006). McClean, Johnson, Rogers, Daniels, Reber, Slator, and White (2005) identified V-cell animation as typical examples of an animation used to teach molecular biology in a Life Sciences classroom.

Winslow (1996) argues that in VR classrooms there an occurrence of learner de-socialisation, drawing form Vygotsky's Social Learning Theory. Vygotsky (1978) asserts that learning takes place in a social setting. Hence, Winslow (1996) claims that the use of VRs is a draw back on the learning process because it allows the user to lose social presence. The integration of VR use in the classroom may lead to disturbance of task-centred learning owing to learners 'growing interest in the medium and not on the content (Winslow, 1996). For example, VR by itself may not provide knowledge and can act as noise. Stuckey-Mickell and Stuckey-Danner, (2007) argue that while VR can be a great asset for most of the existent fields of activity, it can also be a huge disadvantage. These authorities also assert that traditional education is based on personal human communication and interpersonal connections. A VR learning environment is unique as it focuses on an individual and the software programme. This can negatively impact on the relationships between learners and teachers. Dipietro (2010) suggests that teacher might not be ready to use VRs in the classrooms or might not be in possession of required knowledge and/or skills.

There has been an incline in the promotion of various forms of multimedia in schools (DBE, 2012). All forms of VRs are components of multimedia and animations are a part of VRs. Animations are a form of VRs. Rutten, van Joolingen and van der Veen (2015) define animations, as a program that contains a model of a system, be it natural or artificial. Bailey, Tettegah and Bradley (2006) define animation as techniques of imitating the behaviour of some situations or process especially for the purposes of study. In this study, animations are brought in as substitutes to practical investigations in poorly resourced schools. Rutten et al (2015) assert that the use of animations in the classroom has the potential to generate higher learning outcomes. They further argue that animations assist learners to refine conceptualisation of phenomena in less time than textbooks do. As mentioned before, the whole idea of animations falls under the employment of ICT in the classroom. The present research uses animations as an intervention strategy to teach mitosis to a Grade 10 Life Sciences class.

Animations are multimedia enhanced learning tools that support and enhance learning practice (Mayer, 2014). Youngblut (1998) observes that the introduction of animations in science education began in the early 1990s with projects such as Science Space, Safety World, Global Change, Virtual Gorilla Exhibit, Atom World, and Cell Biology. He further asserts that techniques employed in these animations ranged from using specially designed glass cubicles called Cave Automatic Virtual Environment (CAVE) to projecting on the walls of a room. The use of the animations in education is an issue that has received extensive attention. According to Hussein and Nätterdal (2015), there are some obvious advantages of using animation when compared to traditional in-class education. As stipulated by Posey, Burgess, Eason, and Jones (2010), one significant advantage is that the animations in the science classroom can help with instructor organisation. This includes areas for science content, assignments, class notes and other information can be readily categorised. They further argue that VRs like animations can facilitate the creation of a “virtual notebook” which can make locating documents easier for both teachers and learners.

Animations can help learners learn abstract concepts because they can experience and visualise these concepts in the virtual environment (Sala Ripoll, Oparka, Campbell, & Erolin, 2017). Ray and Deb (2016) concur with this notion and argue that as compared to traditional learning process, which is usually language-based, conceptual, and abstract, a VR learning environment based on animations fosters active learning and helps learners grasp abstract knowledge. Lee and Wong (2014) argue that low-spatial ability learners particularly benefit from VR because the visualisations help lower the extraneous cognitive load of the learning objectives. They also argue that animations allow the learners to comprehend systems or objects that are of widely different scales.

Husu (2000) asserts that another advantage of animations in the science classroom advantage lies in the intellectual and social partnership created by multimedia of the virtual classroom. His assertion is that learners exposed to animations engage in additional social skills and spontaneously take leadership roles in relation to other learners. Husu (2000) also claims that animations in the science classroom increases group cohesion and mutual support especially in the remote classroom. Posey et al. (2014) concur with this notion as they assert that animation is suitable for small-group work and its interactive mode both contribute to the development of skills using information and communication technologies. Mayer (2012) stresses that VRs in the classroom also developed a range of communication and social skills that allowed the learners to overcome their relative isolation by communicating with learners in similar situations.

According to Choi (2011), animations can help to achieve some science educational aims. Song, Sun and Rees (2002) concur with this notion as he claimed that many of the research studies confirmed the importance of the use of simulation in the field of teaching because of its numerous advantages and benefits. Lunce (2006) postulates that animations have been used in learning activities for a long time, facilitating accurate representations of real objects and turning learners into interactive participants. Choi (2011) argues that animations also help learners to identify the functions and methods of their work. Moreover, they help learners to predict the outcomes of the implementation of the experiments and educational projects, and stimulate creative thinking among learners to provide new educational ideas.

The use of the virtual realties like animations in the science classroom causes many teachers to step out of their comfort zones because various types of VRs goes against the traditional method of teaching (Mayer, 2012). On the same token, Tinker (2011) asserts that for application of animations in classrooms, teachers are required to adjust their curriculum to meet the standard requirement for providing the right resources for learners. He further asserts that use of animations in the classroom if not well planned require more time. Husu (2000) argues that lack of face-to-face interactions with other classmates and the teacher can be a disadvantage for both learners and teachers. Such critical aspects of learning and teaching such as desired the immediate feedback from the teachers might be impossible through animations. There is general fear that VRs in the forms of animations and computer simulations could take over many of the instructional duties that now define teachers' duties Mayer (2012). Mayer (2012) also emphasises that all forms of VRs including animations in the science education pose new challenges for teachers. One such challenge is the destruction of the long existed culture of learning which provided for face-to-face instruction and closely monitored learning progression.

The Life Sciences CAPS curriculum calls for 'Doing Science'. This implies that pedagogical strategies that teachers incorporate should include practical activities. In some schools, carrying out practical activities becomes impossible owing to lack of resources. Randal (2002) suggests that animations can be used as substitute for practical activities. He argues that computer-based simulations built for experimental learning and observation provide an opportunity to practice and learn within a controlled environment. The simulation computer programs have a clear and important effect on facilitating both teaching and learning of biological processes. Animations for biological desertions and those that provide representations of things that happen and cannot be seen with a naked eye such as gene interaction, cell division, photosynthesis, and cellular respiration can be best dealt with through animations (Merchant et al., 2012). According to Peffer, Beckler, Schunn, Renken, M, and Revak, (2015) , simulations could replace laboratory apparatus when they are expensive, or when the laboratory experiments cannot be performed in the school laboratory; for example, the experiment that releases toxic substances.

According to Yilmaz (2006) and Peffer et al. (2015), simulations that can be used in a biological classroom are physical simulations. They claim that physical simulation deals with the physical material to be used and to identify its nature, such as the equipment of the scientific laboratory that are used desertions experiments, which in the real laboratory are dangerous. They also identify procedural simulation as appropriate for biological classrooms. Peffer et al. (2011) observes that the aim of this type of simulation is to learn a series of steps in a process. Procedural simulation suits this study, as it will illustrate the process of mitosis cell division.

Rooney (2012) asserts that the decline of inquiry-based learning in the science classroom over the last two decades could be due to limited support provided by animations, the growth in the usage of computers in classrooms. Mayer (2012) notes a disproportion between the current level of computer multimedia available and the reality of its implementation in classrooms. One such disparity is teachers' lack of knowledge and skills of using computers as teaching tools (Weintrop, Beheshti, Horn, Orton, Jona, Trouille & Wilensky, 2016). According to Rooney (2012), most teachers need specialised guidance in the methods that use VRs such as animations in their preparation for teaching. In this regard, Sheingold and Hadley (1990) observe that teaching with multimedia seems to influence teaching style toward an increasingly learner-centred and active learning orientation. A shift from traditional teaching methods towards the adoption of learner-centred methods in teachers with progressive beliefs about teaching tends to be drawing toward using multimedia. As stipulated by Honey and Moeller (1990), teachers with a high level of multimedia inclination tended to concentrate on instilling a sense of curiosity and desire to learn in their learners. They further assert that such teachers tend to reduce the amount of time spent on content and devoted more time to an inquiry-based approach which helped learners develop critical thinking. Teachers with a low level of multimedia implementation were more heterogeneous. They claimed that when these teachers used multimedia, their motive would be to reinforce basic skills or to increase motivation rather than to improve the curriculum. Such teachers would revert to inquiry (Honey & Moeller, 1990).

2.3.3 Inquiry based learning and virtual realities

The literature of science education offers important data to the science inquiry and modelling. According to Ramnarain (2015) the main characteristic of inquiry learning is that learners learn by acting as scientists. He further asserts that in inquiry based learning learners approach problems in a scientific manner using scientific methods. The importance of the process of inquiry is that the content standards describing what all learners need to know and be able to do include standards of science as inquiry. Inquiry is a set of interrelated processes by which learners pose questions about the phenomenon being studied (Schwartz & Crawford, 2006). Inquiry is more than asking questions represents a state of inquisitiveness of the mind. Learners need to learn the principles and concepts of science, acquire the reasoning and procedural skills of scientists, and understand the nature of science as a particular form of human endeavour (Schwartz & Crawford, 2006). These inquiry standards specify the abilities learners need in order to inquire the experiments and extract the knowledge that will help them understand inquiry as the way that knowledge is produced. A lot of effort has been put into how to improve learners' inquiry skills (Cuevas, Lee, Hart & Deaktor, 2005). It is expected that through methods similar to the scientific methods learners will approach the problems under study more deeply, an approach leading to a better understanding, and therefore they will learn about the nature of the scientific knowledge, including the involved processes of knowledge building (Ramnarain, 2014). Many researchers also agree that modeling should be the main technique of teaching sciences (Lederman & Lederman, 2017). For science education, it is especially important that learners learn how to develop models and how to draw explanations of natural phenomena. In the present research inquiry based learning is viewed as a package from where practical investigations and use of multimedia and more specifically computer simulations are drawn from.

2.3.4 Cooperative learning

Cooperative learning emerged at a time after classroom teaching had been largely teacher-centred and advocated for transmission of learning for many decades (Bond & Fotiyeva, 2010). According to Denton (2012), cooperative learning presents an opportunity for students to be organised in a purposeful way for learning within a topic. Cooperative learning activities promote peer interaction, which helps the development of language and the learning of concepts and content. Bond and Fotiyeva (2010), identify that cooperative learning complements Vygotsky's sociocultural theory, which views knowledge as a social construction. According to Bond and Fotiyeva (2010), the key feature of cooperative learning is positive interdependence that affords an opportunity for learners to rely on each other during the learning process. Cooperative learning also provides for considerable face-to-face interaction (for socially constructing knowledge) and frequent use of the relevant interpersonal and small-group skills.

Hurley, Allen and Boykin (2009) assert that cooperative learning is important when dealing with learner diversity because it teaches learners to appreciate each other and their different diversity orientations. For the purpose of the present research, diversity might be owing to the different knowledge systems (IKSs) that learners bring to the science classroom. As observed by Hurley, et al. (2009), cooperative learning allows a learner to interact on a more personal level with other learners whom they may not have talked to before. Cooperative learning allows learners to share prior experiences and different prior knowledge's with each other, creating a more comfortable learning environment (Bond & Fotiyeva, 2010).

Academic learning success for each individual and all members of the group is one feature that separates cooperative learning groups from other group tasks (Fotiyeva, 2010). According to Hurley et al. (2009), in order for a lesson to be cooperative, five basic elements are essential and need to be included. The five essential elements are Positive Interdependence, Individual Accountability, Face-To-Face Promotive Interaction, Social Skills, and Group Processing (Hurley, Allen and Boykin, 2009) . There are five types of cooperative learning, namely, Student-Teams-Achievement-Divisions (STAD), Teams-Games-Tournaments, Jigsaw, Team-Accelerated Instruction, and Cooperative Integrated Reading and Composition (Fotiyeva, 2010). These strategies can be used to enhance student learning. Cooperative learning can be used to improve academic achievement, motivation and promote teamwork among students (Fotiyeva, 2010).

Cooperative learning, when instituted and successfully practiced, creates an environment that involves all learners regardless of their prior experiences (Hurley et al., 2009). According to Hurley et al. (2009), when striving to teach learners to create, monitor and evaluate the equity in their cooperative group, teachers teach them how to begin to create a classroom that takes care of learners' prior knowledge. Cooperative learning has been widely embraced by science teachers, as well as, for scientific literacy teaching (Bond & Fotiyeva, 2010). Hurley et al. (2009) assert that cooperative learning is a great tool to improve learner's achievement through integrating IK in school science. Hurley et al. (2009) also accentuate that cooperative learning also fosters tolerance and acceptance in the community, which improves quality of everybody's life. In addition, Hurley et al. (2009) and Fotiyeva (2010) have shown that cooperative learning strategies can be utilised to promote deeper understanding. Teachers can use various strategies of cooperative learning to enhance learning in a classroom. This will result in higher learner achievement.

2.4 Learning styles

Learning styles are ways in which learners prefer to organise, classify and assimilate information about the environment (Dunn, Griggs, Olson, Beasley & Gorman, 1995). In a diverse science classroom there is a likelihood that there are different learning styles that learners bring along. Dunn et al. (1995) indicate that different learners have different learning style and identifies common examples of such learning styles as few examples of learning styles as auditory learners, visual learners and kinaesthetic learners. Dunn et al. (1995) describe auditory learners as those who prefer to receive ideas and information by hearing them. These students may struggle with reading and writing, but excel at memorising spoken words such as song lyrics. They often benefit from discussion-based classes and the opportunity to give oral presentations (Dunn et al., 1995).

2.4.1 Verbal/oral learners

Cheng (2014) auditory learners learn through listening. As such, lecture, chalk and talk methods are absolutely essential for these learners. Fleming (2008) argues that auditory learners learn best through verbal lessons, discussions, talking things through and listening to what others have auditory learners interpret the underlying meanings of speech through listening voice, pitch, and speed. According to Cheng (2014), auditory learners often, benefit from reading text learns through listening. Auditory learners learn best by hearing or listening. They prefer talking about a situation; express emotions verbally; enjoy listening, but cannot wait to talk; like hearing, themselves and others talk; learn best through verbal instruction; move lips or sub-vocalise when reading; remember auditory repetition; study well with a friend to discuss material. These include auditory stimulation for auditory learners. Short lectures of ten minutes or less, followed by verbal interaction, help auditory learners acquire and process information (Sek, YongWee, McKay, & Deng, 2014).

2.4.2 Visual learners

According to Dunn (1990), visual learners prefer to receive information by seeing it. Typically, visual learners pay much attention to detail. They are less likely to speak in class than their auditory peers, and generally use few words when they do. Visual learning materials such as pictures are useful in helping these students learn. Franzoni and Assar (2009) highlight that visual learners learn through seeing, so tools like diagrams, flowcharts, pictures and symbols can be key to understanding new concepts. Cheng (2014) asserts that for visual learners, it is often far easily for them to recall work with images as oppose to working with words. These learners form mental images while recalling content. They interpret retention of images quicker compared to texts. Visual learners include spatially rearranging of their scripts instead of writing across scripts horizontally; write in a way that is more descriptive of the relationship being described. For example, write the words out in a circular pattern if that more truly represents the relationship you are describing.

Cheng (2014) argues that visual learners prefer to observe the teacher's body language facial expression to interactive whiteboards and work on worksheets. Cheng (2014) further contends that during a lesson or in the classroom visual learners often prefer to take detailed notes to absorb the information. Therefore, visual learners learn best by seeing. They prefer watching demonstrations; have intense concentration and ability to visually imagine information; remember faces but forget names; write down things and take detailed notes; doodle; find things to watch; look around and study their environment; facial expression is a good indication of emotions; quiet, do not talk at length; become impatient when extensive listening is involved; learn best by studying alone.

2.4.3 Kinesthetic learners

Dunn (1990) asserts that kinaesthetic-tactile learners tend to learn best through movement and touch, Kinaesthetic-tactile learners also known as "hyperactive learners" because they tend to move around a great deal. Kinaesthetic-tactile learners like movement, they may take many notes and learn best when allowed to explore and experience their environment. Table 2.2 summarises common learning styles that are possibly found in classroom situations. Sek and McKay (2014) emphasise that kinaesthetic learners learn through doing. This is perhaps the most challenging learning style for teachers who struggle to organise practical activities for their learners as there are not always many opportunities to engage in hands on learning in lessons. For this, VR and more specifically virtual laboratories become even more essential for these learners. Table 2.2 provides a summary for the learning styles discussed above.

Table 2.2

Different learning styles (adapted from Dunn & Dunn 1986)

Visual style	**Auditory style**	**Kinaesthetic/Tactile style ('Doer')**
Likes to see text, pictures, illustrations, charts, maps	Likes to listen, hear and discuss	Likes hands-on experiences, working with peers and going outside the classroom to investigate
Likes to read notes and write summaries	Learns well when the presenter is interesting and clear	Enjoys physical exercise, handcrafts, gardening, etc.
Enjoys reading	Reviews notes by reading aloud and talking with peers	Likes to 'do' things, scribble and draw
Could be meditative	Enjoys telling stories and jokes	Eager to participate in various activities
Learns and remembers things by writing them down	Plans the work by talking it through with somebody	Likes to study in a group and use models and charts
Benefits from writing formulas and instructions on cards and reviewing them	Memorises formulas and instructions or talk aloud	Likes to draw plans for projects and activities on large sheets of paper
Makes lists and keeps detailed calendar	Recognises faces and places but not names	Enjoys using blocks, marbles, and other three-dimensional models
Has a good visual memory for faces, places, instructions	Repeats instructions	Has a good memory of events, but not for faces or names
Has a good sense of directions	Enjoys rhyming, likes to talk	Likes to try out things, doesn't bother about errors
		Enjoys exploring

Characterisations demonstrated in Table 2.2 should not be used to categorise learners; for example, to 'visual' or 'tactile' learners but to enhance the range of possibilities for stimuli and activities in the learning process. Most learners use various styles and no one style is better than the other. When there is a significant unaddressed mismatch between teaching and learning styles, learners might be inattentive, bored or discouraged, and perform poorly (Dunn & Dunn, 1986). In response, educators may become critical of their learners, misinterpret poor scores as low ability or become discouraged with teaching. Therefore, teachers should be able to identify different learning styles that their science learners bring to science classrooms and adapt their pedagogical strategies to match the identified learning styles. They can use differentiated pedagogical strategies that are varied enough to meet students' needs while respecting diversity. Flexible teaching and assessment benefits learners who choose among standards based learning methods and products. If teachers teach exclusively in a learner's less preferred style, discomfort may interfere with learning. Learning in early stages of a curriculum unit may be more efficient using a different style than later in the same unit. It is important that the teacher balances pedagogical strategies so that all learners are taught partly in their preferred styles, but also practice teaching in less preferred modes. Teaching that addresses all learning styles is more effective compared to a single-dimensional teaching approach.

2.5 Theoretical Framework

The use of VR in improving the learning of mitosis lends the present research adopting Mayer's (2014) CTML and Mnguni's (2014) model of visualization processes as the theoretical framework. The cognitive theory of learning is a comprehensive theory that can be dated back to the 1800s and 1900s (Harasim, 2012). This field of study focuses on cognitive development in terms of information processing, conceptual resources or perceptual skills by the brain (Demetriou, Shayer & Efklides, 2016). Renowned cognitivist Jean Piaget (1970) asserts that the cognitive development field examines the construction of thought processes: remembering, problem solving and decision-making from childhood through adolescence to adulthood.

The cognitive theory of multimedia learning (CTML) as developed by Mayer (2005) is a compilation of Bradley's model of working memory; Paivio's dual coding theory and Sweller's theory of cognitive load which provide descriptions of how the brain processes information or how learning occurs. The CTML emphasises the combination of texts and pictures enables effective learning compared to learning with only words or pictures (Mayer, 2003). Mayer (2002) proposes three assumptions: the dual-channel assumption, the limited capacity assumption and the active processing assumption. The dual-channel assumption states that separate channels process pictorial and auditory information (Pavio, 1986) in the working memory (Baddeley, 1986). The channels have a limited capacity for processing asserted by the limited capacity assumption (Sweller, 1994). The active processing assumption suggests that people construct knowledge meaningfully when cognitive processes are carried out in a coordinated manner during learning; for example, during a lesson selecting relevant material, organising it into coherent mental structures, and integrating it with their existing knowledge (Mayer, 1997). Multimedia entail the combination of words and pictures, which suggests that learning through multimedia occurs when mental representations are formed from the words and pictures (Mayer, 2005). The words can be vocalised or written and pictures can be any form of graphical imagery including diagrams, animations, or simulations. Multimedia instructional approaches attempt to use the cognitive research to combine words and pictures to optimize learning as illustrated in Figure 2.1 below:

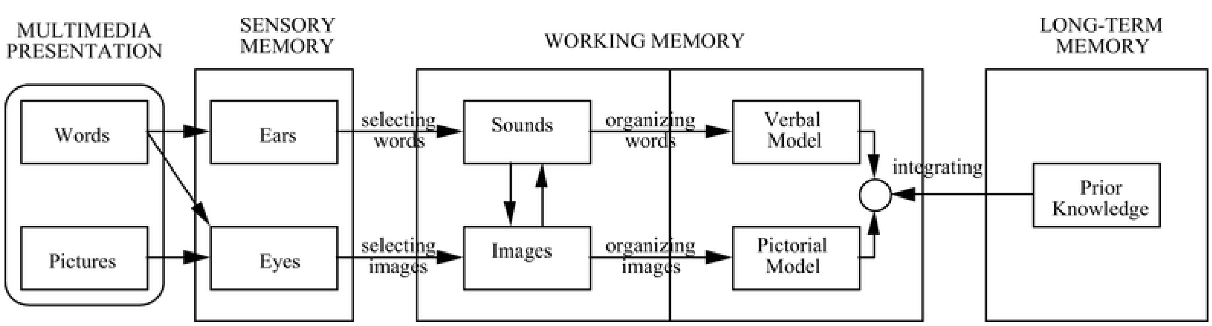


Figure 2.1. A representation of how memory works according to Mayer's CTML (adopted from Mayer, 2005).

Figure 1 above illustrates Mayer's (2005) CTML which presents five stages of representation of words and pictures that occur as information is processed by memory. Each form represents a particular stage of processing in the three-memory stores model of multimedia learning. The first stage of representation is the words and pictures in the multimedia presentation itself. The second stage is the acoustic representation (sounds) and iconic representation (images) in the sensory memory. The third form is the sounds and images in working memory. The fourth stage of representation is the verbal and pictorial models which are also found in working memory. The fifth stage is prior knowledge, or schemas, which are stored in long-term memory.

Mayer (2005) claims that content knowledge held in schemas which are cognitive constructs that organise information for storage in long-term memory. This concurs with cognitive constructivism of Piaget (1958) who describes new knowledge as forming new schemas during the learning process. Schemas organise simpler elements that can then act as elements in higher order schemas (von Glesserfield, 2003). Mayer (2005) declares that as learning occurs, increasingly sophisticated schemas are developed and learned procedures are transferred from controlled to automatic processing. Automation opens capacity in working memory for other functions. This process of developing increasingly complicated schemas that build on each other is also similar to the explanation given by Chi, Glaser and Rees (1982) for the transition from novice to expert in a domain. The CTML underpins this research as it guides and informs the manner in which this research will be approached, conducted and interpreted. The CTML is significant in responding to the research questions as it places emphasis on how knowledge is constructed or could be enhanced. The CTML declares that the role of the learners is to be active in the construction process to ensure enhanced learner performance (Mayer, 2009).

Adopting the CTML as the lens to view the outcomes of the present research is done in consideration that instructional method is important, not the multimedia, no matter how sophisticated. Ultimately, the validation of the results of the study using the CTML lens lies in the fact that this theory has exhibited “staying power” and that continues to demand attention and exert influence in the fields of science education. The power of the theory lies in its dynamic structure, in which it is expected and even driven to constantly change as new information and multimedia is discovered and tested in the field of cognitive science (Mayer, 2009).

Mayer (2001) presents 12 principles that educators can use in the selection and integration of multimedia in the classroom. Figure 2.2 summarises the multimedia learning design principles.

Principle	Definition
Five Evidence-Based and Theoretically Grounded Principles for Reducing Extraneous Processing	
Coherence	Reduce extraneous material
Signaling	Highlight essential material
Redundancy	Do not add on-screen text to narrated animation
Spatial contiguity	Place printed words next to corresponding graphics
Temporal contiguity	Present corresponding narration and animation at the same time.
Three Evidence-Based and Theoretically Grounded Principles for Managing Essential Processing	
Segmenting	Present animation in learner-paced segments
Pre-training	Provide pre-training in the name, location and characteristics of key components
Modality	Present words as spoken text rather than printed text
Two Evidence-Based and Theoretically Grounded Principles for Fostering Generative Processing	
Multimedia	Present words and pictures rather than words alone
Personalization	Present words in conversational style rather than formal style

Motivational Design Principles

Figure 2.2. Mayer's Multimedia Learning Design principles (adopted from Mayer, 2001:2008)

Congruently, Mnguni's (2014) model of visualisation processing asserts that learning occurs in three main stages; internalisation, conceptualisation and externalisation. Internalisation describes how sense organs (eyes and ears) assist the brain to absorb information from the environment. Conceptualisation focuses on the construction of meaning and cognitive visual models. Furthermore, prior knowledge that has been stored as cognitive visual models may be retrieved from long-term memory and reconstructed or revised in working memory, based on new knowledge during conceptualisation. Lastly, externalisation refers to the production of external visual models by way of expressing cognitive mental schemas (Mnguni, 2014). For example, learners express the information through writing, orally or drawing mind maps.

In conclusion, the CTML and Mnguni's (2014) model of visualisation are relevant to the present research, as they point out the attributes of VR in mental processing and positive influence it presents on learners' understanding of mitosis. Furthermore, it plays an imported role in analysing the effects of the application of VR in the Life Science classroom. Overall, the theoretical framework guided the research design, methodology and data collecting instruments and data analysis as described in the next section.

2.5.1 Application of theoretical framework to present research

In the present research, an animation is used as an intervention strategy in the Life Sciences classroom. The researcher used Mayer's 12 principles of Multimedia learning in selecting the appropriate animation to be used in the intervention lesson. In this regard, the animation is considered as both an instructional strategy and as an alternative to practical activities. Clark and Mayer (2009) emphasise the power of VR in being alternative to practical activities while Winn (2010) highlights the strength of VR in providing a constructivist learning environment. Based on these assertions in mind the present research is based on the differences in performances of learners from the experimental group in pre- and post-test. To measure the difference in performance, a single test was used as both pre- and post-test. The items of the knowledge test were selected to measure the impact of VRs in that it included items that could be represented in both words and pictures (Mayer, 2009; Mnguni, 2014).

Mayer (2009) emphasises that VR in the educational context refers to learning media that cater for different learning styles. The present research took into cognisance that VR might impact differently on learners with different learning styles. The questionnaire that was used as one of the data collecting instruments which was designed to detect the impact of the animation used as an instructional media to learners with different learning style. Semi-structured interviews were used to track what learners had expressed in both the questionnaire and the tests for further elucidations.

This chapter explored the key debates in the literature on the relevance of VRs in the classroom. Various learning theories examined and how they influence the process of teaching and learning of science. The literature review addresses learning in the Life Sciences classroom in relation to different learning styles. The chapter also reviewed literature that speaks to various teaching strategies such as inquiry-based learning and cooperative learning. There were discussions on the effectiveness of virtual learning as an alternative to hands-on practical activities learning and teaching of biological concepts. The virtual learning environment (VLE) explores its role in relation to managing available resources.

CHAPTER 3: RESEARCH DESIGN AND METHODOLOGY

3.1: Introduction

In the previous chapter, literature was reviewed on the effectiveness of animations on learners' conceptualisation of scientific content. The researcher discussed following: theories of learning, teaching and learning in a science classroom, learning styles and the theoretical framework which informs the present study. The present research aimed to investigate the extent to which the use of an animation in learning Life Sciences could improve Grade 10 learners' understanding of mitosis. The present chapter therefore describes the research approach, research design, population and sampling, data collection techniques and data analysis.

3.1.1: Methodology

Creswell (2013) defines research methodology as a systematic, theoretical analysis of the methods applied to a field of study. He further asserts that 'methodology' comprises theoretical analysis of the body of methods and principles associated with a branch of knowledge. According to Buchanan and Bryman (2009), research methodology refers to the philosophy and framework that fundamentally guide the entire research process. According to Creswell (2013), there are three traditional approaches to conducting research namely quantitative, qualitative and the mixed-methods approach. The choice of the research method should be based on the researcher's convictions, beliefs and interests (Creswell, 2013). Other important factors in choosing research method include research aim and questions, epistemological and norms and practice of the researcher (Lincoln & Guba 1985). Another significant aspect of the methodology is the research paradigm, which is discussed in detail in the following section.

3.1.2 Research Paradigm

Research paradigms refer to the intrinsic beliefs held by researchers and they guide the research approach (Thanh & Thanh, 2015). Thanh and Thanh (2015) state, that term paradigm refers to a research culture with a set of beliefs, values and assumptions that a community of researchers has in common regarding the nature and conduct of research. In the present research, paradigm implies a pattern, structure and framework or system of scientific and academic ideas, values and assumptions (Olsen, Lodwick & Dunlop, 1992). Creswell (2013) proposed four widely accepted research paradigms, namely, positivism, critical theory, constructivism, and realism.

Henning, Van Rensburg and Smit (2004) assert that positivist paradigm entails social reality that is on philosophical ideas. They assert that observation and reason are the best means of understanding human behaviour; true knowledge experience of senses and can be obtained by observation and experiment. Positivism is concerned with uncovering truth and presenting it by empirical means (Henning et al., 2004).

Critical theory assumes that social reality is historically constituted and that it is produced and reproduced by people (Mayer, 2009). Critical theory seeks to transcend beliefs, values and social structures by making these structures and the problems they produce visible, by encouraging self-conscious criticism, and by developing emancipatory consciousness in scholars and social members in general (McLaren, Peter, Hammer & Rhonda, 1989; Creswell , 2013). Creswell (2013) further asserts that the aim of the critical theory is to openly critique the status quo, focus on the conflicts and constraints in contemporary society, and seek to bring about cultural, political and social change that would eliminate the causes of alienation and domination.

Creswell (2013) describes the constructivist paradigm as multiple local constructed realities that result in subjected or created findings. The interpretivist research paradigm is associated with the constructivist paradigm. As observed by Creswell (2013), interpretive researchers believe that reality consists of people's subjective experiences of the external world; therefore, they may adopt an inter-subjective epistemology and the ontological belief that reality is socially constructed. Realism is an increasingly useful worldview for some social scientists (Sobh & Perry, 2006). Indeed, it is a "growing movement transforming the intellectual scene" in management research. Its philosophical position is that reality exists independently of the researcher's mind, that is, there is an external reality (Bhaskar, 1978; Harre & Madden, 1975).

Similarly, Creswell (2013) asserts that in the realism paradigm reality is real but only imperfectly and probabilistically apprehensible.

This external reality consists of abstract things that are born of people's minds but exist independently of any one person; it "is largely autonomous, though created by us" (Magee, 1985, p. 61). A person's perceptions are a window into that blurry, external reality. Lastly, Gummesson (2000), as referring to this external reality as consisting of structures that are themselves sets of interrelated objects, and of mechanisms through which those objects interact. Therefore, realism research is searching towards an understanding of the common reality of an economic system in which many people operate interdependently (Shob & Perry, 2012). Realists believe that there is a "real" world "out there" to discover (Guba & Lincoln, 1994).

The present research employed the realism paradigm as it enables the use of common methodologies such as case studies or convergent interviews, as well as, the interpretation of research issues by qualitative and some quantitative methods such as structural equation modelling. Furthermore, in the realism paradigm findings are said to be true as the researcher is value-aware and triangulates any perceptions he/she collects (Creswell, 2013).

3.2 Different research methodologies

In this section, the researcher presents different research methods available to researchers, together with their advantages and disadvantages. Thereafter she will indicate which methods were adopted in the present study and why such a decision was made.

3.2.1: Qualitative Research Approach

Holliday (2007) asserts that qualitative research puts emphasis upon exploring and understanding the meaning individuals or groups ascribe to a social or human problem. Denzin and Lincoln (2005) describe this approach as gaining a perspective of issues from investigating them in their own specific context and the meaning that individuals bring to them. According to Creswell (2014), qualitative research focuses upon drawing meaning from the experiences and opinions of participant, meaning, purpose, or reality. Cohen and Arieli (2011) and Merriam (2009) describe qualitative research methods as inductive, with the underlying assumptions being that reality is a social construct, that variables are difficult to measure, complex and interwoven, that there is a primacy of subject matter and that the data collected will consist of an insider's viewpoint. Almalki (2016) eludes the point that qualitative research study values individuality, culture and social justice, which provides a content and context rich breadth of information, which, although subjective in nature, is current.

According to Creswell (2014), qualitative research is an exploratory approach emphasising words rather than quantification in gathering and analysing the data. Qualitative research methodology involves inductive, constructivist and interpretative exploratory approach with the following main stresses: to view the world with the eyes of the examinees, to describe and take into account the context, to emphasise the process and not only the final results, to be flexible and develop the concepts and theories as outcomes of the research process (Bryman, 2017). As observed by Opie (2004), in a qualitative research methodology data are gathered more in a verbal and visual than in a numeric form. When analysing the gathered data, statistical procedures are also not used, but instead predominantly qualitative analysis, the essence of which is searching for codes in the analysed materials (Bryman, 2017). Charmaz (2006) asserts that the coding process forms the main part of the qualitative analysis of the material. Bryman (2017) argues that qualitative analysis of the material starts with defining the coding units, followed by the appropriate phenomena records according to our judgment and analysing the characteristics of these phenomena.

In many cases, qualitative research methodology is oriented towards examining individual cases (Creswell, 2014). For this purpose, the qualitative study is conducted as a study of one case only or a smaller number of cases. Therefore, the techniques of data collection are adjusted to a small-scale analysis, enabling the researcher to get to know the social environment. In data collection Creswell (2013) observes that the researcher is not limited to one source or one technique only as apart from the data acquired by interviews and observation, usually also different documentary sources are used.

3.2.2: Quantitative Research Approach

According to Rovai et al. (2014), quantitative research is regarded as a deductive approach towards research. In this regard, Lincoln and Guba (1994) observed that quantitative researchers regard the world as being outside of themselves and that there is an objective reality independent of any observations. Lincoln and Guba (1994) also contend that by subdividing this reality into smaller, manageable pieces, for the purposes of present research, this reality can be understood. It is within these smaller subdivisions that observations can be made and that hypotheses can be tested and reproduced with regard to the relationships among variables. Creswell (2014) observed that the researcher typifies quantitative research method putting forward a theory that is exemplified within a specific hypothesis, which is then put to the test; conclusions can then be drawn with regard to this hypothesis, following a series of observations and an analysis of data. A feature of this approach towards research is that the collection and analysis of information is conducted utilising mathematically based methods (Muijs, 2011).

Bernard, Wutich and Ryan (2016) assert that a quantitative approach makes use of numerical data from a sample of a population to generalise findings of the population that is being studied. According to Creswell (2012), quantitative research method is used to quantify the problem by way of generating numerical data or data that can be transformed into usable statistics. He further asserts that quantitative research method is used to quantify attitudes, opinions, behaviours, and other defined variables – and generalise results from a larger sample population. Bernard et al. (2016) observe that quantitative research uses measurable data to formulate facts and uncover patterns in research. Quantitative data collection methods are much more structured than qualitative data collection methods.

On the other continuum, a qualitative approach entails an in-depth study of a phenomenon, while, a mixed methods approach incorporates elements of both quantitative and qualitative approaches for data collection. Opie (2005), Lincoln and Guba (2007) and Creswell (2013) define qualitative research as exploratory research that is used to gain an understanding of underlying reasons, opinions and motivations. Creswell (2013) further asserts that qualitative research method provides insights into the problem or helps to develop ideas or hypotheses for potential quantitative research. According to Lincoln and Guba (2007), qualitative research is used to uncover trends in thought and opinions, and search deeper into the problem. Qualitative data collection methods vary using unstructured or semi-structured techniques.

According to Creswell (2014), qualitative research is characterised by data are gathered more in a verbal and visual than in a numeric form. He further asserts that when analysing the gathered data, statistical procedures are also not used, but instead predominantly qualitative analysis, the essence of which is searching for codes in the analysed materials. The main part of the coding process, i.e. interpreting the analysed text and attributing the meaning (of key words, notions, codes) to its individual parts (Charmaz, 2006; Bryman, 2004; Flick, 1998) respectively.

Lincoln and Guba (2007) observe that qualitative research study is oriented towards examining individual cases (idiographic approach). Creswell (2014) agrees with this notion and further asserts that the study is mostly conducted as a study of one case only or a smaller number of cases, therefore the techniques of data collection are adjusted to a small-scale analysis, enabling the researcher to get to know the social environment. Creswell (2014) further observes that in qualitative study data collection one is not limited to one source or one technique only. Apart from the data acquired by interviews and observation, usually also different documentary sources are used, such as personal documents (a birth certificate, an employment record, a passport, letters and photos), different records produced in the process of data collecting, transcriptions of tape recordings, video and shots. According to Creswell (2014), only the triangulation – the pluralism of data collection techniques and their mutual combination can provide for linking the findings of individual phenomena or aspects into a meaningful integrity.

3.2.3: Mixed research approach

The mixed-methods approach entails the combination of both quantitative and qualitative approaches. Mixed-methods approach proposes two categories of research designs, namely, sequential and concurrent designs (Creswell, 2013). A sequential mixed-methods designs (explanatory or exploratory) refer to the collection of the first set of data using one method, followed by the second method; for example, the collection of quantitative data thereafter the collection of qualitative data. The analysis of the data from the first method precedes design or execution of data collection in the second method. On the contrary, in concurrent mixed-methods designs (convergent or embedded), the quantitative and qualitative data are gathered during the same time period, often from the same participants (Guba & Lincoln, 1994).

The present research adopted a sequential mixed method approach to benefit from the advantages of both qualitative and quantitative approaches. Creswell (2013) defines mixed-methods research as a method for conducting research that involved collecting, analysing, and integrating quantitative and qualitative research in a single study or a longitudinal programme of inquiry. This research approach aims to provide a comprehensive understanding of the research problem compared to the use of a quantitative or qualitative approach independently. This type of approach was suitable for the present research because it enabled the collection of both quantitative and qualitative data in the investigation of the effectiveness of VR in enhancing Grade 10 learners' understanding of mitosis. The mixed-methods approach enabled the researcher to draw from the strengths of both qualitative and quantitative research methodologies in examining the same phenomenon. Triangulation highlights aspects of a phenomenon more accurately by approaching it from different vantage points using different methods and techniques (Creswell, 2013).

3.2.4: Advantages of a mixed methods approach

Quantitative approaches to research include discrete data and provable results, such as experiments and surveys (Lincoln & Guba, 2007). Creswell (2013) describes qualitative research as being more subjective, often including observation and interpretation of data via ethnography and personal interviews. The present research was designed to include qualitative and quantitative research a mixed-methodology research design. There are some advantages and disadvantages to this approach.

According to Creswell (2013), mixed method research approach employs both quantitative and qualitative approaches concurrently or simultaneously to create a research outcome stronger than either method individually. He asserts that combined quantitative and qualitative methods enable exploring more complex aspects and relations of the human and social world. In the present research, some of these aspects and relationships were analysed quantitatively and qualitatively. In both quantitative and qualitative methods, concepts can be imprecise and open to interpretation. According to Lincoln and Guba (1995; 2007), the issue is not quantitative versus qualitative methods at all, but whether one is taking an “analytic” approach to understanding a few controlled variables, or a “systemic” approach to understanding the interaction of variables in a complex environment.

3.3: Justification for the choice of mixed method research approach

The present research adopted a sequential mixed method approach because the approach provides a broader perspective on the phenomenon being studied. Opie (2004) observed that a single-approach design might only include experiments to determine cause and effect regarding a specific issue. In this manner, it might only use observation to tell the story of why a problem occurred. Opie (2004) and Creswell (2013) argue that a mixed-approach design uses the strengths of both methodologies to provide a broader perspective on the overall issue. A mixed method approach limits personal bias. Charmaz (2009) claims that a pragmatic researcher leans more to the definitive answers provided in quantitative research while those who think in a less linear manner might have a better ability to perform qualitative analysis. If a researcher leans toward a particular research methodology, the research could suffer from personal bias unless adjustments are made to account for a methodology.

Creswell (2013) also declares that mixed-method design expands the research in a way that a single approach cannot. The process of offering a statistical analysis, along with surveys and interviews, makes the research more comprehensive. The present research gleaned information from other research studies and mixed methodologies which offer the collection of more data. As a result, there is simply more information from which to develop more hypotheses. In this regard, Charmaz (2009) argues that mixed methodology research may advance the timeline of a debate by offering more data for future discussions and research hence the present research adopted this research approach. Literature has reported that a mixed method approach provides diverse answers to the research problem.

Lincoln and Guba (2007), claim that quantitative analysis inherently seeks for one answer. For example, when conducting experiments, the goal is to find the one consistent truth throughout the experiment. On the other hand, Lincoln and Guba (2007) also claim that qualitative research inherently sought multiple answers as interviews reveal a variety of information that may be different, yet true at the same time. Using the typology of Creswell and Plano Clark (2007), the mixed methods research design for the present research may be described as a triangulated multilevel model. Kumar (2019) describes this variant as employing different methodologies (quantitative and qualitative) to address different levels (macro and micro) within a system.

Creswell (2013) proclaims that most research studies begin with a qualitative observation of an event or phenomenon. He asserts that a qualitative study offers the opportunity to provide subtle details that outline a research problem. A mixed method approach enables the validation or invalidation data when multiple data collection strategies are combined. This approach relegates qualitative analysis to an exploratory tool and does not maximise quantitative analysis as a tool to both explore and define a problem and potential solutions. For these reasons, a mixed method approach was the suitable research methodology for the present research.

3.4 Sample description

Having decided on the research approach, another critical aspect of research is to decide on the sampling approach to be used. Alvi (2014) defines a sample population as a group of relatively smaller number of people selected from a population for investigation purpose. Alvi (2014) further states that the process of selecting appropriate participants from a population is sampling. In this regard, Creswell (2014) observes that in a research study, it is impossible to assess every single element of a population so a group of people (smaller in number than the population) is selected for the assessment. Based on information obtained from the sample, the inferences are drawn for the population. The more the sample is representative of the population, the higher is the accuracy of the inferences and better is the results generalizable (Alvi, 2014). According to Creswell (2014) and Alvi (2014), a sample represents the characteristics of elements that are similar to that of entire target population. The results are said to be generalisable when the findings obtained from sample are equally true for the entire target population (Creswell, 2014). The present research employed a purposive sampling method as this method enabled the selection of respondents based on specific characteristics that make them holders of the data required for this study. This present research employed a criterion sampling strategy. According to Creswell (2014), the criterion sampling technique enables the researcher to decide on the typical characteristics of the participants and the number of the participants. For example, the age, place of residence, gender class, profession, specific learning barrier.

In the present research, data were collected from a school in Tembisa Township in Johannesburg. There are eight secondary schools in Tembisa. The researcher divided the schools into two quadrants according to their geographical location. The researcher then picked up one quadrant randomly. From the selected quadrant, one school was selected randomly. This school would therefore be used in the present study as a case study which could provide an indication of the impact of an animation on Grade 10 learners' understanding of mitosis. The selected school met the conditions that suited this study in that it is one of the under-resourced schools in Ekurhuleni District. The researcher was interested in investigating the effectiveness of an animation on grade 10 learners' content understanding. Two grade 10 Life Sciences classes that were taught by the same teacher were randomly selected. The experimental group consisted of 36 learners and the control group consisted of 31 learners (n=67). As Table 3.1 depicts the experimental group consisted of 16 boys and 20 girls. The control group consisted of 15 boys and 16 girls. The participants' ages ranged between 15-18 years. Table 3.1 provides a demographic summary of the participants.

Table 3.1

Demographic information of the participants

	Males	Females	Ages 15-16	Ages 17-18	Ages 18+	Total
Experimental group	16	20	21	15	0	36
Control group	15	16	23	7	1	31

3.5 Data collection instruments

Creswell (2013) defines data collection as the process of gathering and measuring information on variables of interest, in an established systematic fashion that enables one to answer stated research questions, test hypotheses, and evaluate outcomes. He further asserts that data collection component of research is common to all fields of study including physical and social sciences and humanities. While methods vary by discipline, the emphasis on ensuring accurate and honest collection remains the same (Opie, 2004). According to Lincoln and Guba (2009), data collection methods can be divided into two categories: secondary methods of data collection and primary methods of data collection.

Opie (2004) defines secondary data as a type of data that has already been published in books, newspapers, magazines, journals, online portals etc. Opie (2004) asserts that there is an abundance of data available in these sources on the research area in business studies, almost regardless of the nature of the research area. Therefore, application of appropriate set of criteria to select secondary data to be used in the study plays an important role in terms of increasing the levels of research validity and reliability (Opie, 2004). These criteria include, but not limited to date of publication, credential of the author, reliability of the source, quality of discussions, depth of analyses, and the extent of contribution of the text to the development of the research area (Lincoln & Guba, 2009).

In accordance with Opie, Creswell (2014) defines primary data as information collected by a researcher specifically for a research assignment. In other words, primary data are information that a researcher must gather because no one has compiled and published the information in a forum accessible to the public (Creswell, 2014). Opie (2004) declares that primary data is collected only when a question, issue or problem presents itself that is sufficiently important or unique that it warrants the expenditure necessary to gather the primary data. Opie (2004) observes that primary data are original in nature and directly related to the issue or problem and current data. In this regard, primary data are the data which the researcher collects through various methods like interviews, surveys and questionnaires.

3.5.1 Instrument design

This section explains the development and implementation of data collection instruments used in the present research. A knowledge test, questionnaire and semi-structured interviews were adopted as data collection instruments. In achieving the research aim and objectives, a mixed method approach enabled the triangulation of the data collection instruments. Triangulation increases the validity and reliability of results as it involves the combination of multiple independent measures (Creswell & Clark, 2017). This limits the flaws of an individual approach as they are countered by the combination. As a result, increasing the credibility of results and providing a comprehensive picture of findings.

3.5.2 Content knowledge test

The content knowledge test comprised two sections (A and B). Section A consisted of 12 alternative closed-ended multiple-choice questions that required respondents to select between a range of alternatives along a pre-specified continuum (A, B, C, D). The items were adopted from previous grade 10 Life Sciences past exam papers from the DBE. These items tested for the definition, significance and identification of phases during Mitosis. CAPS (2011b) assert that it is crucial for learners to able to identify, explain and define mitosis in ensuring basic understanding of the subject matter. Section B consisted of three questions that aimed to test learners' higher levels of thinking by soliciting for the application, analysis and evaluation of mitosis cell division process (Bloom, Engelhart, Furst, Hill & Krathwohl, 1956). The items were adopted form (Sterrenberg & Fouche, 2013) Life Sciences textbook. Item 2.1 required learners to identify the different phases of mitosis. Item 2.2 required learners to apply their basic understanding of the concept and provide the sequence in which mitosis occurs. Item 2.3 tested for learners' understanding by evaluating the cell components during the cell division. These items assess key aspects of mitosis hence they are regarded as the most suitable items in evaluating learners' conceptual understanding of mitosis cell division.

Creswell (2013) asserts that a content knowledge test best measures the degree of change after an intervention. Content knowledge tests are said to be easy to code, analyse, interpret and are relatively economic data collection tools for the researcher (Creswell, 2013). This instrument supports the objectives of evaluating how VR impacts learners' understanding of mitosis. In relation to the present research, the content knowledge test examined grade ten Life Sciences learners' conceptual understanding before and after the intervention lesson. The content knowledge test also enabled the gathering of data in a short space of time which was economically efficient for the researcher. Consequently, a content knowledge test was deemed as the most suitable data collection instrument in addressing research sub-question (a) in the present research. Content validity and reliability of the content knowledge test was ensured by subjecting the instrument to a panel of experts and the instrument was piloted to a small number of grade 10 Life Science learners in a high school. The knowledge test standardised the format of assessment for all participants. Cronbach Alpha value was calculated to ensure reliability of results (Refer to Chapter 4.1).

3.5.3 Questionnaire

The present research adopted a questionnaire as a data collecting instrument in addressing research sub-question (b) stated in chapter one. Questionnaires consist of questions that have been printed and distributed to the respondents for completion (Creswell, 2014). Similarly, Warwick and Lininger (2014) define questionnaires as a written set of questions or statements that assess attitudes, opinions, beliefs, and biographical information. Bearing in mind that both qualitative and quantitative approaches were used; questionnaires that combine both the close-ended and open-ended formats were designed. In the present research, the questionnaire had open-ended sections that required learners to elaborate on their choice of response.

The questionnaire consisted of ten closed and open ended items which solicited for learning difficulties associated with learning through an animation. The open ended items required respondents to elaborate on their choice of selected alternatives along a pre- specified continuum (Agree, Neutral & Disagree). Each item solicited for a learning difficulty that were identified and mentioned in the literature review by (Inna & Lowther, 2010; Cook, 2010);learning through an animation; interpretation of pictures; understanding language; following pace; paying attention when learning through VR. The questionnaire was subjected to a panel of experts, as well as, piloted on a sample of learners who had been exposed to learning through an animation. As stipulated by Opie (2004), a useful method for checking a questionnaire and making sure it is accurately capturing the intended information is to pre-test among a smaller subset of target respondents. The questionnaire enabled the collection of appropriate data in a short space of time, allowed for comparable and amenable analysis, minimized bias in formulating and asking questions, and to make questions engaging and varied (Creswell, 2014). For these reasons, a questionnaire served as the most suitable data collection instrument in addressing research sub-question (b) (Refer to Appendix F).

3.5.4 Semi-structured interviews

Semi-structured interviews are in-depth interviews that require respondents to answer pre-set open-ended questions (Bryman, 2017). Creswell (2013) asserts that semi-structured interviews are conducted with the use of a guide to the questions and topics to be covered. The interviewer has some discretion about the order in which questions will be asked, but the questions are standardised, and probes will be provided to ensure that the researcher covers the correct material. Brinkmann and Kvale (2014) declare that this kind of interview collects detailed information in a style that is rather conversational. Semi-structured interviews are often used when the researcher wants to investigate deeply into a topic and to understand thoroughly the answers provided. In the present research, the interview schedule consisted of ten key questions that solicited the central research question on learning difficulties associated with learning through an animation.

The questions aimed to gain deeper understanding precisely of the learning challenges with interpretation and understanding of imagery, sound and texts as well as pacing in learning through an animation. The research adhered to the following multimedia principles during the question development stage: providing clear questions, avoiding non-multi dimensionality and misguiding questions (Bogdan & Biklen, 1997).

During the research, it was necessary to pay particular attention to the following during the semi-structured interviews: avoiding guidance, non-deviating from the aim and providing adequate time to respond (Krueger & Casey, 2000). In ensuring validity, the interview schedule was piloted to a small number of learners that had been mentioned in the previous paragraph. The semi-structured interviews were audio-recorded to avoid reporting relatively unreliable data through means of handwritten notes. This guides the researcher to focus on interview content and verbal prompts, hence enabling the generation of a verbatim transcript of the interview. Ethical issues were adhered to in ensuring respondents anonymity during the interview (Refer to Appendix G).

3.5.5 Administration of data collection instruments

After the development and piloting of the data collection instruments, an animation was selected. Purposeful sampling was adopted in the selection of a School. Two grade 10 Life Sciences classes were randomly assigned either being the experimental group or control group. Pre-intervention tests were administered to learners in both groups. Thereafter, the teaching of mitosis using an animation occurred in the experimental group while traditional teaching of mitosis occurred in the control group. Two weeks after intervention lessons post-tests where administered to learners in both groups. A questionnaire was administered to learners from the experimental group soliciting for learning difficulties associated with an animation. Semi-structured interviews were conducted on a selected number of learners from the experimental group as illustrated by *Figure 3.1* below.

3.6: Animation

The animation used in the present research was adopted from (https://www.youtube.com/watch?v=SEJuGFsNeBI). The narrated animation represented the process of mitosis and took three minutes 18 seconds to run. The animations began by defining mitosis and displayed the formation of chromosomes. The animations illustrated the different phases of mitosis, interphase, prophase, metaphase, anaphase, and telophase. Moreover, it depicted the changes occurring at each phase of mitosis. The animations used graphical conventions of various colours and shape to represent all the cellular structures and components relevant to mitosis. As the animations displayed dynamic pictures, texts were also displayed on the pictures corresponding to the visual pictures of mitosis. The text explained mitosis process by describing what was happening in the animations while it ran. The narration had similar words as the text and both played simultaneously to explicitly explain the changes occurring at each stage. The researcher adhered to Mayer's principles of multimedia learning in selecting the animation (Refer to Figure 2.2).

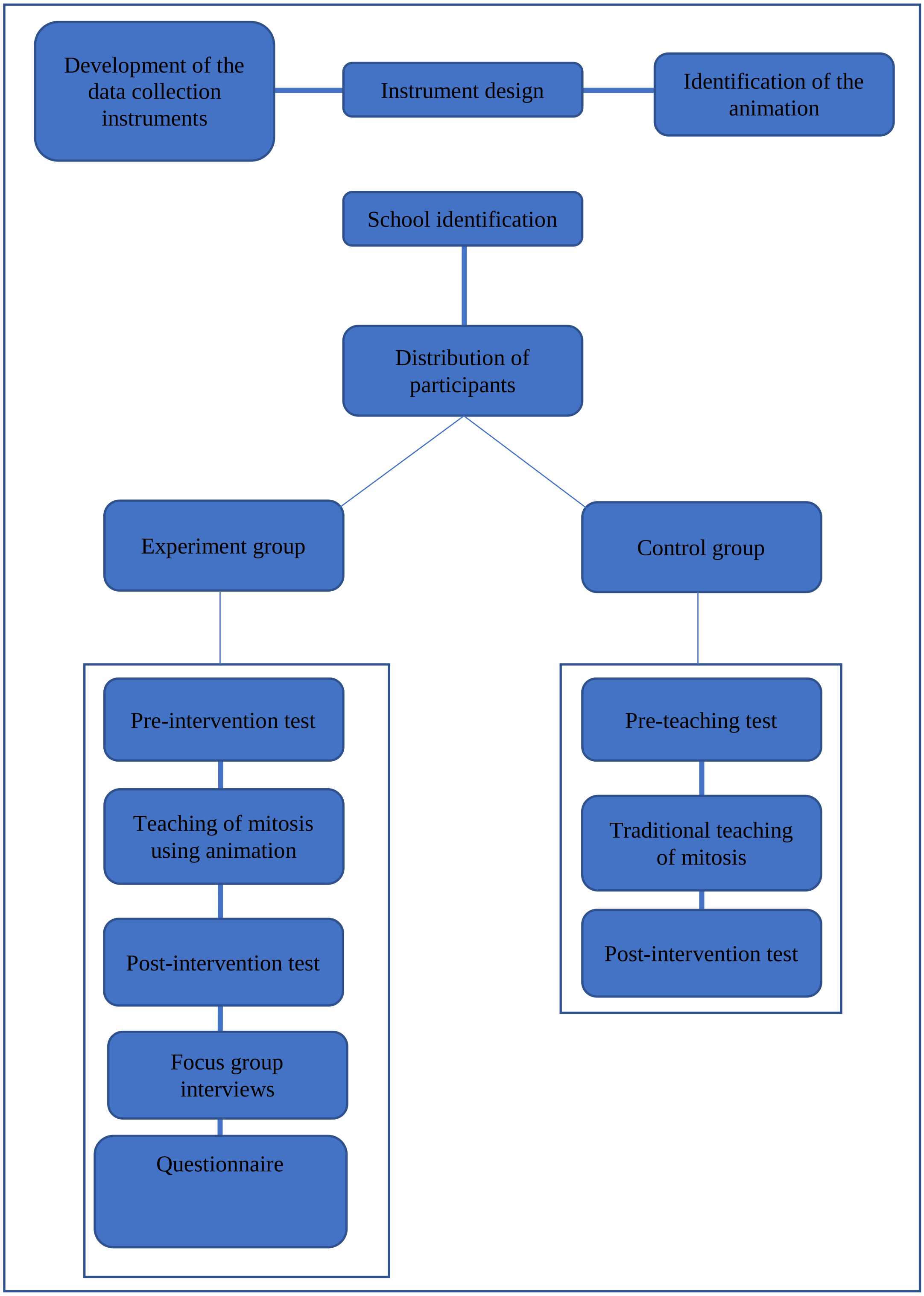


Figure 3.1 A summary of data collection

3.7: Data analysis methods

Data in this mixed-methods research were analysed quantitatively and qualitatively. Data collected through tests were analysed quantitatively and qualitatively. Quantitative data analysis aimed at summarizing and making generalizations from the sample to the population. A systematic manner of gathering data was adopted in order to understand and interpret the meaning of responses provided. For the quantitative phase of the study, calculations of descriptive statistics such as frequency distribution, mode, mean and standard deviation using of SPSS software (Creswell, 2013; Pieterson & Maree 2007; Ary, Jacobs, Irvine & Walker, 2018). These statistical measures of central tendencies collectively aid in determining, quantitatively, whether there will be a significant difference in performance between the pre-test and post-test scores.

After completing the administration of the tests and questionnaires, *IBM SPSS software* was used for statistical analysis of the data. The software was used to generate tabulated reports, charts, and plots of distributions and trends, as well as generate descriptive statistics such as means, medians, modes and frequencies in addition to more complex statistical analyses like regression models. In the previous section, a summary of qualitative data analysis has been presented. In addition, in this section, a summary of quantitative data analysis is presented. Data from sections of the tests and questionnaires were analysed quantitatively to deal with the statistical differences between the variables, ranging from the variables obtained from the learners' preferences/negativities information about the use of animation in the Life Sciences classroom.

In analysing the data, part of the process implied the researcher understands how she was actually to make sense of the data. This entailed a form of 'engagement' with the data, which meant risking her everyday stance, attitudes or knowledge in order to acknowledge the 'liminal' experience of living between familiarity and strangeness (Kerdeman, 1998; Denzin & Lincoln, 2000). As such, the researcher's feelings ranged between a feeling of familiarity with the learners' attributions of meaning in their lives and a feeling that I could not identify personally with what they could be feeling or describing. Knowing that I would encounter this 'liminal' experience encouraged me to explore the data with a sense of flexibility and open-mindedness, improvisation and creativity as well as planning and adherence to steps and rules (Janesick, 1998, in Denzin & Lincoln, 2000). Analysis transforms data into findings by bringing order, structure and meaning to the mass of collected data (Patton, 2002, in de Vos et al., 2005). The analytical process "does not proceed tidily or in a linear fashion but is more of a spiral process; it entails reducing the volume of the information, sorting out significant from irrelevant facts, identifying patterns and trends, and constructing a framework for communicating the essence of what was revealed by the data" (de Vos et al., 2005:333).

There is an "inseparable relationship between data collection and data analysis, and this is one of the major features that distinguish qualitative research from traditional research" (de Vos et al., 2005:335). Accordingly, as the data was being transcribed and translated, the researcher found herself identifying patterns of expressions that alerted me to be aware of similar or divergent themes as more data unfolded. Furthermore, "data analysis does not in itself provide answers to research questions as these are found by way of interpretation of the analysed data" (Kruger, de Vos, Fouché & Venter, 2005:218). Interpretation involves explaining and making sense of the data (de Vos, 2005; Denzin, 1989). This again involves an on-going engagement with the process, in that interpretation and analysis are closely intertwined as the researcher automatically interprets as he or she analyses (Kruger et al., 2005). Hence, it was from this combined process of data collection and analysis that a "plausible and coherent" interpretation developed (de Vos, 2005:335). The qualitative data analysis employed the notes and coding method (Opie, 2004). Open and axial type of coding was used. According to Creswell (2014), in open coding, the researcher forms initial categories of information about the phenomenon being studied by segmenting information. Within each category, as suggested by Altheide and Schneider (1996), the researcher then searches for several properties, or subcategories, and looks for data to measure or show the extreme possibilities on a continuum of the property. Open coding preceded axial coding.

Axial coding method in this study involved the investigator assembling data in new ways after open coding. Altheide and Schneider (1996), allude that this method of data analysis involves using a coding paradigm or logic diagram in which the researcher identifies a central phenomenon (i.e., a central category about the phenomenon), explores causal conditions (i.e., categories of conditions that influence the phenomenon), specifies strategies (i.e., the actions or interactions that result from the central phenomenon), identifies the context and intervening conditions (i.e., the narrow and broad conditions that influence the strategies), and delineates the consequences (i.e., the outcomes of the strategies) for this phenomenon. Figure 3.2 below is a summary of data analysis procedure:

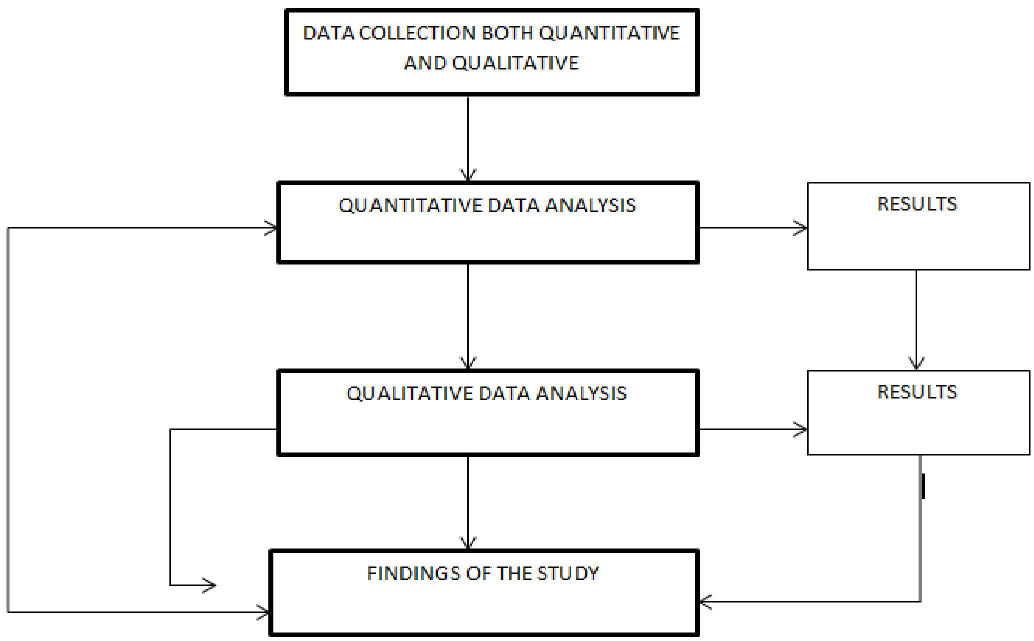


Figure 32. Synthesis of qualitative and quantitative data analysis.

As shown in Figure 3, quantitative and qualitative data were analysed separately but not completely discrete from each other. Results emanating from both qualitative analysis and quantitative analysis were then emerged to generate the findings. Some results emanating from individual quantitative and qualitative data analysis were directly interpreted to generate findings without being merged. This was done to allow these sets of data to validate each other.

3.8: Validity, Reliability, Trustworthiness and Credibility (including triangulation)

In ensuring that appropriate data was collected and analysed in the present research, data collection instruments were subjected to issues of validity and reliability. Validity refers to the extent to a concept is accurately measured whereas reliability refers to extent to which an instrument is accurate (Heale & Twycross, 2015). Heale and Twycross (2015) describe three types of validity; content validity, construct validity and criterion validity. Content validity ensures that the instrument adequately covers the entire domain related to the variable. The researcher may require domain experts' opinion on whether the instrument measures the concept intended (face validity), which is a subset of content validity. On the other hand, construct validity refers to the extent to which an instrument measures an intended construct while criterion validity refers to the extent one instrument relates to other instruments that measure the same variable (Heale & Twycross, 2015). Reliability is the consistency of a measure; internal consistency is commonly used to assess item-to-total correlation (Shutterworth, 2015). For example, Cronbach's alpha is the most commonly used test to determine internal consistency. A reliability score of 0.7 and higher is regarded as acceptable (Fletcher, LoBiondo-Wood, Haber, Cameron & Singh, 2013). Similarly, Lincoln and Guba (2007) proclaim that Cronbach's alpha score is a convenient test used to estimate the reliability, or internal consistency, of a composite score. Creswell (2014) declares that Cronbach's alpha is used under the assumption that there are multiple items measuring the same underlying construct: like in the present research, there were several learning difficulties that were measured in the questionnaire.

Validity and reliability in a quantitative data collection approach is ascertained through the use of statistical instruments such as measures of correlation and regression and t-test. Triangulation refers to the use of several data sources and aims to improve the validity and reliability in quantitative research approaches as an exception may lead to disconfirmation (Creswell, 2013). In the qualitative phase of the present research an area of concern was the qualitative aspects of the present research with reference to Naturalistic Inquiry of Lincoln and Cuba, (1985) and in search of subjectivity-one's own (Stoynoff, 1997). According to Cuba and Lincoln (2007), trustworthiness in a qualitative research may be summarized as follows: transferability, dependability, confirmability, and credibility.

Transferability*:* As defined by Opie (2004), this refers to applicability of the research findings. The envisaged problems in this regard would be the representative nature of the study population. Investigating effectiveness of animations as alternatives to practical activities among learners who have vast knowledge of multimedia might result in misguided conclusions as attitudes of learners towards use of multimedia in the classroom in Gauteng might vary from area to area.

Dependability: Opie (2004) claims that dependability refers to the consistency of the situation. Lincoln and Cuba (1985) argue that reliability is not static and as a result, inconsistency is inevitable in terms of the results obtained by similar research projects. Consistency in the present research was evaluated through triangulation which involved comparison of results from three research instruments (knowledge test, questionnaire and semi-structured interviews) further more consistency was also evaluated through checking whether the interview questions were eliciting the desired knowledge from the learners for instance, if the learners would respond honestly. Sometimes a negative response during an interview might be regarded as a breach of etiquette. Such cultural dictates of behaviour might have serious implications for the dependability of phenomenological research methods in South Africa.

Confirmability: According to Opie (2004), this referred to inter-subjective judgment. Conducting more than two group focus interviews might increase the confirmability although personal biases certainly played a role. One of the biases might be enthusiasm in appreciating the existence of different animations amongst the Life Sciences learners and educators.

Credibility: Golafshani (2003) asserts credibility of a study refers to the extent to which the study corresponds with reality. That there would be a fair correspondence in the conclusions to be drawn from interviews with learners. In the present research credibility was achieved through the use of a variety of data collection instruments (knowledge test, questionnaire and semi structured interviews).

Schwandt, Lincoln and Guba (2007), assert that in qualitative research, a proposition is true if it corresponded to the reality that it attempted to describe. Reality in this research was achieved through striving for objectivity. The researcher strived to avoid being influenced by personal feelings or opinions in considering and representing facts. The employment of more than two research instruments allowed triangulation as means of trustworthy and applicability of results. Creswell (2011) asserts that a qualitative study aims to probe for a deeper understanding and not to search for causal relationships in order to penetrate the human understandings and constructions around a phenomenon. Different insights described the different perspectives that reflect the unique reality and identity of participants. Triangulation is based on the assumption of a fixed object whereas crystallization allowed for an infinite variety of shapes and angles. In that regard, the reality emerged from various data gathering techniques and findings were described as they crystallized from the data (Creswell, 2013).

The present research ascertained validity and reliability by calculating T-test scores (p value) and Cronbach's alpha score to determine validity and reliability of data. T-test (p score) was used to ascertain validity and reliability of results from data collected through the knowledge test while Cronbach's alpha score was used to ascertain validity and reliability of results from data collected through questionnaires. According to Crammer and Howitt (2004) and Gelman (2012) , the p score is a continuous measure of evidence it is typically trichotomized approximately into highly significant, marginally significant, and not statistically significant at conventional levels, with s used as the alpha level for statistical analysis $p \leq 0.01$, $p \leq 0.05$ and $p > 0.10$. Gelman (2012) highlights that the p value is a measure of the rational grounds for accepting or rejecting the hypothesis. The three data collection instruments were triangulated with purpose of qualitative data (questionnaires and semi-structured interviews) confirming quantitative results from the knowledge test.

3.9: Ethics

Ethics relates to the application of moral principles to prevent harming or wronging others, to promote the good, to be respectful and fair (Sieber, 2012:14; Opie, 2004). The researcher has considered the ethical implications for present research and in terms of the University of South Africa Policy on Research Ethics. Ethical clearance certificate form the UNISA College of

Education has been attached as Appendix H and the researcher adhered to the rules and requirements that have been stipulated in the Ethics Policy. School principals of the participating schools were briefed about the intentions of the present research and letters of consent were signed granting permission to carry on with the research (Appendix A). Information sheets (Appendix E,F& G) ensuring confidentiality, anonymity and disclosing all aspects of my research and consent forms were given to the school (Appendix A), parents (Appendix B), teachers (Appendix C) and learners (Appendix D) requesting permission for participation in the research. Participants were also informed that they could withdraw from the study at any time.

CHAPTER 4: RESULT PRESENTATION

4.1: Introduction

The present research investigated the impact of animations as alternatives to practical activities in the Grade 10 Life Sciences classroom. In this chapter, the results are presented which emerged from both quantitative and qualitative data analysis. These results seek to answer the research questions, which are stated in Chapter 1 as:

a) What is the impact of the use of animations in learning Life Sciences on Grade 10 learners' understanding of mitosis?
b) What are the learning difficulties associated with the use of animations in learning Life Sciences Grade 10 Mitosis?

Since the present research employed a sequential mixed method, the data was first analysed quantitatively as a way of exploring the related phenomena and then qualitative in order to explain the emerging phenomena. Presentation of results followed the same sequence even though the results from both quantitative and qualitative analysis were used to validate and complement each other.

Reliability of data for learning difficulties (data from questionnaire) was ascertained through the use of Cronbach's alpha calculated score. The attained score of 0.820 indicates that the data can be considered as reliable since it falls in the score fall within the range of zero and one and is above 0.7 as indicated by Creswell (2013). This score is an indication that should a similar study is carried out under similar conditions same results will emerge.

Concerning the pre- and post-test, the researcher tested the hypotheses:

a) That there is no difference between the scores pre- and post the intervention of the control group.
b) That there is no difference between the scores pre- and post the intervention of the experimental group.

c) That there is no difference between the pre- test scores of the control and experimental group.
d) That there is no difference between the post-test scores of the control and experimental group.

The above hypotheses were tested using the student t-test as well as correlation testing. Results are presented below in table 4.1.

4.2: Responding to the first research question: students' knowledge of mitosis

4.2.1 Students knowledge of mitosis prior to the intervention

The first part of the present research investigated students understanding of mitosis. This was done by giving students a pre- and post-test (Appendix E) to the control and experimental groups of students. The results are presented below per group.

Results showed that students in both groups had a relatively low understanding of mitosis concepts prior to the intervention. For example, the control group had a mean score of 34% (S.D. 8.58%) while the experimental group had a score of 28% (S.D. 8.08%) (Table 4.1).

Table 4.1

Student's performance in the knowledge test

		No	Mean	Std. Deviation	Std. Error Mean
Within control group	Pre-test Control	31	34.1561	8.58226	1.54142
	Post-test Control	31	31.2152	11.35797	2.03995
Within experimental group	Pre-test Experimental	36	28.4314	8.07772	1.34629
	Post-test Experiment	36	51.1438	9.41381	1.56897

As shown in Table 4.2, it was also observed that in the pre-test, the students in the control group had the most difficulties (i.e. scoring less than 50% on average) in items probing their knowledge of the sequence of mitosis, the number of cells after mitotic division, phases of mitosis, the number of chromosomes in a cell, interphase, prophase, and the components of a cell during mitosis. Students performed worse on the item probing the sequence of mitotic phases. The students however performed best on items asking about the definition of mitosis.

Table 4.2

Control group students' performance in the pre-test and post-test in individual items

Items	**Pre-test Control**			**Post-test Control**			**Mean difference**
	N	Mean	Std. Deviation	N	Mean	Std. Deviation	
Definition of Mitosis	31	65%	49%	31	71%	46%	6%
Significance of mitosis	31	48%	51%	31	42%	50%	-6%
Definition of Mitosis	31	81%	40%	31	29%	46%	-52%
Process of mitosis	31	84%	37%	31	84%	37%	0%
Number of cell after cell division	31	29%	46%	31	55%	51%	26%
Phases of mitosis	31	35%	49%	31	19%	40%	-16%
Number of chromosomes in cell	31	48%	51%	31	71%	46%	23%
Anaphase	31	61%	50%	31	32%	48%	-29%
Definition of mitosis	31	97%	18%	31	97%	18%	0%
Interphase	31	39%	50%	31	61%	50%	22%
Significance of mitosis	31	71%	46%	31	58%	50%	-13%
Cell division	31	71%	46%	31	58%	50%	-13%
Prophase	31	42%	50%	31	32%	48%	-10%
Anaphase	31	77%	43%	31	45%	51%	-32%
Telophase	31	74%	44%	31	52%	51%	-22%
Interphase	31	45%	51%	31	32%	48%	-13%
Metaphase	31	71%	46%	31	52%	51%	-19%
Sequence of mitotic phases	31	19%	40%	31	35%	49%	16%
Cell components during mitosis	31	10%	15%	31	14%	13%	4%

Results also showed that in the pre-test, the experimental group had similar conceptual problems as identified in the control group (Table 4.3). However, they performed poorly in some of the items that the control group performed exceptionally. For example, on the items asking about the definition of mitosis, the control group scored 81% (S.D. = 40%) while the experimental group scored an average score of 42% (S.D. = 50%). Likewise, on the item asking about the significance of mitosis, the control group scored 71% (S.D. = 46%) while the experimental group scored an average score of 20% (S.D. = 41%). It is noteworthy that in almost all the items the standard deviation was high, suggesting a significant difference in students content understanding within each group.

Table 4.3

Experimental group students' performance in the pre-test and post-test in individual items

Items	**Pre-test Experiment**			**Post-test Experiment**			**Mean difference**
	N	Mean	Std. Deviation	N	Mean	Std. Deviation	
Definition of Mitosis	36	39%	49%	36	72%	45%	33%
Significance of mitosis	36	33%	48%	36	36%	49%	3%
Definition of Mitosis	36	42%	50%	36	61%	49%	19%
Process of mitosis	36	64%	49%	36	89%	32%	25%
Number of cell after cell division	36	39%	49%	36	67%	48%	28%
Phases of mitosis	36	14%	35%	36	56%	50%	42%
Number of chromosomes in cell	36	50%	51%	36	56%	50%	6%
Anaphase	36	39%	49%	36	36%	49%	-3%
Definition of mitosis	36	94%	23%	36	92%	28%	-2%
Interphase	36	42%	50%	36	50%	51%	8%
Significance of mitosis	35	20%	41%	36	44%	50%	24%
Cell division	36	39%	49%	36	47%	51%	8%
Prophase	36	31%	47%	36	86%	35%	55%
Anaphase	36	47%	51%	36	92%	28%	45%
Telophase	36	53%	51%	36	92%	28%	39%
Interphase	36	39%	49%	36	92%	28%	53%

Metaphase	36	36%	49%	36	89%	32%	53%
Sequence of mitotic phases	36	36%	49%	36	86%	35%	50%
Cell components during mitosis	36	21%	19%	36	50%	19%	29%

4.2.2. Learning Difficulties

a) Genetic terms

A qualitative analysis of the data revealed that students had a number of difficulties with genetics definitions. For example, in the pre-test, majority of students in both groups believed that "mitosis is the division of body cells that results in growth of an organism". However, students from both groups did not realize that in this definition, 'body cell' could include sex cells. They also did not realise that mitosis may not necessarily lead to 'growth of an orgasm' as is the case in mitosis that leads to cell repair. Further analysis also showed that majority of students in both groups believed that "DNA replication is the process whereby one cell gives rise to two cells with the identical genetic make-up as the original cell". In this instance, it is apparent that students confused the doubling (replication) of genetic material in a cell, with the potential doubling of cells as is the case in mitosis.

b) Sequence of mitosis phases

Results also showed that majority of students in both groups could not correctly identify the sequence of phases in mitosis. For example, students (64% in the experimental group) suggested that the sequence of mitosis phases is "interphase, prophase, anaphase, metaphase and telophase". Similarly, in the control group, students (55%) suggested that the sequence of mitosis phases is "telophase, interphase, anaphase, metaphase, and prophase". The same problem was observed when students were asked to label a diagram representing different phases of mitosis in sequence. In Figure 4.1 for example, Student 001 incorrectly identified the different the phases of mitosis.

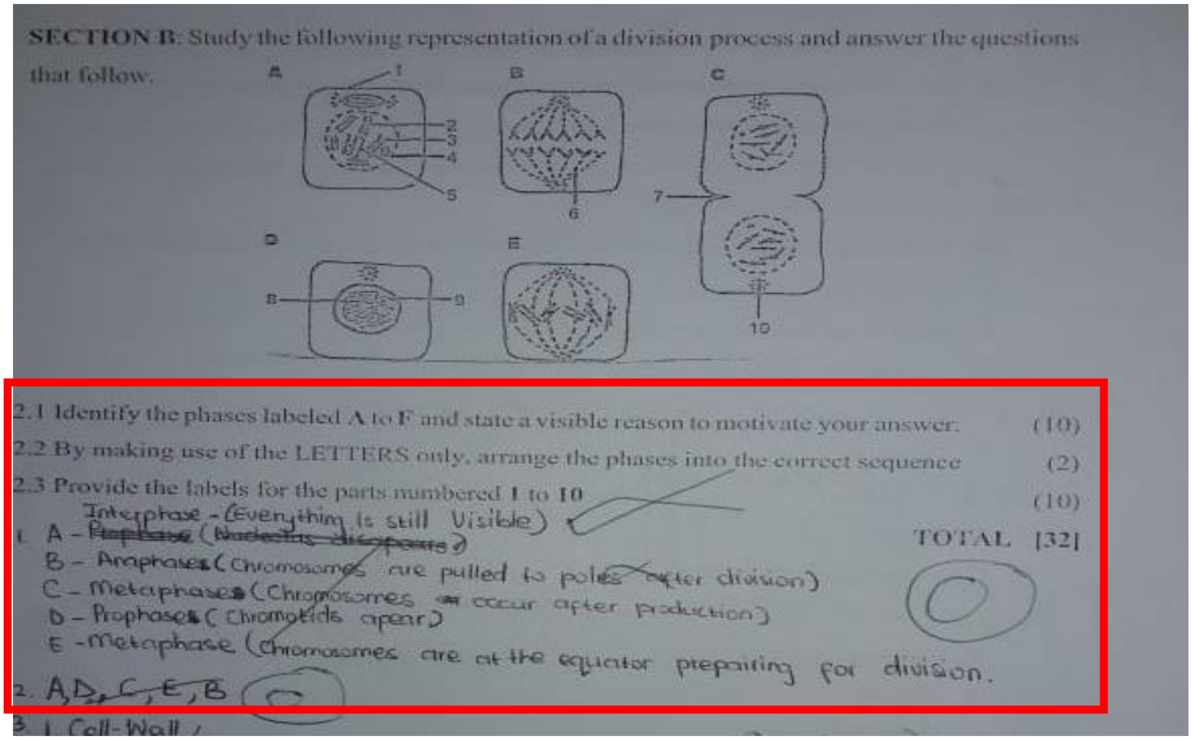


Figure 4.1. An example of how students failed to correctly label and/or arrange mitosis phases.

e) Reasoning difficulties

Data analysis also revealed that majority of students in both groups could not correctly respond to questions where they were required to reason extensively (i.e. higher order cognitive skills). For example, on the item asking students to determine the total number of cells after three mitotic division originating from one parental cell, students could not correctly identify the correct answer. Most students (60% in the control group and 58% in the experimental group) here indicated the answer was either 4 cells or 6 cells, both which are incorrect.

4.2.3 Students knowledge of mitosis after exposure to the intervention

Data analysis revealed that in the control groups, students' performance in the post-test was poorer than in the pre-test. For example, the control group mean score went from 34% (S.D. = 8.58) to 31% (S.D. = 11.36%) (See Table 4.3). A t-test was then carried out to test the hypothesis that *there is no difference between students' performance in the pre- and post-test* (Table 4.4).

Results here showed that there was no statistically significant difference between the performance in the pre- and post-tests (i.e. $p > .05$). However, Levene's test for equality of variances showed that the variance was significantly different in the two tests, albeit mildly (i.e. $p = 0.030$). These results suggest that exposure to the traditional revision session may have had a negative impact on students' understanding of mitosis.

Table 4.4
A t-test comparing the results of the control group in the pre- and post-test.

	Levene's Test for Equality of Variances		t-test for Equality of Means						
	F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
								Lower	Upper
Equal variances assumed	4,963	0,030	1,150	60	0,255	2,94097	2,55683	-2,17345	8,05539
Equal variances not assumed			1,150	55,835	0,255	2,94097	2,55683	-2,18131	8,06325

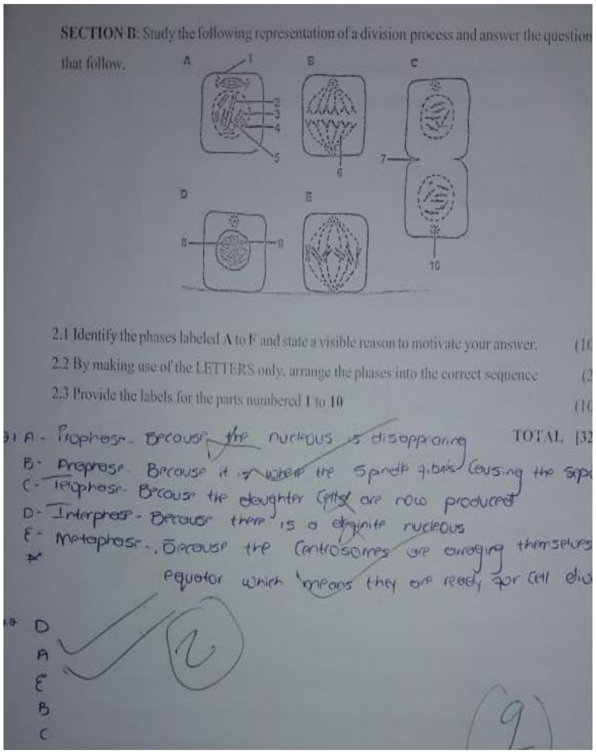
Results also revealed that the in the control group, students' understanding of mitosis concepts dropped on a number of items in the post-test (see Table 4.3). For example, in the pre-test, students obtained an average score of 81% (S.D. = 40%) in item 3 which probed students' knowledge of the definition of mitosis. However, the average score was 29% (S.D. = 46%) in the post-test. The same trend was observed in items probing students' knowledge of the significance of mitosis, phases mitosis and cell division. In all these items, the change (i.e. lower average score in the post-test) was statistically significantly (i.e. $p < 0.05$). There were instances, however, where students' performance improved. For example, the average scores improve significantly (i.e. $p < 0.05$) on items testing students' knowledge of the number of cells after cell division, the number of chromosomes in a cell, interphase, the sequence of mitosis phases, and cell components during mitosis (see Table 4.2).

With regards to the experimental group, however, students' performance improved on average from 28% (S.D. = 8.08%) to 51% (S.D. = 9.41%) (see Tables 4.1 and 4.3). In this instance, Levene's test for equality of variance showed that the variance was not significantly different in the two tests (i.e. p = .403) (see Table 4.5). However, results showed a statistically significant difference in the mean scores (i.e. p < .001) (see Table 4.5). Students' performance improved significantly (p < .05) in all items except the item, which probed students' knowledge of the definition of mitosis in which the mean difference was a 2%. A significant major difference was on the item that asked students to label the phases of mitosis. In these items, the mean difference ranged from 39% to 55% (see Table 4.3). These results suggest that exposure to the animation may have had a positive impact on students' understanding of mitosis.

Table 4.5
A t-test comparing the results of the experiment group in the pre- and post-test.

	Levene's Test for Equality of Variances		**t-test for Equality of Means**						
	F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
								Lower	Upper
Equal variances assumed	0,707	0,403	-10,986	70	0,000	-22,71242	2,06740	-26,83572	-18,58912
Equal variances not assumed			-10,986	68,422	0,000	-22,71242	2,06740	-26,83739	-18,58744

Notably, students in the experimental group had a better understanding of the sequence of phases of mitosis. For example, Learner 51 (experimental group) was able to correctly identify and label all mitosis phases in the post test (Figure 4.2). However, for other students, no change was observed (e.g. Learner 17, control group, Figure 4.3).

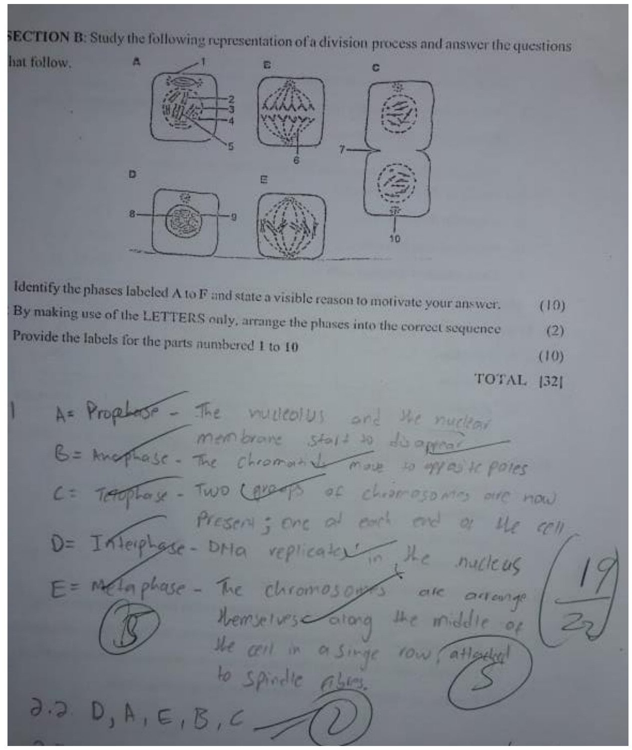


SECTION B: Study the following representation of a division process and answer the question that follow.

2.1 Identify the phases labeled A to F and state a visible reason to motivate your answer. (10)
2.2 By making use of the LETTERS only, arrange the phases into the correct sequence (2)
2.3 Provide the labels for the parts numbered 1 to 10 (10)
TOTAL [32]

2.1 A - Prophase. Because the nucleous is disappearing
B - Prophase. Because it is where the spindle fibres causing the sep
C - Telophase. Because the daughter cells are now produced
D - Interphase - Because there is a definite nucleous
E - Metaphase. Because the centrosomes are arraging themselves equator which means they are ready for cell div

2.2 D A E B C



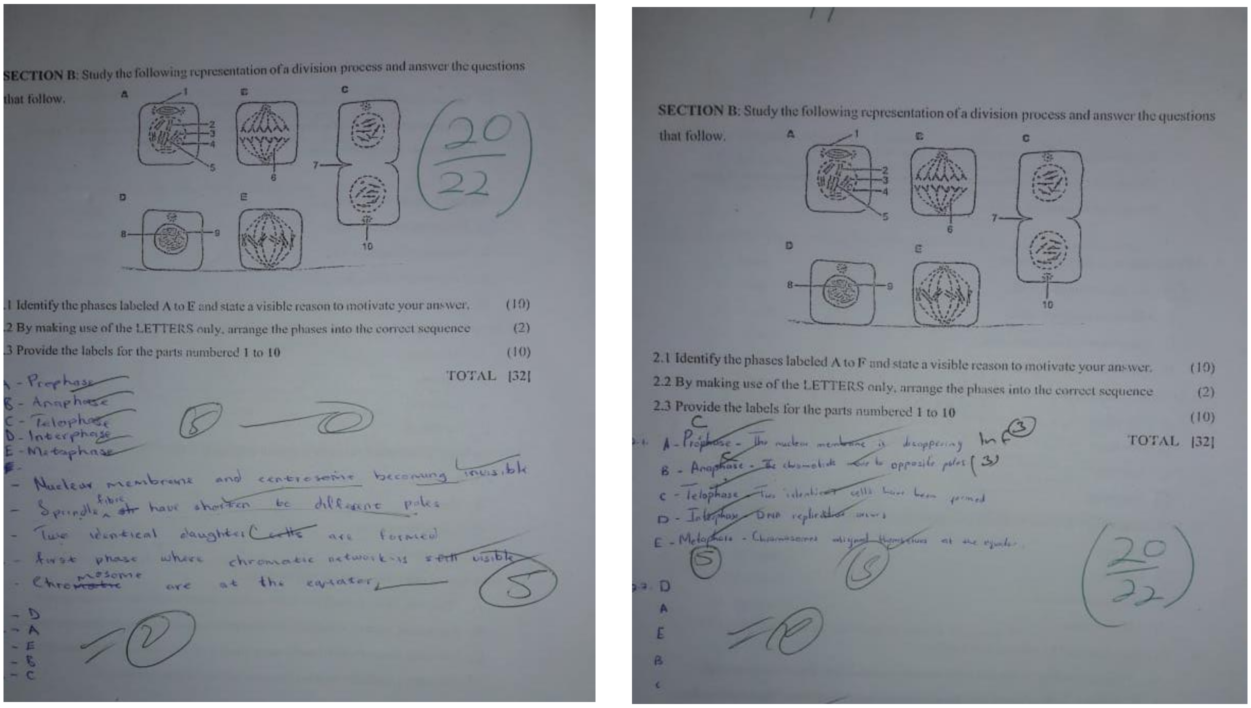
SECTION B: Study the following representation of a division process and answer the questions that follow.

Identify the phases labeled A to F and state a visible reason to motivate your answer. (10)
By making use of the LETTERS only, arrange the phases into the correct sequence (2)
Provide the labels for the parts numbered 1 to 10 (10)
TOTAL [32]

A= Prophase - The nucleolus and the nuclear membrane start to disappear
B= Anaphase - The chromatids move to opposite poles
C= Telophase - Two groups of chromosomes are now present; one at each end of the cell
D= Interphase - DNA replicates in the nucleus
E= Metaphase - The chromosomes are arrange themselves along the middle of the cell in a single row, attached to spindle fibres.

2.2 D, A, E, B, C

Figure 4.2. An example of learner's improved ability to correctly identify the sequence of mitosis phases.



SECTION B: Study the following representation of a division process and answer the questions that follow.

2.1 Identify the phases labeled A to E and state a visible reason to motivate your answer. (10)
2.2 By making use of the LETTERS only, arrange the phases into the correct sequence (2)
2.3 Provide the labels for the parts numbered 1 to 10 (10)
TOTAL [32]

SECTION B: Study the following representation of a division process and answer the questions that follow.

2.1 Identify the phases labeled A to F and state a visible reason to motivate your answer. (10)
2.2 By making use of the LETTERS only, arrange the phases into the correct sequence (2)
2.3 Provide the labels for the parts numbered 1 to 10 (10)
TOTAL [32]

Figure 4.3. An example of a learner where there was no change in content knowledge on the pre- and post-tests.

4.3: Responding to the second research question: learning difficulties associated learning through an animation

4.3.1 Students' opinion on learning mitosis

Results from the questionnaire revealed a positive self-reported impact of the use of animation in the classroom. In this instance, learners were given a close-ended questionnaire (Appendix F) where they select agree, disagree or neutral to each of the items of the questionnaire. The questionnaire sought to provide data that addressed the two sub-research questions that guided the present research. Learners were asked their opinions on learning Mitosis through animations.

In every item of the questionnaire, the percentage of learners who expressed that they had no problems with the use of animations in the Life Sciences classroom was higher than the percentage of those who claimed that they experienced problems (see Table 4.6). For instance, in understanding Mitosis, 36% of the experimental group indicated that they were comfortable in being taught through animations even though they had never been. This was greater the percentage of those that indicated discomfort in being taught through an animation. The pattern was the same for items of the questionnaire that dealt with pictures; pacing; following pictures of phases of Mitosis and following instructions in the animations. For these items of the questionnaire, the percentages of learners who claimed that they were comfortable being taught through animation as compared to traditional teaching ranged from 28% to 33%. In the other items of the questionnaire which included language, interpretation of the animation, attention span, following animation for the entire duration, and following the phases of Mitosis in an animation the percentage of learners who were comfortable with animation ranged from 44% to 72%. In each case, the percentage of positive impact was greater than that of negative perception (see *Table 4.6*).

Table 4.6

Summary of student responses regarding learning difficulties.

Item	Agree	Disagree	Neutral
I difficulty in understanding Mitosis when being taught through computer simulations.	13,89	36,11	50,00
I difficulty in interpreting pictures that illustrate Mitosis phases in computer simulations	19,44	44,44	36,11
I difficulties in understanding the language used in the computer simulation on Mitosis	11,11	55,56	33,33
I difficulties in interpreting pictures of the phases of mitosis in a computer simulation.	25,00	27,78	47,22
I have difficulties in following the pace of computer simulation on Mitosis	30,56	33,33	36,11
I difficulties in paying attention when learning Mitosis through computer simulations	5,56	72,22	22,22
I difficulties in following the pictures in a computer simulation on Mitosis	19,44	36,11	44,44
I difficulties in following instructions and interpreting pictures in computer simulation on mitosis	11,11	30,56	58,33

I difficulties in following the computer simulation on Mitosis for its entire duration	19,44	44,44	36,11
I difficulties in identifying phases of Mitosis when learning through a computer simulation	13,89	44,44	41,67

4.3.2 Semi- structured interviews

Ten learners from the experimental group were selected for semi-structured interviews (Appendix G). Selected learners fell into three categories. The first category consisted of learners whose performance in the post-test showed a remarkable improvement. The second group of learners selected for interviews consisted of learners whose performance in the post-test showed a remarkable decline. The third group consisted of learners who had special issues in their post-test that the researcher intended to pursue through an interview. Data collected through semi-structured interviews were analysed qualitatively and some quantitative variables such as totals and percentages were used to validate the results that emerged.

All interviewed learners expressed satisfaction with reservations for the use of computer animations in the learning of Mitosis. Learners whose marks remarkably improved claimed that the use of animations helped them understand Mitosis better. One of them had this to say:

> *"The animations were actually showing us what happens in each phase of cell division. I could follow the phases of mitosis through watching the animations. The sound was also clear."*

The learner claimed that the simulation and the accompanying explanation voice contributed to her understanding of the process of Mitosis. Learners who expressed similar sentiments spoke of animations as media that they are used to and that which they use for entertainment and hence when used as learning media made learning to be interesting. Of note was that these learners claimed that the usual learning method where the teacher took the centre stage was not interesting. A total of 70% of the interviewed learners reported that the use of animations enhanced their understanding of Mitosis.

Most of the interviewed learners claimed that animations being modern technologies have a place in the Life Sciences classroom. One learner said:

> *"Our teachers should use multimedia like computer animations because the help us understand better. In our daily lives we use computers so it becomes easy to learn using them."*

All learners including claimed that use of animations in Life Sciences identifies the classroom with new technologies. Learners also claimed that use of animations in learning caters for their level of interest. However, learners observed that the total ceding of the power of the lesson to multimedia does not work for them. They called for a form of multimedia-teacher/learner interactive learning process. Learners advocate for an integration of animations in Life Sciences. They observed that total use of animations as teacher substitute to the teacher is undesirable to them and the traditional teacher-centred lessons are neither desirable.

During the interview, learners were asked to identify the challenges they encountered in a lesson where animations was used. Six learners claimed that they did not encounter any challenge and were happy with all aspects of the lesson. However, one of the six learners observed that they would benefit more if the animations is used as a slot in a lesson that would allow them to interact with the content as a class and in groups rather than for them to listen and observe. The other four learners cited challenges that related to picture quality, sound quality and pacing of the lesson. Two of the four learners further cited language used in the animations being an additional challenge. They claimed that the animations used abstract language without giving explanations of terms that was new to them.

Learners were asked whether use of animations in Life Sciences generated any new interest in the subject. It seems as if common interest for all learners was owing to use of multimedia in the classroom. All learners liked the use of animations as learning tools. There were different views though on how animations could be used as learning media in the classrooms. Three learners observed that their interest is mainly is use of animations as introduction to new concepts. They claim that when animations are used as introduction it will give them time to interact with the content through engaging with textbooks, other learners and the teacher. Two of the interviewed learners cited the presentation of 3D pictures is key to their interests in the use of animations in Life Sciences. One learner noted that having a textbook and teacher substituted by animations was of interest. The learner described the everyday lessons as being monotonous and uninteresting.

Results emanating from all data collecting instruments (pre- and post-tests, questionnaire and interviews) indicated that learners' conceptualisation in the Life Sciences classroom was enhanced by the use of VRs. Learners responding to the interviews indicated that learning was made easy by use of modern technologies in the classroom. Themes that emerged from data collected through both interviews and questionnaires were that VR is appreciated for its modernity, VR through its sound and accompanying visuals presents the concept better than textbooks and teacher' illustrations and that VR brings about variety in terms of instructional strategies.

Learners responding to interviews associated the use of animations in the science classroom as means of motivation towards learning. They associated animations with media that is of their generation interest. One learner had this to say:

> *"It's easy for me to follow a lesson presented in what we are used to. Animations are things that we use to send messages with in our phones. I enjoyed the lesson that used the animations."*

It became clear that learning was enhanced by use of media (animations) because learners associated such media with their level of interest. Even though some aspects of the animations such as sound and picture quality were of problem to some learners, there was a general appraisal of animations as preferred learning media.

Interviewed learners were asked if ever they would request their teacher to use animations in Life Sciences. All the interviewed learners agreed that animations enhance understanding though 10% of the interviewed learners claimed that while animations enhance learning, they are not yet ready for total shift from traditional learning to the use of animations. When further probed about readiness the learners cited that the attention and effort, they are required to put in animations is very intense as compared to the traditional way of learning. They claimed that in animations once you do not understand a concept, you have to just follow without further explanation. An overwhelming 90% of the interviewed learners claimed, that they are happy with the introduction of animations in the classroom and will encourage their teacher to use animations frequently. Learners cited the strengths of animations as the power to demonstrate microscopic processes and its animations, which demonstrate how the processes occur.

Negativity on the use of animations in the Life Sciences classroom emerged from interviews. Ten learners as observed earlier were interviewed, 30% of the interviewed learners expressed negativity on the use of animations. One of the learners whose marks showed remarkable decline cited that there was no time given to them to adapt to the new learning media. The learner claimed that they were used to the method where the teacher either reads or explains or the teacher asks questions for them to answer. The other learner claimed that while they are used to watch animations, the use of animations as learning media was new to them. The learner claimed that they could not pay as much attention as they do in their ordinary lessons where the teacher stands in front of the class and explains concepts. Two interviewed learners observed that the use of animations in the classroom disadvantages them. They cited that animations are not interactive. The learners claimed that people who did not know about their learning needs designed animations. As a result, prefer that their teacher whom they understand better and who knows them better.

Learners from the experimental group were requested to respond to a questionnaire and semi-structured interviews carried out to selected learners from the experimental group. The questionnaire was developed by the researcher with an intention to investigate the possible difficulties that were likely to be experienced by learners during a lesson that employed intervention as an intervention strategy. The questionnaire consisted of closed question where learners were to choose between disagree, neutral and agree. The ‘disagree’ responses were an indication that learners did not experience any one of the listed possible problems. Conversely, ‘agree’ was an indication that learners experienced problems. Neutral was considered a situation where the learners’ choices were indecisive of the preferred medium of learning between traditional learning methods and methods that use animations. Data were analysed quantitatively as mentioned previously.

In all the items of the questionnaire, there were many neutral responses, which were for the purposes of the present research were classified as indecisive responses. Such indecisive responses had their percentages ranging from 22% to 58%.

Negative impact of the use of animation in the Life Sciences classroom emerged from the results obtained from the questionnaire. In terms of understanding, Mitosis taught through animation only 14% of the experimental group had difficulties. Only 19% of the learners who responded to the questionnaire reported having difficulty in interpretation of pictures of Mitosis in an animated lesson. Only 8% of the respondents claimed that they met difficulties in understanding the language used in the animation. Of interest was that there was correlation in learners who claimed that they experienced difficulties in picture interpretation as observed above and those that met difficulties identifying pictures of phases of Mitosis. About 17% of the respondents claimed that they met difficulties in identification of phases of Mitosis through animation.

Difficulties that relate to pacing and attention in a simulated lesson and pacing of the simulated lesson showed disparities even though the two problems are similar. About 17% of the respondents claimed that they had difficulties in following the pace of Mitosis while only 3% of the respondents claimed that they experienced problems in paying attention for the entire of the duration of animation. In addition, 11% of the learners claimed that they experienced difficulties in following the animation for its entire duration. Some 8% of the respondents observed that they could not follow the phases of Mitosis presented as animation. Only 8% of the respondents observed that it was difficult in both pictures interpretation and following instructions simultaneously. Table 4.6 provides a summary of the responses from the questionnaire. The table indicates that the percentages for learners who experienced difficulties in learning through an animation are less than those who were comfortable in learning through the multimedia.

CHAPTER 5: DISCUSSION OF RESULTS AND CONCLUSION

5.1 Introduction

This chapter presents a detailed discussion of the results in Chapter 4. The results are discussed in the context of the literature reviewed in Chapter 2. Literature has emphasised the impact of VR and in particular, the use of animations as both instructional strategies and as alternative to practical activities in the science classrooms (Clark & Mayer, 2016; Win, 2005; Rutten et al., 2010). Discussion of the results is also enhanced by the use of the conceptual framework that was used as the lens of the present research. Results that were analysed qualitatively and quantitatively are synchronised into a single report. Discussion of the results is also being guided by the research aim and questions of the present research. Discussion of results will focus on how the research questions aim and allow emergence of new knowledge. The results are discussed through the lens of the two theories that guided the present research. Mayer's (2005) CTML describes learning through multimedia as taking place through the dual-channel, the limited capacity and the active processing. Mnguni's (2014) theory of learning through multimedia described learning as taking place through three main stages; internalisation, conceptualisation and externalisation. The theories were discussed in detail in Chapter 2.

The main research question of the present research is: To what extent could the use of VR in teaching Life Sciences improve Grade 10 learners' understanding of mitosis? The results that emerged from this study indicate that intervention lesson through animations benefited the learners. The differences in performance of the experimental group as compared to control group are an indication of the effectiveness of the animations in a science classroom. Learners through responses to the questionnaire, interviews and the performance of the experimental group in the post intervention test indicated that the animation had a positive effect in improving learners' understanding of Mitosis. This is in line with Choi (2011) and Song (2002) who argue that animations help learners to identify the functions and methods of their work; also it helps learners to formulate mental pictures of microscopic processes.

5.2 Results that support literature review

Results analysed from all data collecting instruments (tests, interviews and questionnaires) indicate that use of VRs in the classroom could enhance learning and related content understanding. Comparison of pre- and post-tests results of the experimental group and control group indicate that exposure to the animation could have a positive impact in the Life Sciences classroom. These results are in line with Kozma and Russel (2005) and Mayer (2001) who in separate studies observed that VRs like animations improve learning and retention of concepts. Similarly, Hazmat, Bellow and Abimbola (2017) assert that the use of computer animations improves students' achievement in biology. This finding is also supported by Fan, Salleh and Laxman (2018, p. 217) who recently found that the use of animation in teaching biology concepts leads to a "greater improvement in students' conceptual understanding of the biology concept…, thus demonstrating the positive impact of embedding video technology into classroom lessons planned using TPACK framework". In line with these researchers, the present researcher therefore argues that the use of animations to teach genetics concepts such as mitosis, could lead to improved content understanding in a township school. This finding on the observation that concepts that learners were taught in traditional method (traditional teaching method in the present research is considered to be the common chalk and talk teaching method) and learners did not manage to answer correctly in the pre-tests managed to respond correctly in the post-test. A typical example was the sequencing and identification of Mitosis stages. Learners performed badly in the pre-test as compared to the post-test. Between the two tests, learners from the experimental group were subjected to an intervention using VRs. Learners from the control group never recorded any significant change between pre- and post-test. The disparities in performance between the control group and the experimental group are indicative of the power of VRs in enhancing conceptualisation in the Life Sciences classroom.

There was improvement in all sections of the tests. The experimental group in the same section attained learner performance of the control group increased by 4% in the multiple-choice section, and 16% increase. This indicated that the use of VRs as intervention yielded positive results. Interviews aim to pursue such abnormalities as severe or decline or a big leap in performance.

When learners from the experimental group were interviewed and asked about what contributed to their improvement learners cited the employment of VRs as the reason. Two of the learners claimed that use of any form of multimedia in the classroom is in line with their level of interest. In this case, interviews validate results emanating from the pre- and post-test.

Learners of the experimental group also performed exceptionally high in long questions of the post-test as compared to the control group. The 23% improvement of the experimental group in post-test and the decline of 3% in the post test in the control group indicate that since only the experimental group was subjected to the VRs intervention this is testimony of the power of VRs in enhancing an analysis of learners' long responses indicate an improvement in usage of scientific language. The animations used as VRs managed to match the language with the simulation and made it possible for the learners to make connections between the language and the process.

There is evidence that the use of VRs as intervention in the experimental group. In response to the question*: Identify the phases labelled **A** to **F** and state a visible reason to motivate your answer* learners could appropriately use scientific terms in describing the activities that of each stage of Mitosis. Such terms as *'spindle fibres', 'chiasmata' and 'chromatids',* were appropriately used by learners in their responses. In follow up interviews one of the learners said:

> *I saw the chromatin network becoming visible, chromosomes splitting to form chromatids, I also saw the spindle fibres and chromatids lining at the equator before moving to the opposite poles.*

This is testimony that learners through their like of engaging with multimedia becomes an interphase of introducing VRs in the classroom. Regardless of how abstract the concept is use of what learners would like to associate with in the classroom makes learning easy.

As indicated in the previous chapter, the post-intervention results using animations as reflected by the improved results of the experimental group. Results obtained through pre- and post-tests, interviews and questionnaires indicated that learners' understanding of the topic taught through animations was enhanced. Most learners as indicated by statistical evidence (in Chapter 4) indicate that learners are comfortable in learning through animations. Learners particularly enjoyed the use of animations in the classroom. The dual-channel assumption of learning through multimedia (Mayer, 2003) proposes that learning through multimedia takes place through separate channels of pictorial and auditory information this was evident in responses of learners who either claimed that the picture and sound enhanced their understating of Mitosis or that the two hindered their understanding of the process of Mitosis. Results that emerged in the present research confirm the assertions made that animations improve the process of knowledge construction in the science classroom (Stuckey-Mickell, Stuckey-Danner & Taylor, 2007; Clark & Mayer 2009).

The theoretical framework that guided the present research was summarised as consisting of a combination of words with visuals (Mayer, 2009) and as consisting visualization- internalization and externalization (Mnguni, 2014). The results that emerged from present research indicate the power of a conglomeration of visuals with words in the facilitation of construction of knowledge in the Life Sciences classroom. Comparison of pre- and post-tests results of the experimental group indicated that use of animations in the Life Sciences classroom beard a positive impact. These results were confirmed by responses from the questionnaires that reflected a greater percentage of learners who expressed that they did not experience any difficulty in such aspects as language, pacing, following instructions, and interpretations of various aspects of the animation. These results confirm the theory proposed by Mnguni (2014) which describes learning as taking pace through internalisation using sense organs (eyes and ears) to assist the brain to absorb information.

As displayed by the results, there was learning enhancement through the use of animations. This concurs with Stuckey-Mickell et al.'s (2007) assertion, who described VR as one of newer application for enhancing teaching and learning while centred mainly on the merging of education with entertainment. There was evidence from the learners' responses to questionnaires and interviews that while learning took place there was more of entertainment that was induced by the use of animations. Learners observed that the simulation through the 3D animations pictures they were able to see the process of Mitosis and the stages were well elaborated. That the animations clip used as animations provided cognitive processes that carried out in a coordinated manner during learning facilitated enhancement of retention of what was learnt during the lesson (Mayer, 2003).

The results of learners' responses to questionnaires and semi-structured interviews on the use of animations were highly positive. All learners from the experimental group agreed that the animations helped them to understand Mitosis and avoid mistakes during the post intervention test. The experimental group achieved a mean score of 51% while the control group's mean score performance in the same test was 34% the differences in performances is testimony to the power of animations in enhancing understanding of Mitosis. As means of validating results from the tests in response to semi-structured interviews and questionnaires, learners recommended that animations be used again in future lessons. However, there were three learners who indicated the animations was only "somewhat" easy to follow but gave them problems that related to sound quality, picture quality and sustenance of attention span. One key difference between these animations and our other animations is that there was narration or audio to accompany the animations and step-by-step instructional captions. Interestingly, two of the three learners who claimed that they met these challenges also indicated that they preferred animations to traditional learning. These results show that while animations alone are a powerful learning tool, audio or narration is also very important to some learners.

The implication of the observed improvement in content understanding is that the ongoing use of computer-based learners in schools, especially in Gauteng, could ultimately lead to improved learner performance, at least in Life Sciences. As suggested in the CTML (which was used in the present research as a theoretical framework), the use of animations could positively impact on learners' motivation to study related concepts. While the present research did not explore reasons why the animation improved learners understanding of mitosis, the researcher believes that learners were cognitively better engaged with the concepts that they were without the animation. Consequently, the researcher strongly supports the use of computer-aided teaching approaches as also recommended by the DBE in Gauteng.

5.3 Results that contradict literature review

There were mixed reactions on the picture quality of the animations. Some learners as seen in the previous chapter expressed discomfort with picture quality. This calls for use of animations that take into consideration the contextual factors of the learners. Such issues as learners' interests, their daily experiences and their level of cognitive development need to be taken into consideration. At this juncture use of animations accessed through the internet are being used. For instance, the present research used a VR intervention for was accessed from Pearson Education**.** The design of the animations did not target the group that it was used to but for universal application. This might have been the cause for some learners claiming that they were not comfortable with the picture quality.

Some learners claimed that it was difficult to adjust to the pacing of the animations clip used as VRs. As learners further claimed they could not fully pay attention for the duration of the lesson. Learners usually get encultured to a system of learning in their school and in particular to their classroom system**.** A sudden change from their usual culture of learning to a situation where a pre-programmed technological gadget and software are used becomes problematic. While VRs were observed as improving learning in the science classroom, their ultimate introduction should be so systematic as not to results in some negative impact. Associated with picture quality and pacing of the lesson was the language used in the animations clip. Learners are accustomed to a specific classroom learning language and more specifically as claimed by Setati, Chitera and Essien, (2009) classroom teaching language is largely characterised by code-switching from language of instruction to home language. That may be some learners were used to code switching a sudden change to the language of instruction only might have impaired their attention.

Animations were not of benefit to all learners as some learners claimed that various challenges hindered their understanding of mitosis. The most cited challenge was that of picture quality. The issue of picture quality became a learner personal issue. Some learners prefer particular colours over others. This challenge could be addressed through taking into consideration the learners' interest when choosing or designing animations for use in the classroom. One other challenge cited by some learners was that of language. This is an indication that using animations that was not specifically designed for a particular class of learners could be problematic. Language is a contextual factor which teachers and designers of animations could take into consideration when designing or selecting animations for use in the classroom.

Learners from the experimental group also claimed that while they gained more from the use of VRs in their classroom they experienced differing degrees of personalisation in that the teacher being withdrawn from being the at the centre stage in the classroom and learner to learner interactions was too sudden a change for them for adaptation. They suggested the degree, to which learning could be personalised, and the degree to which animations could be fully utilised should be done gradually and selection of animations should also involve learners.

5.4 Results that had not been reported in literature review

While the use of animations in teaching and learning is well documented in the developed world, there remains a significant dearth of knowledge regarding the effectiveness of these technologies in the developing countries, particularly Africa. Scholars (e.g. Koseoglu & Efendioglu, 2015) have attempted to explore this field. However, the lack of computer-based teaching and learning resources in rural and township schools has constantly been a hindrance. As a result, the findings of the present research lay a foundation to further research regarding the use of computer-based learning in rural and township schools.

In particular, the major findings of the present research, which are novel, are as follows:

a) *Animations can improve Grade 10 learners' understanding of mitosis, in a South African township teaching and learning context.*
b) *Traditional methods of teaching could lead to confusion and misconceptions among Grade 10 learners' understanding of mitosis, in a South African township teaching and learning context*
c) *There are learning difficulties associated with the use of animations in learning Life Sciences Grade 10 Mitosis.*

These findings also provide direct responses to the research questions of the present research.

5.5 Recommendations for future studies

Results from this study indicate that interventions through animations are effective and are well received by learners, but there is still much work to be done. Since a significant fraction of learners have commented that they would prefer improved sound and picture quality of animations clips used as animations learner diversity and contextual issues should be considered when selecting or developing animations. There is need for research studies whose focus would be to investigate the effects of such learner diversities and the use of in science classrooms. Owing to the success of the selected animations clip which was used as animations in the teaching of Mitosis research studies that focus on other Life Sciences concepts are recommended. Teacher's pedagogical strategies for use of animations would be another area of interest to back up results from the present research.

5.6 Conclusion

The research suggests that learners tend to see the virtual classroom environment as enhancing learning abilities requiring greater learner independence and self-motivation than most conventional classrooms. However, some learners manage in virtual classes better than others, and there are differing preferences of picture, sound and learning styles that should be incorporated as components of animations. Some learners tended to think that sufficient support and resources were already available for full-scale virtual classrooms, and that it is mainly the learners' own responsibility to adapt to the environment where VR is employed. Learners suggested that virtual classrooms were best suited for complex concepts with microscope processes such as cell division and are appropriate for use in learners who were already capable of working well in the independent environment, and that it was in learners' best interests if virtual classrooms were not offered to those who would not or could not display these capabilities.

However, other learners saw teachers as having a much more proactive role in supporting virtual learning, and this included adapting their teaching approaches and using different strategies to try to support and engage all learners. Some of these learners wanted teachers to go “the extra mile” to create an environment that worked for their particular learners. An important dimension of this seemed to be the emergence of VR as intervention or supporting strategy to the long in existence traditional teaching and learning methods. Learners seemed to appreciate VR as a strategy that could be used to enhance or support these traditional methods.

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APPENDIX A: PERMISSION LETTER TO SCHOOL

PERMISSION LETTER TO SCHOOL

Re: <u>Request for permission to conduct research at your school.</u>

Research title: “The effectiveness of an animation on Grade 10 learners’ understanding of Mitosis in Tembisa, South Africa

The Principal

School Address

Insert contact person’s telephone number and email address

Dear Principal,

I, DudrahMN. Moyo am doing research under the supervision of Lindelani Mnguni, a professor in the Department of Science and Technology towards a Master’s Education degree at the University of South Africa. The study is not funded. We are inviting you to participate in a study entitled “The effectiveness of virtual reality in improving the learning of Grade 10 Mitosis, Tembisa, South Africa”.

The aim of the study is to investigate the extent to which virtual reality improves Grade 10 learners’ understanding of mitosis in Tembisa.

Your school has been selected because the school falls under Tembisa which is the area where the study has its focus.

The study will entail requesting learners to write a pre-test and post-test as part of assessing their response to computer simulation. I will also observe lessons where teachers will be teaching Life Sciences concepts using computer simulations. Finally I will carry out semi-structured interviews for selected learners.

The benefits of this study are that teachers will be equipped with innovative teaching strategies that will benefit learners especially in cases where practical activities could not be done due to financial constraints. Learners will also be exposed to simulated concepts which are hoped that it will improve their understanding and retention of concepts which under normal circumstances are considered to be abstract.

In this study there are no foreseeable risks

Feedback procedure will entail me sharing with the teachers the best possible strategies of using computer simulations for their adaptation into their day to day teaching.

Yours sincerely,

Dudrah M.N Moyo

Student: UNISA (Student No. 61642916)

APPENDIX B: CONSENT LETTER TO PARENTS

Research title: “The effectiveness of an animation on Grade 10 learners’ understanding of Mitosis in Tembisa, South Africa

Dear Parent

I would like to request your child to participate in my research project being undertaken at your child’s school. My research topic is “The effectiveness of virtual reality in improving the learning of Grade 10 Mitosis, Tembisa, South Africa.”

This research will entail the observation of your child inside the classroom during Life Science lessons. Your child will be part of the children in the class I will be observing for a month. I will not be teaching your child but I will be present in class when his/her teacher teaches them. I will be a passive participant who will do audio recordings and take field notes while the teacher and the learners are busy in class. Your child will participate in pre-test and post-test, questionnaires, as well as, semi-structured interviews.

I would like to promise you that the information obtained from this study will be treated in the strictest confidentiality possible, and it will be used for this research purposes only. Your names and the child’s names will not be revealed instead pseudo names will be used.

The information obtained from this research will be made available to your child’s school and can be used by the teacher to help your child during science lessons. In conclusion I would like to thank you most sincerely in your assistance in this research, and I hope that this research make a contribution towards meeting the needs of diverse learners found in science classrooms.

Yours sincerely

Dudrah M.N Moyo

If you are willing to allow your child to participate in this study, please sign this letter as a declaration of your consent, i.e. that your child participate in this project with your permission and that you understand that he/she may withdraw from the research project at any time. Under no circumstances will the identity of participants be made known to any parties/organizations that may be involved in the research process.

Any information that is obtained in connection with this study and can be identified with your child will remain confidential and will only be disclosed with your permission. His or her responses will not be linked to his or her name or your name or the school's name in any written or verbal report based on this study. Such a report will be used for research purposes only.

There are no foreseeable risks to your child by participating in the study. Your child will receive no direct benefit from participating in the study; however, the possible benefits to education are that the study seeks to improve the teaching and learning strategies through use of computer simulations. Neither your child nor you will receive any type of payment for participating in this study.

Your child's participation in this study is voluntary. Your child may decline to participate or to withdraw from participation at any time. Withdrawal or refusal to participate will not affect him/her in any way. Similarly you can agree to allow your child to be in the study now and change your mind later without any penalty.

The study will take place during regular classroom activities for the lesson and pre-tests/post-test while interviews might be done at times convenient to your child with the prior approval of the school and your child's teacher. However, if you do not want your child to participate, an alternative activity will be available.

In addition to your permission, your child must agree to participate in the study and you and your child will also be asked to sign the assent form which accompanies this letter. If your child does not wish to participate in the study, he or she will not be included and there will be no penalty. The information gathered from the study and your child's participation in the study will be stored securely on a password locked computer in my locked office for five years after the study. Thereafter, records will be erased.

If you have questions about this study please ask me or my study supervisor, Prof Lindelani Mnguni, Department of Science and Technology, College of Education, University of South Africa. My contact number is 0766833915 and my e-mail is dudrahsimanga@gmail.com. The e-mail of my supervisor is mngunile@unisa.ac.za. Permission for the study has already been given by UNISA faculty of Education and the Ethics Committee of the College of Education, UNISA.

You are making a decision about allowing your child to participate in this study. Your signature below indicates that you have read the information provided above and have decided to allow him or her to participate in the study. You may keep a copy of this letter.

Name of child: ____

____

Parent/guardian's name (print)   Parent/guardian's signature   Date

____

Researcher's name (print)   Researcher's signature   Date

APPENDIX C: CONCENT LETTER TO TEACHERS

Research title: "The effectiveness of an animation on Grade 10 learners' understanding of Mitosis in Tembisa, South Africa."

Dear educator

Re: Educator- Request for your participation.

My name is Dudrah Moyo and I am a Master's student at the faculty of Education student at the University of South Africa. I would like to conduct my research in your Life Sciences classroom on the above mentioned study. I hereby request your permission to administer a pre-test and post-test, questionnaire and conduct interviews with a selected number of learners, as well as, analyse your lesson plans.

Your participation in this research process is voluntary and you may choose to withdraw from this process at any time. If you choose not to participate or withdraw from the research process, there will be no penalty. Furthermore, written consent will be obtained from you and the findings will be discussed with you.

For the purposes of anonymity and confidentiality the names of both your school and yours will not be mentioned throughout the data and findings of the case study. Pseudonyms (another name instead of your name) will be used in the writing of the final assignment. The collected data will be for the purpose of this study. This information will be treated with the strictest of confidentiality. Should you so require, please do not hesitate to contact me on: 0766833915 or send my supervisor Prof LE Mnguni an email: mngunile@unisa.ac.za.

Thanking you in advance.

Yours sincerely

Dudrah

I hereby confirm that I understand that Dudarh Moyo is conducting her study on the effectiveness of virtual reality in improving the understanding of grade 10 Mitosis. I hereby state that I will allow her to conduct the research in this in my Life Sciences lessons to use the findings for the purpose her studies.

______________________ ______________________

Educator's Name Date

____

Signature

APPENDIX D: ASSENT LETTER TO LEARNERS

Dear learner

I am doing a study on "The effectiveness of an animation on Grade 10 learners' understanding of Mitosis in Tembisa, South Africa" as part of my studies at the University of South Africa. Your principal has given me permission to do this study in your school. I would like to invite you to be a very special part of my study. I am doing this study so that I can find ways that your teachers can use to virtual reality better. This will help you and many other learners of your age in different schools.

This letter is to explain to you what I would like you to do. There may be some words you do not know in this letter. You may ask me or any other adult to explain any of these words that you do not know or understand. You may take a copy of this letter home to think about my invitation and talk to your parents about this before you decide if you want to be in this study.

I would like you to write a pre-test and post-test, respond to a questionnaire and engage you in an interview for approximately fifteen minutes. I will write a report on the study but I will not use your name in the report or say anything that will let other people know who you are. You do not have to be part of this study if you don't want to take part. If you choose to be in the study, you may stop taking part at any time. You may tell me if you do not wish to answer any of my questions. No one will blame or criticise you. When I am finished with my study, I shall return to your school to give a short talk about some of the helpful and interesting things I found out in my study. I shall invite you to come and listen to my talk.

If you decide to be part of my study, you will be asked to sign the form on the next page. If you have any other questions about this study, you can talk to me or you can have your parent or another adult call me at: 0766833915. Do not sign the form until you have all your questions answered and understand what I would like you to do. You may also contact my supervisor Prof LE Mnguni on 0114294614 or send an email: mngunile@unisa.ac.za.

Do not sign written assent form if you have any questions. Ask your questions first and ensure that someone answers those questions.

INTERVIEW ASSENT AND CONFIDENTIALITY AGREEMENT

I____ grant consent/assent that the information I share during the semi-structures interviews may be used by Dudrah MN. Moyo for research purposes. I am aware that the discussions will be digitally recorded and grant consent/assent for these recordings, provided that my privacy will be protected. I undertake not to divulge any information that is shared in the interview to any person outside the group in order to maintain confidentiality.

Participant‘s Name (Please print): ___________________________________

Participant Signature: ____

Researcher's Name: (Please print): __________________________________

Researcher's Signature: ____

Date: ____

APPENDIX E: PRE-POST TEST

Thank you for accepting to participate in my study that seeks to investigate the effectiveness of virtual reality in improving the learning of Grade 10 Mitosis. At this stage of my study I invite you to respond to the following base line test. You are kindly requested to take for 30 minutes. Your responses are not for marks and will be confidential and only used for the purpose of this study.

Section A: In each of the following cases you must choose the answer that best suits the statement or question. Write down the letter only.

1. What is mitosis?
    - A. The division of body cells that results growth of an organism.
    - B. The process of cell division during which gametes are formed.
    - C. The cell division of the nucleus and chromosomes.
    - D. The cell division of the cytoplasm, organelles and cell membrane.
2. What is the role of mitosis?
    - i. Ensuring growth of an organism.
    - ii. For repairing and replacing damaged cells.
    - iii. For asexual reproduction in simple organisms.
    - iv. For replacing, repairing cells and growth of an organism.
    - A. (ii)
    - B. (i),(ii),(iii)
    - C. (iii) and (iv)
    - D. (i),(ii),(iii) and (iv)
3. The process whereby one cell gives rise to two cells with the identical genetic make-up as the original cell is a definition of?
    - A. Meiosis
    - B. Mitosis
    - C. DNA replication
    - D. Cell division

4. What is the correct sequence of the mitosis phases?

   A. Prophase, Metaphase, Telophase, Anaphase and Interphase.

   B. Telophase, Interphase, Anaphase, Metaphase and Prophase

   C. Interphase, Prophase, Metaphase, Anaphase and Telophase.

   D. Interphase, Prophase, Anaphase, Metaphase and Telophase.

5. If a cell divides by mitosis, how many cells will there be after three divisions?

   A. 3 cells

   B. 4 cells

   C. 6 cells

   D. 16 cells

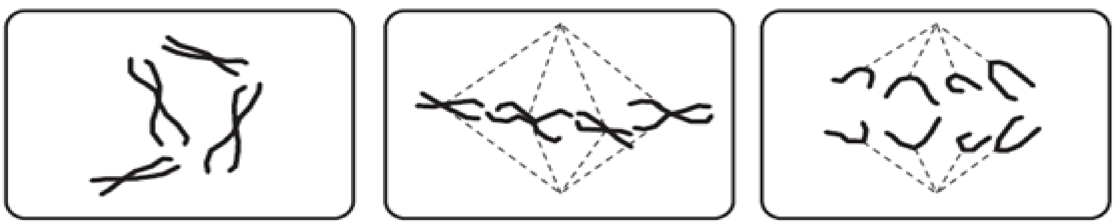


Diagram A	**Diagram B**	**Diagram C**

6. **Diagram A** above represents which phase of the cell division being demonstrated?

   A. Interphase

   B. Metaphase

   C. Prophase

   D. Anaphase

7. What is the total number of chromosomes in **Diagram B**?

   A. 2

   B. 4

   C. 6

   D. 8

8. **Diagram C** is demonstrating?

   A. The movement of daughter chromosomes to opposite poles.

   B. The movement of spindle fibres.

   C. The formation of chromosomes.

   D. The assembling of the chromosomes at the equator of a cell.

9. Mitosis results in the formation of ?

   A. 2 identical daughter cells.

   B. 4 identical daughter cells.

   C. 2 non-identical daughter cells.

   D. 4 non-identical daughter cells.

10. In which phase in the cell cycle does DNA replication occurs?

   A. Telophase

   B. Prophase

   C. Anaphase

   D. Interphase

11. Which type of cell division results in growth of organisms?

   A. Meiosis

   B. Mitosis

   C. Cell differentiation

   D. Mitochondria

12. A division of one cell by mitosis will produce...?

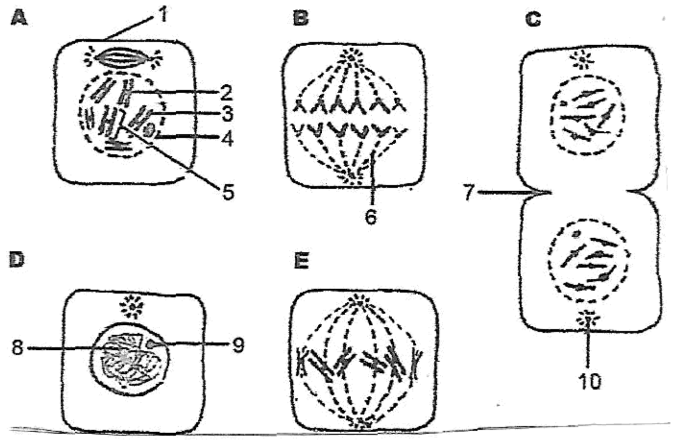
   A. Two cell, each of which has a chromosome number half that of the parent cell.

   B. Four nuclei, each of which has chromosomes number half that of the parent nucleus.

   C. Two cells, each of which has the same number of chromosomes as the parent cell.

   D. Four nuclei, each of which has the same number of chromosomes.

SECTION B: Study the following representation of a division process and answer the questions that follow.



2.1 Identify the phases labeled **A** to **F** and state a visible reason to motivate your answer. (10)

2.2 By making use of the LETTERS only, arrange the phases into the correct sequence (2)

2.3 Provide the labels for the parts numbered **1** to **10** (10)

TOTAL [34]

APPENDIX F: THE QUESTIONNAIRE

QUESTIONNAIRE

Dear learner

Thank you for your willingness to complete the following questionnaire. The purpose of this questionnaire is to determine what your views are on the use of computer simulations in learning Mitosis. There are no right and wrong answers. Your real name will not be revealed when I read report on the findings.

Class: ______________________________

Age: ________________________________

1.1 I have difficulty in understanding Mitosis when being taught through computer simulations.		
Agree	**Neutral**	**Disagree**

Please explain your response in the lines provided below.

____

____

____

1.2 I have difficulty in interpreting pictures that illustrate Mitosis phases in computer simulations.

Agree	Neutral	Disagree

Please explain your response in the lines provided below.

____

____

____

1.3 I have difficulties in understanding the language used in the computer simulation on Mitosis.		
Agree	**Neutral**	**Disagree**

Please explain your response in the lines provided below.

____

____

____

1.4 I have difficulties in interpreting pictures of the phases of mitosis in a computer simulation.		
Agree	**Neutral**	**Disagree**

Please explain your response in the lines provided below.

____

____

____

1.5 I have difficulties in following the pace of computer simulation on Mitosis.		
Agree	**Neutral**	**Disagree**

Please explain your response in the lines provided below.

____

____

____

1.6 I have difficulties in paying attention when learning Mitosis through computer simulations.		
Agree	**Neutral**	**Disagree**

Please explain your response in the lines provided below.

____

____

____

1.7 I have difficulties in following the pictures in a computer simulation on Mitosis.		
Agree	**Neutral**	**Disagree**

Please explain your response in the lines provided below.

1.8 I have difficulties in following instructions and interpreting pictures in computer simulation on Mitosis.		
Agree	**Neutral**	**Disagree**

Please explain your response in the lines provided below.

1.9 I have difficulties in following the computer simulation on Mitosis for its entire duration.		
Agree	**Neutral**	**Disagree**

Please explain your response in the lines provided below.

1.10 I have difficulties in identifying phases of Mitosis when learning through a computer simulation.

Agree	Neutral	Disagree

Please explain your response in the lines provided below.

____

____

____

APPENDIX G: INTERVIEW SCHEDULES

INTERVIEW SCHEDULE

Thank you for your willingness to answer a few questions. The purpose of this short interview is to determine what your views are on the use of computer simulations in learning about Mitosis. There are no right or wrong answers. Your real name will not be revealed when we report on the findings.

Name/ pseudonym:

1. Which subject(s) and grades are you doing?
2. I can see Life Sciences is one of the subjects that you are doing. Why did you choose it?
3. How did this engagement with the animation improve your understanding of Mitosis?
4. Briefly describe what you liked most in the lessons you engaged in?
5. What were your dislikes in these lessons and why?
6. Do you think that animations have a place in learning Life Sciences (motivate your answer)
7. Would you say that after this short experience you are able to identify animations that you can use to enhance your understanding of any topic in Life Sciences?
8. Would you be requesting your teacher to use the animations in making you understand Life sciences better?
9. What are the difficulties that you experienced when learning an animation in the intervention lesson? Please elaborate
10. Did this short experience in learning through an animation change your interest in learning Life Sciences? Motivate your answer.

Thank you for making the time to discuss the short course with me. I greatly appreciate your feedback.

APPENDIX H: ETHICAL CLEARANCE CERTIFICATE

UNISA university of south africa

UNISA COLLEGE OF EDUCATION ETHICS REVIEW COMMITTEE

Date: 2018/05/16

Ref: 2018/05/16/61642916/05/MC
Name: Ms DNM Moyo
Student: 61642916

Dear Ms Moyo

Decision: Ethics Approval from 2018/05/16 to 2021/05/16

Researcher(s): Name: Ms DNM Moyo
E-mail address: dudrahsimanga@gmail.com
Telephone: +27 76 683 3915

Supervisor(s): Name: Prof LE Mnguni
E-mail address: mngunle@unisa.ac.za
Telephone: +27 12 429 4614

Title of research:

The effectiveness of virtual reality in improving the learning of Grade 10 Mitosis, Tembisa, South Africa

Qualification: M Ed in Science and Technology Education

Thank you for the application for research ethics clearance by the UNISA College of Education Ethics Review Committee for the above mentioned research. Ethics approval is granted for the period 2018/05/16 to 2021/05/16.

APPENDIX I: LANGUAGE EDITING CERTIFCATE

EDITING AND PROOFREADING CERTIFICATE

7542 Galangal Street

Lotus Gardens

Pretoria

0008

23 May 2019

TO WHOM IT MAY CONCERN

This certificate serves to confirm that I have edited and proofread the report for D Moyo's dissertation entitled, **"The effectiveness of an animation on Grade 10 learners' understanding of mitosis in Tembisa, South Africa.**

I found the work easy and intriguing to read. Much of my editing basically dealt with obstructionist technical aspects of language, which could have otherwise compromised smooth reading as well as the sense of the information being conveyed. I hope that the work will be found to be of an acceptable standard. I am a member of Professional Editors' Guild.

Hereunder are my particulars:

Jack Chokwe (Mr)

Contact numbers: 072 214 5489

jackchokwe@gmail.com