The relationship between learning styles, modes of content presentation and visuo-semiotic reasoning in Biology.

By

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Abstract

In the 21st century, acquiring knowledge of the life sciences, particularly in the discipline of biology, requires attaining a set of visualisation skills among students. These skills include the ability to interpret, reason and understand the discipline by processing visual stimuli to comprehend spatial relationships between objects, and to visualize images. Since the start of the 4th industrial revolution, the use of visuo-semiotic models in teaching and learning have increased. The integration of visuo-semiotic models, such as images and visual presentations in textbooks and computer interfaces, have promoted more effective learning of visually and spatially complex topics in biology and molecular biology. The integration and interpretation of visuo-semiotic models is a complex process and depends on prior knowledge of the domain of biology, as well as familiarity with visualisations and complexities of the visuo-semiotic model. Consequently, the present study aimed to investigate the relationship between learning styles, modes of content presentation and visuo-semiotic reasoning in biology. This will aid in understanding how both teaching and learning can be enhanced through visuo-semiotic models, in a preliminary manner. The present study adopted a quantitative, quasi-experimental research approach. A non-probability, purposive sampling method was used to select participants from a public school located in Gauteng, West of Johannesburg. Data was obtained from self-administered questionnaires which were completed by Grade 10 biology students (n=76). The findings of this study suggests that a relationship exists between learning styles, modes of content presentation and visuo-semiotic reasoning associated with learning difficulties related to conceptual understanding of the cell cycle. Furthermore, the results also showed that content knowledge, which was presented using simulations, performed by using bead-work, animation and paper-based worksheets did not improve student performance.

Key Words: 2D static model; animation; biology; learning styles; modes of content presentation; simulation; visual literacy; visuo-semitic models; visuo-semiotic reasoning; visualisation skills.

Declaration

Title: The relationship between learning styles, modes of content presentation and visuo-semiotic reasoning in Biology.

I, Khanyisile Masikane, declare that this dissertation mentioned above is my own work except as indicated in the references and has not otherwise been submitted in any form for any degree or to any University. The dissertation is submitted in fulfilment of the requirements for the degree ***MAGISTER EDUCATIONIS*** at the University of South Africa.

Khanyisile Masikane

Pretoria, South Africa , 28 November 2019

Signed at

Dedication

This dissertation is dedicated to my late uncle, Fortune Nhlanhla 'Japie' Masikane, Constance Sheila Mdakane-Masikane, Nomasonto Masikane, Khensani Makhondo, Victor Sethole, Prof. L.E Mnguni, Kamo Matee, Sifiso Nkosi, Dr.A Buma, Prof. M. Magano, Nosipho Shabangu, Nomfundo Nhleko, Karabo Thateng, Felicity Mogapi, Phuti Mabotja, Vuyo Mbane, Nokulunga Nkome, Dr. Lineo Toolo, Mpho Monete, Neo Sithole, Dr. Nandipha Magudumana, to all my learners and staff members at Florida Park High School.

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1.1 Introduction

Multiple theories are used in an attempt to explain the related learning processes and complexities of learning biology. These include constructivism, inquiry-based learning, experiential learning and multimedia learning, among others. Consequently, biological knowledge is presented through various forms using visuo-semiotic models such as simulations, animations, pictures, diagrams, computer based visual models and physical models. This is important in order to accommodate the varied learning styles of students and improve knowledge accessibility to students. Biology education research, therefore, attempts to explore the effectiveness of these representations in relation to the established and emerging learning theories. It is against this background, that the present study will explore the relationship between learning styles, mode of presentation and visuo-semiotic reasoning.

1.2 Learning biology in the 21st century

The terms 'learning style' and 'cognitive style' are used interchangeably at times, whilst at other times they are given distinct definitions. Mayer & Massa (2003) described "cognitive style 'as a preferred way in which an individual processes information (thinking with words or images), while 'learning style' is concerned with the application of cognitive style (preferring instruction with texts, sounds or graphics).

The significance of learning styles and cognitive styles is seen in the context of the fourth industrial revolution, which is characterized by a rapid increase in the use of visuo-semiotic reasoning models (VSM); such as pictures, animations and diagrams. These VSMs could accommodate various learning styles, thereby increasing students understanding of content (Schönborn & Anderson, 2009). However, the effectiveness of VSMs could be limited if the related learning styles are not accommodated, and if students fail to have the necessary visual literacy and visuo-semiotic reasoning skills to work with VSMs (Taukobong, 2017).

Yeh (2008) described visual literacy as the knowledge and skills required to interpret and understand visual representations. It is also defined as the ability of an individual to generate mental modes, by decoding and encoding visual representations (Arneson & Offerdahl, 2018). These visual representations have been defined by Mnguni (2019, p.122), as visuo-semiotic models, which are “visual models that use discipline-specific semiotics to represent phenomena for research, teaching and learning. These include written language, static multidimensional images, animations, simulations and symbols.” Mnguni (2019) refers to cognitive processing of visuo-semiotic models as visuo-semiotic reasoning, which is related to the visual learning style. Effective visuo-semiotic reasoning (VSR) could lead to better content understanding of content presented through VSMs. However, this hypothesis has yet to be confirmed and tested. In fact, the present researcher has not come across any research that attempts to explore the VSR in detail, particularly in biology education.

Researchers (e.g., Mnguni, 2014) suggests that VSR is dependent on the availability of visualisation skills among students. These skills include the ability to understand, reason and to remember by processing visual stimuli, in order to comprehend spatial relationships between objects, and to visualize different scenarios or images. Cognitive functions include perception, attention, memory, motor skills, language, executive functions and visual spatial thinking (Anderson, 2005 & Baddley, 1992). There is a limit to the extent to which biology students have the necessary skills needed to comprehend content which is presented through VSMs.

1.3 Problem statement

The research gap relates to the dearth of research regarding the relationship between learning styles, mode of presentation and visuo-semiotic reasoning. In light of the fourth industrial revolution, the use of VSMs in teaching and learning is increasing. The onset of the fourth industrial revolution has been accompanied by the integration of VSMs in teaching. This has taken the form of images and visual presentations, accompanied by text in textbooks and computer interfaces. (Couse & Chen, 2010) Such advancements in biology education, promote more effective learning of visually and spatially complex topics, especially in molecular biology. The integration and interpretation of VSMs is a complex process, which depends on prior knowledge of biology as well as familiarity with the visualisations and complexities of the VSM (Schnotz & Lowe, 2003).

Schönborn & Anderson (2006) demonstrated that several conceptual difficulties might be linked to the way in which the content is represented, and the way in which the representation is used. VSMs play critical roles in teaching and learning biology, and when used correctly, they can bring about unique benefits to students. However, inappropriate use may lead to poor concept understanding. There is a considerable amount of evidence to indicate that using several modes of representation for conceptual learning may not lead to the successful understanding of the concept (Riding & Rayner, 2013), but may rather incur an extraneous cognitive overload (Amin et al., 2015 & Kapur, 2016 & Sweller, 1994). This is because the student's short-term memory is limited in both its capacity and duration, and this results in little or no learning occurring. The discipline of molecular biology is associated with abstract, scientific terminology which contributes to the learning and teaching difficulties associated with teaching the discipline (Tibell & Rundgren, 2010). Therefore, there is a need for more research to understand the ways in which commonly used and emerging VSMs are perceived. It is necessary to identify visualisation features that are critical for teaching and learning biology. In addition, it is imperative to investigate how these aspects contribute towards poor concept understanding, in relation to the lack of visualisation skills and visuo-semiotic reasoning. The possible misalignment between VSM and learning styles need to also be investigated. Most importantly, there is limited research that describes the relationship between learning styles, modes of content presentation and visuo-semiotic reasoning in biology; and this knowledge gap will be addressed in this study.

1.4 Research aim and objectives

1.4.1 Aim of the study

The present study aimed to investigate the relationship between learning styles, modes of content presentation and visuo-semiotic reasoning in biology, as a preliminary effort to understand how teaching and learning could be enhanced through VSMs. The objectives of the research were focused on Grade 10 Biology students, in order to determine their:

a. most preferred learning style.
b. effective mode of content presentation for teaching the cell cycle.
c. extent of visuo-semiotic reasoning.

1.4.2 Research question

The research question guiding this study was:

> *What is the relationship between learning styles, mode of presentation and visuo-semiotic reasoning amongst Grade 10 Biology students?*

As a result, the sub-questions that guided the present study were as follows:

a. What are the most preferred learning styles amongst Grade 10 biology students, when learning the biological concept known as 'the cell cycle'?
b. What could be the most effective mode of content presentation for teaching and learning the cell cycle, amongst Grade 10 biology students?
c. What is the level of visuo-semiotic reasoning amongst Grade 10 biology students?

1.4.3 Hypothesis

A hypothesis is a tentative explanation that accounts for a set of facts and can be tested by further investigation or a testable answer to a scientific question (Ary et al., 2018 & Mourougan & Sethuraman, 2017). It is a theory that is postulated, based on reasoning, without assuming the truth and it is tested in a study (Balluerka et al., 2005). The hypothesis for this study is:

There exists a relationship between learning styles, modes of content presentation and visuo-semiotic reasoning amongst Grade 10 biology students. These students prefer to learn the cell cycle theory in biology, using a specific style of learning through the use of an effective mode of presentation.

1.5 Rationale

VSMs could play a critical role in teaching and learning. However, it is important to consider the design of VSMs, and their connections to learning goals as well as consider the student's prior knowledge of the discipline when creating and using visualisations in biology education (Cook, 2006). The current study sought to stimulate interest in the effective use of VSMs in teaching and learning, in order to foster visuo-semiotic reasoning. In addition, VSMs can become an essential tool to foster skills such as communication; where the student can communicate by responding to the presented VSM, with the result of fostering critical thinking, creativity and collaboration among students. Visual literacy is expressed through cognitive processes that require visualisation skills (Mnguni, 2007). Hence, the present research will determine which factors influence the extent to which visuo-semiotic reasoning is affected. Success in the ability to identify, analyse and interpret VSMs will lead to conceptual understanding, and an overall increase in student performance.

Difficulties in understanding concepts and reasoning by students, have been major foci of research in science education, particularly in biology education. The difficulties of teaching in the field of molecular biology tend to differ in nature from other domains like physics and chemistry (Taber, 2013). In these disciplines, the fragmentation of knowledge and difficulties in connecting and using knowledge may be more significant than merely understanding theoretical concepts (Bell, 2001). Thus, research regarding student's conceptual understanding of concepts in molecular biology necessitates a different approach and focus. The researcher sought to highlight the significance of understanding the relationship between learning styles, modes of content presentation and visuo-semiotic reasoning.

1.6 Conclusion

This chapter discussed the impact of VSMs on learning, and how their effectiveness could be limited if the related learning styles were not accommodated. Additionally, their effectiveness could be limited if students experience learning difficulties, due to a lack of visual literacy and spatial ability skills. Such skills are essential to work with VSMs. In view of this, VSR is dependent on the availability of visualisation skills, among students. The present study presents a dearth of research regarding the relationship between learning styles, modes of content presentation, and visuo-semiotic reasoning. VSMs play critical roles in teaching and learning biology, and when used correctly, they can bring about unique benefits to students, such as a positive impact on the physiologic brain function by developing cognitive abilities (Morgan, 2014). However, inappropriate use of this technique may lead to a poor conceptual understanding of biological terms. It was for this reason, which the present study aimed to investigate the relationship between learning styles, modes of content presentation, and visuo-semiotic reasoning in biology. This was a preliminary effort to understand how teaching and learning could be enhanced through the use of VSMs.

Chapter Two: Literature Review

2.1 Introduction

The review of literature is conducted to investigate or discover (Onwuegbuzie et al., 2012) what has been researched about a particular phenomenon (Fink, 2019 & Hart, 2018). This includes sharing with readers the findings of other studies which are related to the study being reported (Creswell & Tashakkori, 2008). The current study explored different theories which could help to answer the research question. The theories provided a theoretical framework for the study. A theoretical framework is defined as the structure that can hold or support a research study (Fredricks et al., 2016 & Kumar, 2019 & Osanloo & Grant, 2016). Generally, theoretical frameworks are formulated to explain, predict and understand phenomena. In addition, they help to challenge existing knowledge within the limits of critical assumptions (Baer et al., 2013 & Ngulube et al., 2015).

In the current section, the author reviewed different theories that are important to the study. These include the cognitive theory of multimedia learning, and the theoretical cognitive process of visualization. These two theories are related but are different in terms of their individual components. According to Mayer's (2005a), the cognitive theory of multimedia learning (CTML) focuses on the transfer of knowledge. The emphasis is on how words and pictures are used to promote an understanding of complex terminology. The theoretical cognitive process of visualisation focuses on how the cognitive processes of perceiving, processing and producing visual models takes place (Mnguni, 2014).

2.2 The cognitive theory of multimedia learning (CTML)

Mayer (2005a; 2009) first proposed that CTML occurs when a student builds mental representations from words and/or pictures (Mayer, 2005a). The "words can be in the form of printed text or spoken text, and the pictures can either be in a static form (illustrations, photos, diagrams or charts), or in a dynamic form (animations or videos)" (Mayer, 2008 p.760). Generally, CTML attempts to explain how to structure multimedia instructional practices, and how to implement more effective teaching strategies to help students learn efficiently (Mayer & Massa, 2003 & Sorden, 2012). A fundamental hypothesis which underlies research on multimedia learning, is that multimedia instructional messages are designed on the basis of how the human mind works, and in consequence, are more likely to lead to meaningful learning that those that are not (Clark & Mayer, 2016 & Mayer, 2005a; 2009; 2011 & Salomon, 2012). Consequently, the model of working memory (Baddeley et al., 1986 & Gathercole & Baddeley, 2014), Paivio's dual-coding theory (Paivio, 1986 & Sadoski & Paivio, 2013), and Sweller's theory of cognitive load (Sweller, 1994; 2010) are integral theories that support the overall theory of multimedia learning.

Baddeley et al. (1986) model of working memory, argues that working memory is like a multi-part system, and each system is responsible for a different function. The model of working memory accounted, not only for the standard operations of short-term memory (Jones, 2012 & Unsworth, 2016), but also on how memory is cojoined and directed and also on how it is related to long-term memory (Schneegans & Bays, 2019 & Williams et al., 2013). The model of working memory, Figure 2.1 includes a central executive with three sub-systems (Campos et al., 2013 & Gruszka & Orzechowski, 2016). First, the phonological loop which contains a short-term phonological store of speech and other sounds, and an articulatory loop that maintains information either vocally or sub-vocally (Fürstenberg et al., 2013 & Hackl, 2018). Baddeley (2015) viewed the primary purpose of the phonological loop, as evolving for language acquisition and comprehension (Gathercole & Baddeley, 2014 & Wen, 2014). Second, the visuo-spatial sketchpad forms part of the working memory and is hypothesized to involve the maintenance and integration of visual and spatial elements (Baddeley, 2017a & Hubber et al., 2014 & Morey, 2018 & Roux & Uhlhaas, 2014). Visuo-spatial sketchpad has an important role in spatial orientation, and solving spatial problems (Ha & Fang, 2015 & Kragten et al., 2015 & Wang, 2017). Thirdly, the episodic buffer serves as the memory component of the central executive and integrates and temporarily stores information for the other two sub-systems (phonological loop and visuo-spatial sketchpad) (Baddeley et al., 2019; 2017a; 2000 & Gray et al., 2017 & Hitch et al., 2019).

Working memory involves simultaneous attention to task relevant information, as well as manipulation, processing and storage (Camos et al., 2018 & Myers et al., 2017 & Nyberg & Eriksson, 2016). Working memory also correlates with a number of important practical abilities (Peng et al., 2016), including reading comprehension (Christopher et al., 2016 & Silva & Cain, 2015), vocabulary learning (Baddeley, 2017b & Redick et al., 2016), language comprehension

(Perfetti, 2017), reasoning (Chuderski & Jastrzębski, 2018), and language acquisition (Baddeley, 2017a & Hamrick et al., 2018).

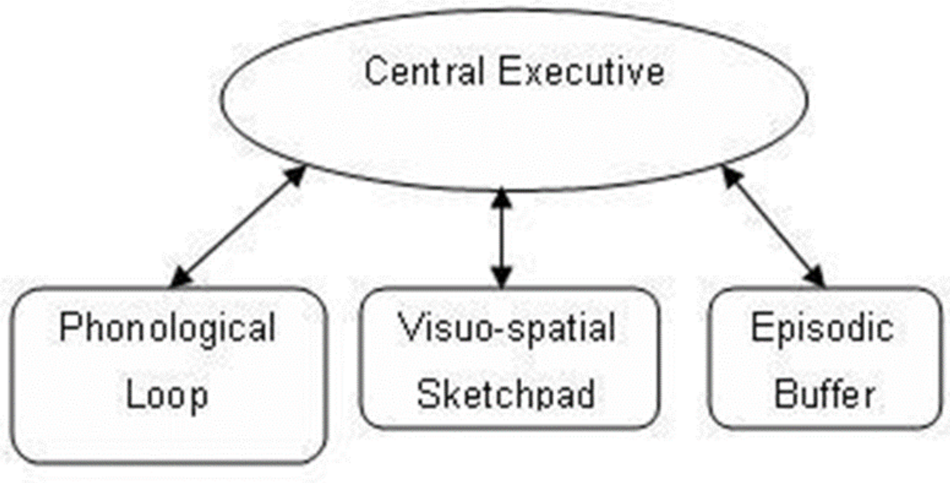

Figure 2.1: Baddeley's Model of Working Memory (1986)

The dual-coding theory attempts to give an equal weight to verbal and non-verbal processing (Holden, 2015 & Paivio, 2014a). The theory (Fig.2.2), assumes that there are two cognitive sub-systems. One which specializes in the representation and processing of non-verbal objects or events, which is known as imagery *(imagens)* (Bishop et al., 2014 & Richardson, 2013), and the other which is specialized for language *(logogens)* (Paivio, 2014c). The language system is peculiar, in that it deals directly with linguistic input and output, in the form of speech or writing, and at the same time, it serves as a simultaneous function to non-verbal objects (images) (Rost & Candlin, 2014). As such, Paivio (2014b) argues that any representational theory must accommodate this dual functionality (Zhao, 2011). Paivio (2013) also postulates two different types of representational units; one for images and the other for verbal units. The dual-coding theory had identified three types of information processing. Firstly, representational, which is associated with the direct activation of verbal or non-verbal representations (Barber et al., 2013 & da Silva & Correia, 2018 & Paivio, 2014a & Yang et al., 2018). Secondly, referential which is associated with either the activation of the verbal system by the non-verbal system, or activation of the non-verbal system by the verbal system (Paivio, 2014a & Schultheiss & Strasser, 2012), and thirdly, associative processing, which is associated with the activation of representations within the same verbal or non-verbal system

(Kusumawati & Rachmawati, 2016 & Paivio, 2014a). Any given task may warrant any, or all of the three kinds of information processing (Holden, 2015).

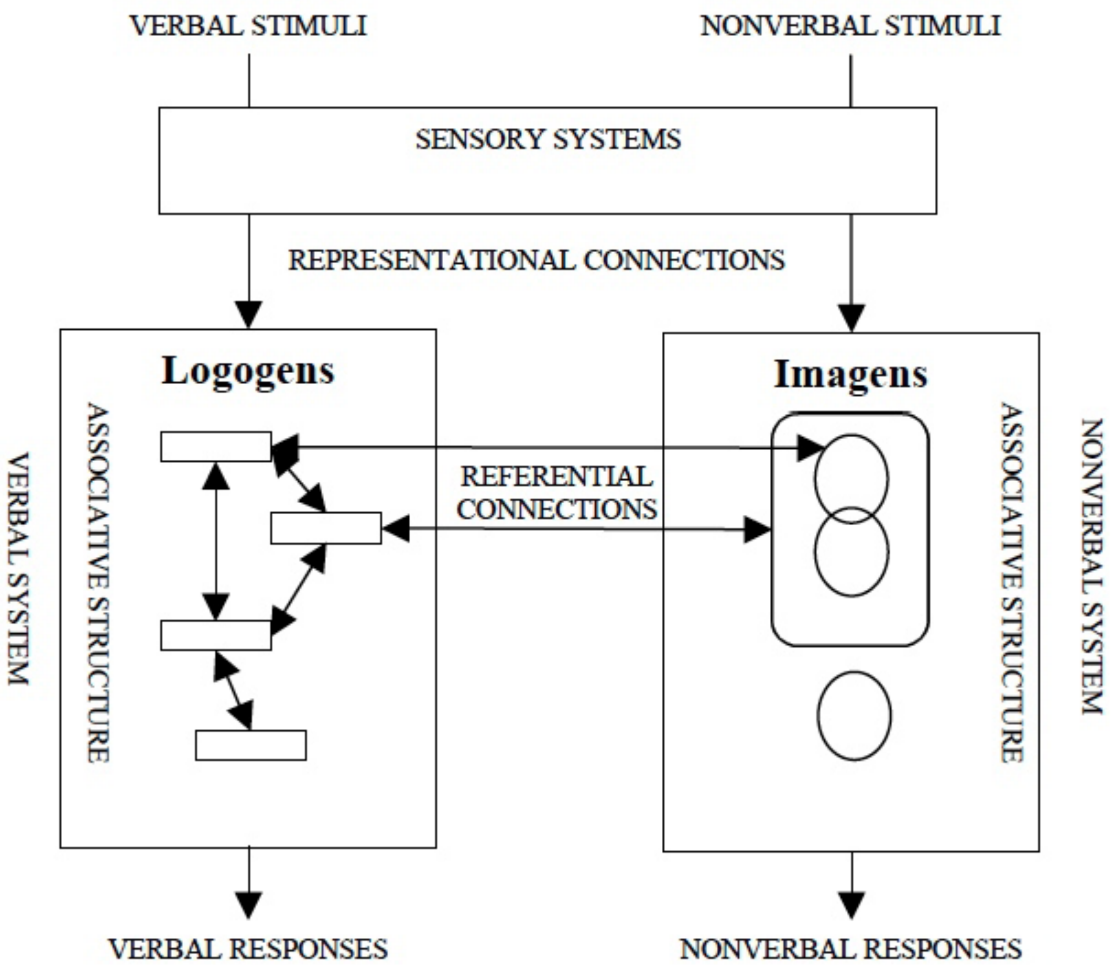

Figure 2.2: Paivio's Dual-Coding Theory (2014a)

Cognitive load theory describes variables that hinder schema development (Leppink & van den Heuvel, 2015 & Young et al., 2014). Schema development refers to acquired knowledge that has been organized and stored in long-term memory (Paas & Sweller, 2014). Cognitive load theory is based on three aspects; that (a) short-term memory (working memory) is limited in capacity (Darabi & Jin, 2013); (b) long-term memory has unlimited capacity, and it is where all acquired knowledge is stored (Paas & Sweller, 2014 & Sweller, 2016a); (c) knowledge is processed and stored in long-term memory as schemata (Young et al., 2014). Cognitive load theory also comprises of three distinct elements; (1) intrinsic cognitive load, (2) extraneous cognitive load, and (3) germane cognitive load (Debue & Van De Leemput, 2014 & Khalil et al., 2005 & Mayer & Chandler, 2001 & Paas et al., 2003 & Sweller, 2010).

The intrinsic load is concerned with the intrinsic complexity of information, which must be understood and learned (Leahy & Sweller, 2008 & Sweller, 2010). The level of intrinsic cognitive load for a particular task, may be determined by the level of element interactivity (Chen et al., 2018 & Sweller, 2016b). An element is regarded as anything that needs to be or has been learned. Extraneous cognitive load is concerned with the manner in which instructional material is designed (Kalyuga & Liu, 2015 & Sweller, 2016b). Since the cognitive load theory is concerned with techniques designed to reduce extraneous cognitive load, it suggests that the way we teach, and what we use to teach will determine the extraneous load (Sweller, 2016b). The germane cognitive load is concerned with the acquisition of knowledge, whereby a decrease in the extraneous load results in an increase in the germane cognitive load (Lange & Costley, 2019). In order for information to go to the long-term memory, it must be in the germane load (Grunwald & Corsbie-Massay, 2006 & Risko & Gilbert, 2016).

Cognitive scientists study how the brain learns, by drawing from research in a number of areas including psychology, neuroscience, artificial intelligence, computer science, linguistics, philosophy and biology (Barsalou, 2014 & Eysenck & Keane, 2015 & Gazzaniga & Ivry, 2013 & Li & Du, 2017 & Sorden, 2012 & Thagard, 2009). The term 'cognitive' refers to mental processes such as perceiving, thinking, remembering, understanding language and learning (Anderson, 2013a & Barsalou, 2008 & Smith, 2014). Cognitive science can provide insight into human nature, and more importantly, provide insight into the potential of humans to use instructional technology as an efficient method of teaching (Bransford et al., 2012 & Pritchard, 2017 & Rendell et al., 2011 & Sorden, 2012). The three cognitive science principles of learning which inform CTML, are:

a. The human information processing system includes dual channels for visual/ pictorial and auditory/ verbal processing; this is known as the dual-channel assumption;
b. Each channel has limited capacity for processing, this is known as the limited capacity assumption and;
c. Active learning entails carrying out a co-ordinated set of cognitive processes during learning, this is known as the active processing assumption.

As a result of technological advances, VSMs are becoming widely available, and aim to improve student acquisition of knowledge, development of VSR and overall performance (Bishop & Verleger, 2013 & El-Hussein & Cronje, 2010 & Harris et al., 2009 & Morrison et al., 2019). For years, words have been the major format for instruction (Sweller et al., 2019). Nevertheless, by simply adding pictures to words, either by dynamic or static form cannot in itself, guarantee an improvement in learning. Hence, it can be concluded that not all multimedia presentations are equally effective (Stiller et al., 2009 & Xie et al., 2019).

2.2.1 Three assumptions of CTML

a. Dual-channel assumption

The dual-channel assumption suggests that humans possess separate information processing channels for visually represented material, and for auditory represented material. When information is presented to the eyes, in the form of illustrations, animations, videos, on-screen texts, humans begin by processing that information in the visual channel. When the information is presented to the ears, these include narration or non-verbal sounds, humans begin by processing that information in the auditory channel (Mayer, 2011). The dual-channel states that the working memory serves to process both visual, and auditory stimuli separately, and that simultaneous intake of multiple sources of stimuli, may result in an overload of information to the brain.

One of the most commonly used presentation tools in education is the use of the PowerPoint. As a presentation tool, it does not reduce extraneous cognitive load, as it fails to eliminate redundant and irrelevant elements (Kalyuga & Singh, 2016 & Khalil & Elkhider, 2016 & Sweller, 2016a). For example, the redundancy principle of CTML states that students learn better from graphics and narration than from graphics, narration and on-screen text alone (Cheah & Lai-Mei, 2019). In consequence, this tool does support the dual assumption theory. Penciner (2013) asked the question, “Does PowerPoint enhance learning?” (2013, p.109), to question the use of this educational tool and its effectiveness. Penciner (2013) argued that there are many books, articles, and websites on how to use PowerPoint effectively; however, there is a dearth in scientific evidence on the effectiveness of PowerPoint in learning and information processing.

Tufte (2003) & Cooper (2009) contended that PowerPoint had many inherent limitations which reduced learning. Tufte (2003) supported this statement, by stating that during a presentation, the average audience had already finished reading the slide, before the speaker had begun their talk. More so, the use of bullets prevented the audience from creating schema (mental modes) or prevented them from making mental connections from the information presented. Essentially, PowerPoint replaces effective communication with presentation (Penciner, 2013). Although information may be taken in by visual and auditory stimuli, it does not account for effective learning. In contrast, Pate & Posey (2016) measured the effect of a 'multimedia design, adherent PowerPoint presentation.' Traditional PowerPoint slides were used to present the lecture information in the first instance, while in the other instance, the lecture format was re-designed to comply with multimedia design principles. Over subsequent years, two versions of an identical lecture were presented in different formats (2011-2013). Pate & Posey (2016), concluded that student performance improved when adherent PowerPoint was redesigned. When applying multimedia design principles, information was presented used adherent PowerPoint. This results in improved retainment of information when the information is presented in a 'multimedia design, adherent' format.

Brünken et al. (2004) used the cognitive load theory, and the cognitive theory of multimedia learning to investigate "if audio-visual presentation of verbal and pictorial learning would lead to a higher demand on phonological, cognitive capacities than the visual-only presentation of the same material. It was also investigated whether adding seductive background music to an audio-visual information presentation, would increase the phonological cognitive load" (2004: p.115). They found that background music does not impose load on an auditory working memory. That is because it does not contain relevant information, and it is not related to the process of knowledge construction. Only in a situation where the auditory channel is already used for information processing; as in the case of the audio-visual presentation, does background music have a load effect, which affects learning negatively (Brünken et al., 2004).

b. Limited capacity assumption

The limited capacity assumption states that we have a limited capacity, within each channel for storing, organizing, and retrieving knowledge. The limited capacity assumption, based on the cognitive load theory (Sweller, 1994), states that each sub-system of working memory has a limited capacity. When an illustration or animation is presented, the student is able to hold only a few images in the working memory at a time (Mayer & Massa, 2003). Brame (2016) suggested that in order to manage cognitive load and enhance germane load, videos should be ≤ 6 minutes.

Castro-Alonso et al. (2019b) highlights that the cognitive load theory can be employed to produce more effective instructional design for science learning, but the limits of visuospatial processing in working memory must be considered in order to be effective. Houts et al. (2006) reported that combining instructional texts with static and dynamic visualisations, could yield positive effects. In their review, participants showed an increase in attention, comprehension, recall and adherence of information. In addition, Vekiri (2002) stated that for visualisations to be effective, student's process pictorial-textual material by teachers scaffolding the verbal information. Scaffolding is usually conceptualized in terms of informational or coordinative support behaviours (Bickhard, 2013). Scaffolding allows an individual to accomplish tasks that he or she otherwise might be unable to accomplish (Hathcock et al., 2015). Therefore, visualisations which are not designed for scaffolding purposes, can be ineffective or even counterproductive for learning (Akyeampong et al., 2006 & Castro-Alonso et al., 2019b).

Mayer (2005b) stipulated that VSR occurs when an individual forms mental images, and manipulates it in a principled manner, in order to identify, integrate, analyze, and perceive details, structure and spatial relationships. Therein, multimedia presentations consisting of words and pictures can be designed to complement VSR during learning, which in turn leads to deeper understanding of the material presented. VSR consists of two elements, i.e. (a) the content of VSR consists of mental images, and the processes of VSR consists of the (b) principled manipulation of mental images. For example, suppose an animation depicting the cell cycle in an animal cell, along with a concurrent narration which described the process was presented to students. Understanding this multimedia presentation requires VSR, because one must be able to manipulate the mental image, based on nonarbitrary principles (set rules or guides); that is, one must think about what happens during the cell cycle phase called Interphase**,** and the importance of DNA replication during this phase. For this reason, a student mentally constructs a "cause and effect" by which one change is related to the effect of the other (a combination of action and reaction). In contrast, an example of an arbitrary mental manipulation is visualizing the shape of the cell, in order to differentiate the characteristics between an animal, and a plant cell. Essentially, VSR refers to the active engagement within the VSM.

Mayer (2005b) suggests that (a) appropriate VSR during learning can enhance the students understanding and, (b) multimedia presentations can be designed to prime appropriate VSR during learning. Assessment of student understanding can involve asking a series of questions, with the aim to probe the student to assimilate, troubleshoot and explain the process. While it is seemingly acceptable that multimedia offers an opportunity for deeper understanding, there exists 8 design principles for fostering VSR in multimedia learning : (1) multimedia principle; (2) spatial contiguity principle; (3) coherence principle; (4) modality principle; (5) redundancy principle; (6) personalization principle; (7) interactivity principle; and (8) signalling principle.

c. Active processing assumption

Active processing assumption suggests that meaningful learning occurs when humans actively process and organize both audio and visual information. People construct knowledge in meaningful ways when they pay attention to relevant material, organize it into a coherent mental structure, and then integrate it along with their prior knowledge (Clark & Mayer, 2016 & Mayer, 2009 & Yilmaz, 2011). Slemmons et al. (2018), investigated the affect that video technology integration had on a middle level, science classroom. The objective was to determine the optimal video length that was needed to promote learning, increase retention and support student motivation. Their review showed that while assessments which directly followed short videos were slightly higher, these findings were not significantly different from scores that followed longer videos. While short-term retention of material did not seem to be influenced by video length, long-term retention for males, and students with disabilities was higher. Students self-reported that they were more engaged, had better focus, and had perceived higher retention of content, following shorter videos. Considering the influence that positive emotions have had on cognitive processes to promote learning, Raihan (2017) investigated how different designs can impact user emotions. Raihan (2017) questioned, "Does the interface design affect users experience with multimedia learning in the learning environment?" (2017: p.116). Interface design refers to designing the interaction between a human and a machine (Helander, 2014 & Raskin, 2000). Research on emotions indicates that they play an important role in cognitive processing, and subsequently enhances cognitive activities (Fredrickson, 2001 & Joormann & D'Avanzato, 2010 & Valiente et al., 2012).

Valiente et al. (2012) suggested that by considering student's emotions on their academic functioning, one is able to understand the circumstances involved in relating emotions to achievement. A few studies have linked positive emotions to achievement (Pekrun et al., 2004

& Valiente et al., 2012). These same studies reveal that emotions like joy, hope and pride are positively correlated with academic interest, effort and overall achievement of students (Pekrun & Linnenbrink-Garcia, 2014). Frederickson (2001) suggested that positive emotions enhance academic competency, because they encourage the ability to explore, integrate diverse materials and introduce a variety of potential methods to solve problems. This relates to the notion of the active processing which suggests that learning occurs when knowledge information is processed and organized into a coherent, mental structure which allows for meaningful learning.

2.2.2 The three-store structure of memory in CTML

There are three memory stores that are associated with CTML, and these are known as (1) sensory memory, (2) working memory and (3) long-term memory (Schweppe & Rummer, 2014 & Sorden, 2012) (Fig 2.3).

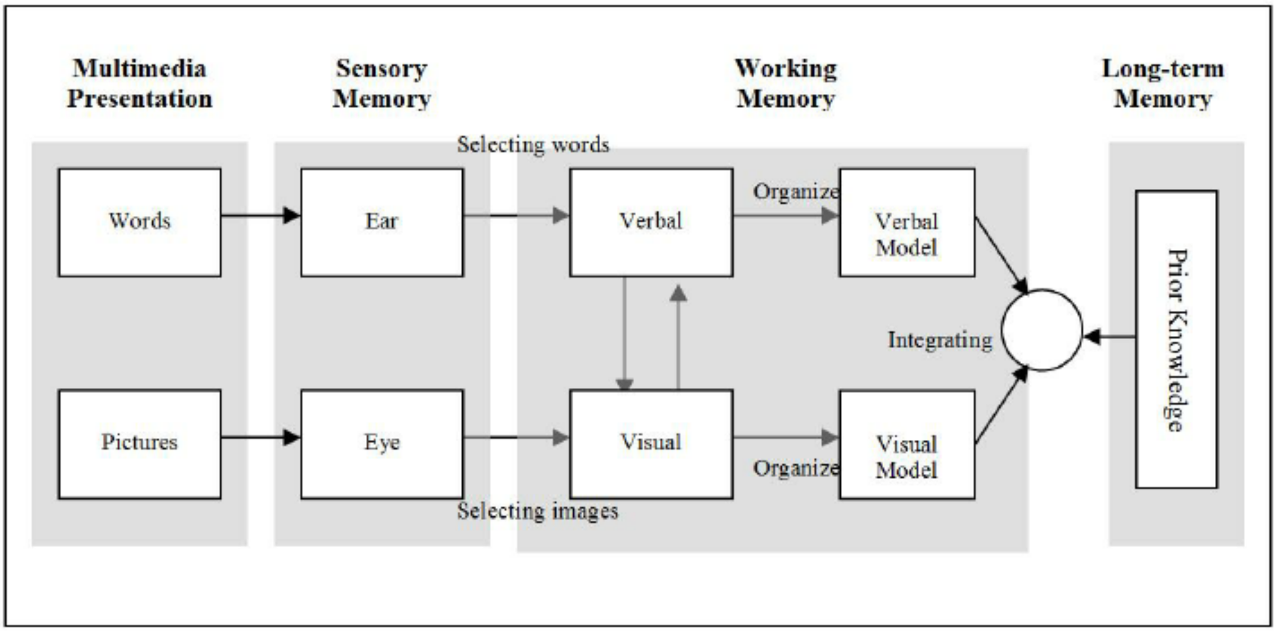

Figure 2.3: Mayer's Cognitive Theory of Multimedia Learning (2005a)

Sweller (2005) defines "sensory memory as the cognitive structure that permits us to perceive new information; working memory as the cognitive structure in which we consciously process information; and long-term memory as the structure that stores our knowledge base." (2005, p.24). The sensory memory structure has a visual sensory memory that briefly holds pictures and printed text as visual images. Auditory memory holds spoken words and sounds as auditory images (De Sousa et al., 2017 & Jenlink, 2019 & Mayer, 2005a). Working memory selects information from sensory memory for processing and integration (Christophel et al., 2017 & Myers et al., 2017 & Zelinsky & Bisley, 2015). While the sensory memory holds an exact copy of what was presented, working memory holds a processed version of what was presented, and can process only a few pieces of material at any one time (Mayer, 2010). The long-term memory holds the entire store of a person's knowledge for an indefinite amount of time (Sweller, 2016b). Figure 2.3 is a representation of how memory works according to Mayer's (2005a) cognitive theory of multimedia learning.

According to CTML, content knowledge is contained in schemas which are cognitive constructs that organize information for storage in long-term memory (Mancinetti et al., 2019). Schemas organize simpler elements that can then act as elements in higher order schemas (Sorden, 2012). Mayer (2010) suggested that meaningful learning from multimedia presentation takes place when the student engages in five cognitive processes: (1) selecting relevant words for the verbal working memory; (2) organizing selected words into a verbal model; (3) organizing selected images into a pictorial model; (4) integrating the verbal and pictorial representations with each other; (5) and with prior knowledge.

Mayer (2010) states that the five cognitive processes of working memory determine which information is selected, which knowledge is retrieved from long-term memory (prior knowledge) and integrated with the new information to construct new knowledge, and ultimately, which parts of the new knowledge is transferred to long-term memory. Knowledge that is constructed in working memory is transferred to long-term memory through the process of encoding (Mayer, 2008). Encoding refers to the input of information to the memory system where it is organized (Herry & Johansen, 2014). On the contrary, Dwyer & Dwyer (2006) caution that applicable encoding requires rehearsal, and since rehearsal takes time, the multimedia lesson must allow an adequate period for incubation or it can be ineffective.

2.2.3 Principles on the instructional design and organization of multimedia presentation

Mayer (2009) distinguishes meaningful learning (effective) from "no learning" and "rote learning" (ineffective), and describes meaningful learning as an active learning component, where the student constructs knowledge. Mayer (2009) defines learning as a "change in knowledge attributable to experience” (2009, p.59). Since learning takes place within the cognitive system of the student, it is personal and cannot be directly observed, and hence it must be inferred through a change in behaviour, such as graded performance on a task or a test (Sorden, 2012). Meaningful learning is demonstrated when the student can apply what was presented in new situations, and students perform better on problem-solving transfer tests when they learn with words and pictures. Mayer (2008) identifies two types of transfers, i.e., the transfer of learning and problem-solving transfer. Transfer of learning occurs when previous learning affects new learning (Mayer, 2008 & Trinchero & Sala, 2016), and problem-transfer occurs when previous learning affects the ability to solve new problems (Loibl et al., 2017 & Mayer, 2008).

Mayer (2008) developed the following principles for meaningful learning in multimedia presentation design and organization:

1. ***Multimedia principle:*** states that students learn more effectively from multimedia presentations than from verbal presentations alone.
2. ***Spatial contiguity principle***: states that students learn more effectively when narration and pictures are presented simultaneously, rather than consecutively. This allows the brain to create connections between two items.
3. ***Coherence principle***: states that students learn more effectively when multimedia presentation is interesting than when it is basic.
4. ***Modality principle***: states that students learn more effectively when multimedia presentation includes images and narration, rather than images and text.
5. ***Personalisation principle***: states that students learn more effectively when the presentation is conversational, rather than expository.
6. ***Signalling principle***: states that students learn more effectively when presenters direct the students to the important passage or events in the passage.
7. ***Redundancy principle***: states that students learn better from graphics and narration than from graphics, narration and on-screen text.
8. ***Temporal contiguity principle***: states that students learn more effectively when corresponding words and pictures are presented simultaneously, rather than successively.
9. ***Segmenting principle***: students learn more effectively when a multimedia lesson is presented in user paced segments, rather than in a continuous unit.

10. ***Pre-teaching principle***: students learn more effectively from a multimedia presentation when they know the names and characteristics of the main concepts.
11. ***Voice principle***: states that students learn more effectively from a multimedia presentation when the narration in multimedia presentation is spoken in a friendly human voice, rather than in a machine voice.
12. ***Interactivity principle***: states that students learn more effectively when they are allowed to control the presentation rate, rather than when they are not.
13. ***Image principle***: students do not necessarily learn better when the image of the speaker is added.
14. ***Individual difference principle***: states that design effects are stronger for low-knowledge students than for high-knowledge students. Also, design effects are stronger for high spatial students than for low spatial students.

CTML centres on the idea that students attempt to build meaningful connections between words and pictures, and that they (students) learn more deeply than they could have with words or pictures alone (Clark & Mayer, 2016 & Beck et al., 2013 & Mayer, 2009 & White & Gunstone, 2014). The student, as an active participant is to make sense of the presented material, ultimately constructing new knowledge (Chi, 2009 & Spiro et al., 2012). A multimedia instructional message is a communication containing words and pictures which is intended to foster learning (Mayer, 2011 & Morrison et al., 2019). The communication, as an instructional message can be delivered using any medium including paper, for example, book-based communication, words that include printed words or spoken words (narration), and pictures that can include static graphics or dynamic graphics as well as interactive simulations (Gilakjani, 2012 & Makrygianni, 2018 & Mayer, 2011).

In attempt to show the diversity of cognitive abilities that are controlled by the visuospatial processor of working memory and their differences, Castro-Alonso & Atit (2019) described working memory and their allocated components that deal with visuospatial ability tasks. Visuospatial tasks described by Mervis et al., (1999) include “drawing, buttoning shirts” (1999, p.1222), simulation by constructing models, making a bed, and last but not least assembling furniture. Essentially, visuospatial construction is a central cognitive ability (Gainotti & Trojano, 2018). Könen et al., (2016) considered working memory as a limited capacity system which is responsible for simultaneously maintaining, or briefly storing and processing information for a higher level cognition (Castro-Alonso & Atit, 2019). Higher level cognition involves reasoning, planning, understanding language and processing as well as problem solving (Conte & Castelfranchi, 2016 & Lee et al., 2016 & Rumelhart, 2017).

Castro-Alonso & Atit (2019) recognised the different components of Baddeley's working memory model (Baddeley, 1992) which describes the system comprising of two 'slave' storage systems, i.e. the phonological loop which processes verbal and auditory information and the visuospatial sketch pad which processes visual spatial information, by which they are demanded by the central executive controller (Baddeley, 1992 & Castro-Alonso & Atit, 2019). Castro-Alonso & Atit (2019) focussed on the "(a) visuospatial sketch pad, a system for storage of visual and spatial information and (b) on the central executive, the system for processing and manipulating this visuospatial information" (2019, p.24).

Castro-Alonso & Atit (2019) define visuospatial processing "as the ability to generate, recognize, transform, store, and retrieve visuospatial information, in both static and dynamic displays." (2019, p.24). Visuospatial processing in working memory allows one to carry out many visual and spatial tasks, such as visualizing and recognizing relationships; observing and predicting the behaviour of objects; transforming visuospatial information from two to three dimensions; conceptualizing space; as well as using geometric models and other visuospatial instruments (Castro-Alonso & Atit, 2019 & Ness et al., 2017).

The implications of visuospatial processing is to be able to carry out visual and spatial tasks as described above, and for instructional designers to stimulate visuospatial processing in science classes by including activities that trigger the visuospatial working memory (Castro-Alonso & Atit, 2019 & Critten et al., 2018 & Zhang, 2016). These activities include the visualization of relationships between science depictions, and to critically note the different small-scale visuo-spatial abilities (Castro-Alonso & Atit, 2019). Visuo-spatial abilities involves mental rotation (Castro-Alonso et al., 2019a & Mitolo et al., 2015), where one perceives a whole figure and visualizes its rotation mentally (Castro-Alonso & Uttal, 2019 & Lin & Chen, 2016). Subjects such as design, physics, chemistry and biology, amongst others require metal rotation abilities and spatial thinking. Research showed that spatial ability facilitates learning biology (Bartholomé & Bromme, 2009 & Castro-Alonso & Uttal, 2019), and another study found that students majoring in physical sciences score higher in mental rotation than those majoring in arts or social sciences (Goldsmith et al., 2016 & Lord & Holland, 1997 & Moè, 2016).

Mental folding relies partially on mental rotation, as it involves mental transformation of the properties of a single object by itself (Selvi, 2018 & Skagerlund & Träff, 2016). When the object is imagined in rotations and folds (motion), this is considered to be intrinsic and dynamic (Newcombe & Shipley, 2015). Hodgkiss et al., (2018) studied the contribution of intrinsic and extrinsic spatial skills to science learning from children aged 7 to 11 years. The results indicated that spatial skills, particularly mental folding, spatial scaling and dissembling are predictive of 7-11 year olds science achievement. These skills made a similar contribution to performance for each age group. While there is ample research that relates spatial ability to science learning amongst adults and adolescents (Gunderson et al., 2012 & Mix & Cheng, 2012), there is little research that addresses this relationship amongst primary-aged children. A study conducted by Punaro & Reeve (2012) investigated the relationships between 9-year-olds' math and literacy worries and their academic abilities. The results indicated that the children's worry ratings varied as a function of task and problem difficulty. The results highlighted that children were sensitive to task demands. Therein, Hodgkiss et al., (2018) found that spatial skills, particularly mental folding was a predictor for science learning and for achievement.

In addition, the cognitive styles known as field independence, in contrast to field dependence (Kogan & Saarni, 2017 & Raptis et al., 2017), have found application in how students learn (Davis, 1991). Field dependent students rely on external cues from their environment (Davis & Cochran, 2017), and they are characterized by having a short attention span as they are easily distracted and prefer a casual learning environment (Hadhi, 2013). On the contrary, field independent students are characterized by their analytical approach and abilities to solve problem (Rassaei, 2015). Hence, these students are task orientated and are more intrinsically motivated in their learning process (Hadhi, 2013 & Khodadady & Tafaghodi, 2013 & Khodadady & Zeynali, 2012 & Witkin, 1949) Similar to mental rotation and mental folding, field independence relies on both the visuospatial sketch pad and the central execution controller of working memory (Castro-Alonso & Atit, 2019). Tinajero & Páramo (1997) re-examined the relationship between field dependence and field independence amongst students who were aged between 13 and 16. Results indicated that field independent boys and girls performed better then field dependent boys and girls. Hadhi (2013) also found that field independence correlated positively and significantly in second language classrooms.

2.3 The theoretical cognitive process of visualization

The theoretical cognitive process of visualisation is based on various studies on general cognitive processes, with specific reference to molecular biology and science education. Mnguni (2014) defines visualization as "the ability to select and effectively use a set of cognitive skills for perceiving, processing and producing visual models." (2014: p.2). Mnguni (2014) highlighted that learning involves processing of information as a way of interaction between the internal (psychological) and the external (physical) domains. Cognitivism, constructivism and related theories such the cognitive theory of multimedia learning, address the input of information from the external world into the cognitive structures; the cognitive processing of this information; and the externalization of information from the mind to the world/ environment. Mnguni (2014) believed that the cognitive processes of visualisation can be divided into three non-linear stages: (1) internalization of visual models, (2) conceptualization of visual models and (3) externalization of visual models (Figure 2.4).

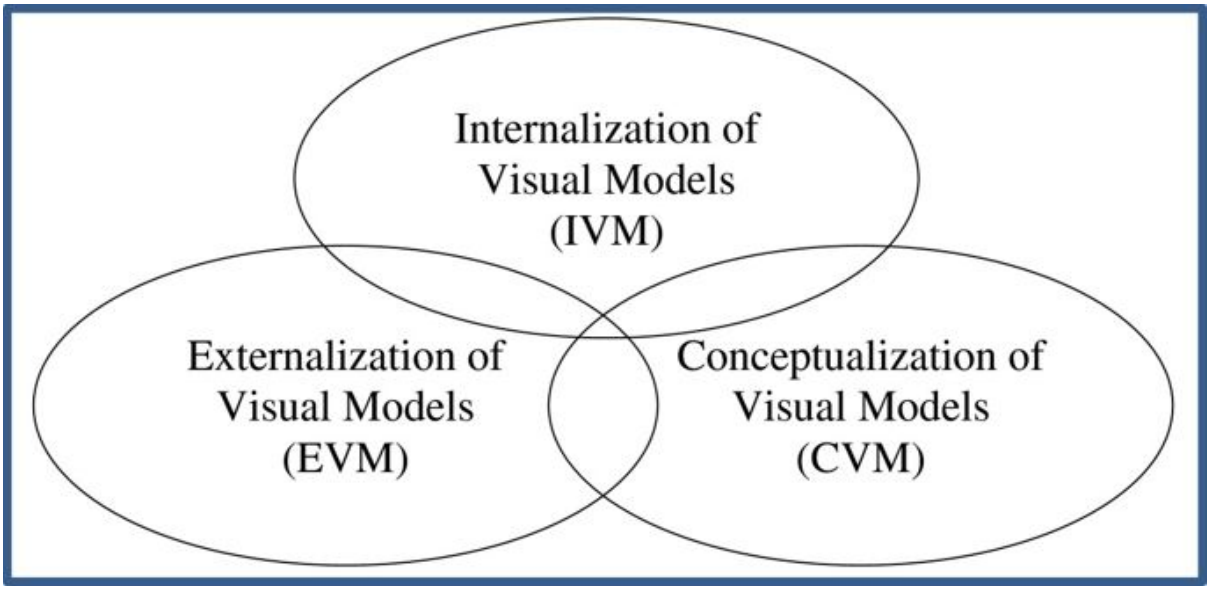

Figure 2.4: The overlapping stages of the cognitive process of visualisation (Mnguni, 2014)

2.3.1 Internalization of visual models (IVM)

Internalization of visual models refers to the process where sense organs such as the eyes work with the brain to absorb information from the world. Mnguni (2014) stipulates that there are at least three levels of IVM, viz; low, middle and high level. The low level IVM involves mainly features of extraction, which involves pre-attentive visual tasks which require minimal effort to perform. These include target detection, region tracking and counting (Kawahara & Yokosawa, 2001). High level IVM involves a cognitively demanding process of concept formulation (Healey, 2005), when a relatively high amount of cognitive effort is applied to internalizing visual information (Van Schoren, 2005). This stage may be interconnected with the CVM stage, as it may require an interpretation of visual models using prior knowledge (Healey, 2005). Once information is internalized, it is then transferred to the working memory for further processing to generate "meaning" by constructing mental schema.

Gestalt principles account for the way visual models are processed cognitively in high level IVM, also called the post-attentive stage (Behrens, 1983). Gestalt principles suggest there are at least four main factors that determine how humans chunk information, viz; closure, proximity, similarity and simplicity. Koedinger & Anderson (1990) regard chunking as a result of information that has been internalized and is organized into coherent patterns called chunks. This chunking may be followed by selecting and rearranging of the information.

1. ***Closure:*** suggests that the mind tends to complete figures, even in cases where information is missing.
2. ***Proximity:*** suggests that when visual features are placed close to each other, they are perceived as a unit.
3. ***Similarity:*** suggests that items have commonalities such as shape, size and colour, texture and orientation.
4. ***Simplicity:*** suggests that items are grouped together according to smoothness, regularity and symmetry.

All these principles reflect the behaviour of the cognitive system toward new visual information. Research in molecular biology has also confirmed the applicability of these principles, among students studying theoretical concepts. Novick & Catley (2007) indicate that students have had more learning difficulties with understanding phylogenetic ladders, compared to phylogenetic trees. This is because the Gestalt principles of continuation (proximity) obscures the hierarchal structures of ladders, which is not the case with phylogenetic trees. Mnguni (2007) posits that a typical learning skill associated with IVM is the ability to comprehend the scientific meaning of the visual model part that lies behind an object in the foreground. The IVM stage is where misconception is likely to occur. Also, IVM is linked to the availability of the conceptual knowledge from the long-term memory.

2.3.2 Conceptualization of visual models (CVM)

Conceptualization of visual models (CVM) is the process where meaning is made, and during which visual models are constructed. During CVM, prior knowledge that is stored as cognitive models may be revised from the long-term memory and reconstructed in the working memory, based on new knowledge (Mayer & Massa, 2003 & Mnguni, 2014). CVM is where students rely on short- and long-term memory to conceptualize visual information by interpreting incoming visual information against prior knowledge. Mnguni (2014) further discusses the Housen model (2001) to characterize people into different stages of cognitive processing, based on their actions as they view visual models. A study conducted by DeSantis & Housen (2001) investigated how students process information when viewing artistic work. These scholars derived five stages of cognitive processing of visual models. The five stages are “accountive”, “constructive”, “classifying”, “interpretive”, and “re-creative” (Housen, 2001).

In the accountive stage, students conceptualize visual models based on what is known, and what is liked as found in their long-term memory (DeSantis & Housen, 2001). In the constructive stage, students employ logical and accessible tools of knowledge to make judgements about visual models. In the classifying stage, students attempt to classify their perceptions into categories that occur in their memory. In the interpretive stage, students allow the meaning of the work to unfold, and appreciate the subtleties of line and shape and colour. In the re-creative stage, students attach varying meanings to an image they view each time, even if they had a previous meaning to the image. In this regard, prior knowledge is used to make new discoveries about the image at hand (Mnguni, 2014). CVM can be understood according to the dual-channel assumption (Mayer & Massa, 2003) which suggests that humans possess separate information processing channels for visually represented material and auditory represented material. Through referential connections, the two subsystems work together to construct and integrate mental visual models which are then memorized and stored in the long-term memory, as the limited capacity theory describes. Therefore, CVM depends on the amount of information presented to each of the cognitive channels.

2.3.3 Externalization of visual models (EVM)

Visualization also involves EVM which expresses cognitive mental schema visual models as external visual models in the form of drawings or verbal descriptions (Mnguni, 2014). EVM produced by students can be classified into three levels, viz, macroscopic, microscopic and symbolic (Tibell & Rundgren, 2010). The macroscopic level suggests that students attempt to produce a visual model of the phenomenon as they directly experience it through any of their senses. The microscopic level suggests that students attempt to produce a visual model of phenomena as they exist in nature. The symbolic level suggests that the visual model produced by students is a qualitative abstraction such as a mathematical model used to represent phenomena.

2.3.4 Application of IVM, CVM and EVM

Mnguni (2014) argues that teachers need to be alerted to the complexity of visualization and also its significance. Such insights will assist them to develop tools to minimize learning difficulties. As stated previously, IVM is characterized by three main components i.e., low, middle and high level that is in relation to the cognitive effort applied to comprehend visual information. Therefore, visualization of tasks relevant to each level must be identified explicitly, so that teaching and learning can encompass a gradual move from a low to a high level. CVM mainly relates the integration of prior knowledge to new knowledge. Therein, information about students existing cognitive skills, prior knowledge as well as misconceptions about the field must be explored, in order to facilitate learning through visual models. Furthermore, students preferred visual learning style must be considered during curriculum design and instructional design (Mnguni, 2014).

The notion of individualized learning styles has been widely recognized in education. Learning styles are ways in which students prefer to concentrate, process, and retain information (Dunn & Honigsfeld, 2013 & Shah & Gathoo, 2017). Dunn & Honigsfeld (2013) argue that the understanding of students learning style is likely to: (a) help teachers recognize the causes of some academic problems and (b) lead to better planned, differentiated instruction. Understanding of students learning styles, will help educators recognize those individual students who have learning difficulties and will ensure a student-level teaching response is provided (Dunn & Honigsfeld, 2013). Fleming & Baume (2006) states that learning styles of students should be understood as a conversation between teachers and students. Learning styles, as informed by Fleming (1995) are preferences that influence the individual's behaviours and their learning. These preferences are not fixed but are rather stable for the medium term. Preferences can be matched with strategies for learning and such information can be accessed and provided to students. Using these preferences allow for conceptual understanding and will be essential in motivating students (Fleming & Baume, 2006).

One of the most accepted understandings of learning styles is that students fall into either one of the following categories, viz; visual learners , auditory learners and kinaesthetic learners (Fleming, 1995). The VARK model of student learning refers to four types of learning styles: auditory, reading/writing, aural and kinaesthetic (VARK). Visual learners prefer the use of images, maps or graphics in order to access and understand new information (Koć-Januchta et al., 2017). Auditory preferring student's best understand new content through listening and speaking in situations, such as group discussions (Kayalar & Kayalar, 2017). Aural students use repetition as a study technique, and benefit from the use of mnemonic devices (Al Yafei & Osman, 2016). Reading and writing preferring students learn best through word, this type of learning style is characterized by note takers and enthusiastic readers who are able to translate abstract concepts into words (Alshumaimeri, 2017). Kinaesthetic learner's best understand new information through tactile representation of information, these students are hands-on, as they like to explore their environment (Gulnaz et al., 2018).

EVM is mainly about the ability of a student to communicate knowledge from their working memory by way of externalizing cognitive visual models. This could be facilitated by determining the student's ability to externalize visual models, so that students do not produce visual models that are beyond their abilities. Moreover, visualization tasks that could improve students' abilities to communicate visually at the different levels, i.e. macroscopic, microscopic and symbolic levels should be incorporated into curricula.

Learning biology in the 21st century requires a set of visualisation skills among students. These skills include the ability to understand, reason and to remember by processing visual stimuli to comprehend spatial relationships between objects, and to visualize different scenarios or images. The diversity of instructional tools for multimedia presentation allows students to experience high levels of interactivity in an educational setting of interactive science multimedia (Castro-Alonso & Fiorella, 2019). Moreno & Mayer (2007) described an interactive multimodal learning environment as "one in which what happens depends on the actions of the learner during learning." (2007, p.310). A non-interactive multimodal on the other hand, entails a multimedia message presented in a 'pre-determined' way, irrespective of the activities that the learner accounts for during learning, for example, a narrated animation or a textbook.

Therefore, Moreno & Mayer (2007) consider 'interactivity' as a "characteristic of learning environments that enable multidirectional communication" (2007, p.310). This underlies interactivity as a two-way action (between learner and instructor) (Moreno & Mayer, 2007). There are five types of interactivity, i.e. dialoguing, controlling, manipulating, searching, and navigating. Castro-Alonso & Fiorella (2019) considered that simulations and video games allow "the greatest interactive capabilities between the students and multimedia" (2019, p.145). Out of the five types of interactivity proposed by Moreno & Mayer (2007), Castro-Alonso & Fiorella (2019) based their study on three levels which increase interactivity, i.e.:

1. ***Level 1***: is characterized as low interactive tools which involve students 'dialoguing' with multimedia. For example, learners can solve a problem presented on-screen. These include computer-based instruction.
2. ***Level 2***: is characterized as medium interactive tools, allows students to 'control' multimedia. For example, students can pause and rewind a presentation; this is included in animations and videos.
3. ***Level 3***: is characterized as high interactive tools which allow students to 'manipulate' the multimedia. For example, learners can drag objects around the screen, these are included in simulations and video games. Simulations are regarded, in an educational setting as an artificial representation of a reality of context within which students interact (Gredler, 2004 & Johnson et al., 2017). Simulations are a form of experiential learning, which allows for the imitation of a form or representation of a process or system that represents its operation over time. Simulations thus allow students to experience reality and to infer meaning from it. Computer simulations have been shown to be an effective tool in traditional learning environments. As the integration of technology and e-learning environments grow in popularity, the need to examine simulation effectiveness and the central role of visualisations have become paramount. Instructional simulations have the potential to engage students in "deep learning", which empowers understanding, as opposed to "surface learning" which requires rote memorization (Indraganti, 2018 & Tahir, 2015). Instructional simulations are student-centred and are not equated to passive learning. Students are active participants in the

learning process by acquiring problem solving skills and decision making skills (Stewart, 2012).

Oliver-Hoyo & Babilonia-Rosa (2017) looked at how teaching in the fields of chemistry and biochemistry occurred, through the use of external representations and visualization tools. They also evaluated the kind of interventions and assessments needed in order to promote and evaluate spatial skills. Their findings indicated that explicit instruction to promote spatial skills has been on the rise, but not at the level of the other cognitive skills (Oliver-Hoyo & Babilonia-Rosa, 2017). Spatial ability refers to the capacity to understand, reason, and remember spatial relations among objects and spaces. Cognitive ability involves the mental capacity to reason, solve problems, plan, think abstractly and comprehend complex ideas. Spatial abilities and their impact on chemistry and biochemistry learning is critical, due to the spatial nature of the molecules as well as their visual representation (Oliver-Hoyo & Babilonia-Rosa, 2017). During the high level of IVM, a considerable amount of cognitive effort is required in order to internalize the visual information and this is true for both spatial and cognitive abilities (Mnguni, 2014 & Van Schoren, 2005).

A case for visuo-semiotic reasoning by Mnguni (2019) involves visual thinking, visualisation as well as cognitive abilities (Avgerinou & Ericson, 1997 & Haciomeroglu, 2016). Haciomeroglu (2016) investigated the relationship between spatial ability, verbal-logical reasoning ability, and mathematical performance. It was found that students who are ‘visualizers’ are not a homogenous group in relation to their spatial ability. There exists two groups of visualizers that use imagery in different ways i.e., object and spatial visualizers (Kozhevnikov et al., 2002). Object visualizers use object imagery to construct detailed images of objects which hinder effective spatial information and successful performance on spatial and mathematical tasks (Höffler et al., 2017 & Pérez-Fabello et al., 2018). Object imagery characterizes colour, vividness, shapes and detailed objects (Blazhenkova, 2016). Spatial visualizers use spatial imagery to create images, representing spatial relations among objects, which facilitates efficient spatial transformations and successful performance on spatial and mathematical tasks (Höffler et al., 2017 & Kato et al., 2019). Spatial imagery depicts spatial location or relations between objects (Höffler et al., 2017 & Pérez-Fabello et al., 2018). The findings indicated that spatial ability, verbal ability, logical reasoning and mathematical performance were all significantly correlated. The results support the existence of two contrasting groups of visualizers with respect to their spatial ability (Haciomeroglu, 2016).

It was for this reasoning, that Mnguni (2019) considered the significance of visuo-semiotic models in biology education. The aim of the study was to develop an instrument for assessing visuo-semiotic reasoning in biology (VSR-b). This is significant because the extent to which biology students have the necessary skills to comprehend content presented through VSMs is scarce. Mnguni (2019) defines visuo-semiotic reasoning as "the ability to internalize, conceptualize and externalize the knowledge of biology content through the use of VSMs. This includes the use of discipline specific semiotics which represent biology content." (2019, p.123). The results showed a significant correlation between content knowledge and the different skills required during visualization. The results also proved that visualisation skills which are tested in CVM and EVM are needed for the development of content knowledge (Mnguni, 2019). The study was informed by Schönborn & Anderson (2009), who empirically validated a model explaining the factors involved in successfully interpreting representation. This was significant because instructional representation is characterized according to level of abstraction. The level of abstraction refers to the level of complexity by which a system is viewed. These factors include individuals content knowledge, ability to reason and the visual characteristics of the representation. Schönborn & Anderson (2009) argued that in order to develop student's visual literacy, instruction should increase student's familiarity and fluency with the key characteristics of the representation (Schönborn & Anderson, 2006). Instructional opportunities that allow students to challenge cognitive elements in order to reduce cognitive load of complex activities, will promote development of cognitive abilities. This is further enhanced if the instruction is scaffolded (Kalyuga & Singh, 2016 & Paas et al., 2004). Visual literacy can be supported through the development of instructional opportunities that independently ask students to reason about one characteristic of representation level of abstractions, while holding to other factors such as organization (Offerdahl et al., 2017). This approach will also reduce the cognitive load experienced by students during learning. Offerdahl et al. (2017), suggested that cognitive load can be reduced by first helping students to become fluent with discrete components (properties and features) of visual representations before asking them to simultaneously integrate these components to extract the intended meaning of a representation, therefore instructional designers should consider the level of abstraction as first step in understanding the opportunities afforded students to develop fluency.

2.4 Current issues in science education

2.4.1 What has been the impact of learning styles in science education, and more in biology education?

It is generally accepted that matching a student's learning style with the appropriate form of instructional intervention, impacts students' performance and achievement of learning outcomes (Buckley & Doyle, 2017). Buckley & Doyle (2017) examined the impact that different learning styles and personality traits have on students' perceptions of engagement with, and overall performance within a gamified learning environment. The findings suggested that there are varied experiences regarding gamified learning environments by students, and this experience generally depends on an individual's attributes. There were a number of correlations existing between learning styles and personality traits. This affected student's perceptions and hence engagement in a gamified learning environment. Students perceive and process information differently. They participate in the learning environment according to their own unique learning style and mental capacity (Duman, 2010). Thus, it is imperative that the organization of the learning environment should also be in accordance with the students preferred learning styles to enable easier processing of information. Günes (2018) evaluated the dominant learning styles of students studying at the Biology Departments which were based in the Faculty of Arts and Sciences, as well as evaluated the dominant learning styles of the prospective biology teachers at the Faculty of education at universities in Turkey. The findings showed that there was no significant relationship among the learning styles of the students studying biology, based on their class level. However, a significant relationship was observed among the prospective biology teachers, based on their class level.

Ikitde & Edet (2013) determined the effect of different teaching strategies i.e., guided-inquiry, demonstration and lecture on student's achievement in biology, based on different learning styles, i.e., sensing or intuitive, active or reflective, visual or verbal, sequential or global. Also, the researchers examined the differences in student achievement in biology, as related to their preferred learning styles. Teaching strategies refer to several ways in which content knowledge is inculcated in student minds within a learning environment (Liu, 2013). A guided-inquiry involves problem solving approaches where students find answers to the instructional topic at hand and is student-centred (Bruder & Prescott, 2013 & Saunders-Stewart et al., 2015). A lecture method is teacher-centred, wherein student participation is limited as they listen, ask questions and take notes (Satyanarayana, 2018). A demonstration method involves students or teacher doing activities in front of the class and explaining as the activity progresses (Conner et al., 2014 & O'Shea & Leavy, 2013). The findings showed that students with sensing or intuitive learning styles performed better than their counterparts when taught with guided-inquiry. Demonstration teaching strategy was the most effective strategy in enhancing the achievement of students with sequential or global learning style, and the lecture method was the most effective strategy for students with visual or verbal learning style (Ikitde & Edet, 2013).

Theories of learning style suggest that individuals think and learn best in different ways (Leite et al., 2010 & Pritchard, 2017 & Schmeck, 2013). Teaching methods are often classified as traditional teaching methods and modern teaching methods and are influenced by technological and economical advancements in the 21st century (Voogt et al., 2013). This has fundamentally altered the foundation of traditional approaches to teaching (Selwyn, 2016), and has created the need to establish a teaching and learning environment to best meet the needs of the student (Drexler, 2010). Modern teaching methods in education include technology-driven classrooms (Holmes et al., 2015), inquiry-based learning (Pedaste et al., 2015), continuous comprehensive evaluation (Chopra & Bhatia, 2016), collaborative learning (Laal & Ghodsi, 2012), problem-based learning (Savery, 2015), amongst others. Traditional teaching methods are generally teacher-directed (Abdi, 2014), where students learn through memorization and recitation techniques (Ebrahim, 2012). It is argued that this approach may not provide students with valuable skills such as critical thinking, problem solving and decision-making skills (Gholami et al., 2016).

2.4.2 What are the effective modes of content presentation in science education, and more on biology education?

Learning with multiple representations that involve the use of VSMs, have been proven empirically (Jornet & Roth, 2015 & Rau, 2017 & Rau et al., 2015 & Tippett, 2016) to promote student's construction of knowledge (Erduran & Kaya, 2018 & Selling, 2016), understanding (Rau et al., 2017 & Santos & Arroio, 2016) and transfer of the represented information (Rau et al., 2017 & Remmele et al., 2015). Learning with VSMs involves processing of the VSM in order to construct an internal representation (Evagorou et al., 2015 & Gordo et al., 2017). Internal representations may include "mental or visual imagery, internal mental modes, memory or knowledge representations that are broader than the mere description of the perceived stimuli. They also include the individual's prior knowledge concerning represented information (Eilam, 2013, p2). Learning with multiple representations, in relation to VSMs involves a combination of external visual representations, internal visualization processes and the storage of constructed internal representation for VSR (De Koning & van der Schoot, 2013 & Eilam, 2013 & Makarova, 2016).

Diagrams are important tools in science education as they allow communication of abstract information (Prain & Tytler, 2012 & Tsui & Treagust, 2013). Process diagrams convey functional information about a dynamic process (Bobek & Tversky, 2016) by spatial configuration of components and arrows (Kang et al., 2015 & Kragten et al., 2015). In biology, "process diagrams explain processes such as protein synthesis, immunology, photosynthesis, cellular respiration, compound cycles, and the like." (Kragten et al., 2015, p.91). Although diagrams aim to facilitate learning, students have difficulties with diagram interpretation (Klingner et al., 2015 & Moreno et al., 2011). Kragten et al. (2015) measured students' ability to solve process-diagram problems in biology and its relationship with prior knowledge, spatial ability and working memory. Results showed that the students' ability to solve process-diagram problems was correlated to prior knowledge, spatial ability and visuospatial working memory capacity (Kragten et al., 2015).

In science, students need to learn to interpret and construct representational modalities (Hubber et al., 2010 & Nitz et al., 2014). The construction of representational models has the potential to deepen student understanding of scientific representation and conceptual understanding (Olympiou et al., 2013 & Waldrip, 2014). Despite the advantages of VSMs, the complex learning environment of multiple representations may hinder student learning (Eilam, 2013). Tippett (2016) explored the trends of representational uses in science instruction and highlighted that the move from learning science *from* representations to learning science *with* representations has had many potential complexities. Using a group of studies, Tippett (2016) collectively found that learning *with* representations is a complex field of study, whereas the views of learning *from* representations may not adequately explain what happens when students create their own diagrams, as they learn with representations (Waldrip et al., 2010 & Wu & Puntambekar, 2012).

While Tippet (2016) investigated the complexities of learning sciences with or from representations, Plass et al. (2014) examined how emotional design factors of colour and shape from VSMs multimedia learning evoke positive emotions in learners, and the effects of these positive emotions on learning. Emotional design describes the visual design elements in multimedia learning environments that affect learners' emotions and foster learning (Leutner, 2014 & Um et al., 2012). The findings showed that emotional design using colour and shape can enhance learning. Shape alone also affected emotion and learning, and colour alone affected comprehension (Park et al., 2014 & Plass et al., 2014). Emotional design of multimedia learning presentation can induce positive emotions in learners, and in turn facilitate comprehension and transfer (Heidig et al., 2015 & Mayer & Estrella, 2014 & Plass & Kaplan, 2016). Central to the relevant issues of emotion and learning are the learner's metacognitive experiences, which can be influenced by positive emotions in order to invest mental effort into the learning task (Le et al., 2018 & Uzun & Yıldırım, 2018).

Consequently, Wu & Puntambekar (2012) argued that although multiple external representations (MERs) are beneficial to learning, they fail to provide information on pedagogical issues (Johnson et al., 2015). One such issue is how and when MERs can be introduced to support student's engagement in scientific processes and how and when can they be introduced to develop competent scientific practices (Anderson et al., 2013b & Tytler et al., 2013). Scientific processes involve asking questions (Hagay & Baram-Tsabari, 2015), planning and carrying out investigations (Pedaste et al., 2015), analysing and interpreting data (Yandell, 2017), constructing explanations (Dresch et al., 2015) and evaluating information (Moore et al., 2015). Wu & Puntambekar (2012) suggest an integration of learning with representations and scientific processes based on the features of a particular representation, which could maximize the benefits and compensate for any limitations.

However, there are difficulties that may hinder student learning as a result of multiple representations. Firstly, the student's characteristics can hinder their own learning. Such characteristics include their prior knowledge, cognitive ability, how the content is represented, and the particular VSM and the technology used to teach (Eilam, 2013). Secondly, the representations characteristics such as complexity, abstractness, spatial attributions, and cognitive load of the VSM can also be an obstacle to learning (Eilam, 2013 & Offerdahl et al., 2017 & Viola et al., 2019). Thirdly, the characteristics of pedagogy applied to the VSM, such as interactive versus passive learning (Eilam, 2013). Lastly, contextual characteristics which may affect further learning processes may include students' sociocultural backgrounds (Eilam, 2013 & Ushioda, 2015).

2.4.3 How significant is visual literacy in science education, and more on biology education?

Visual literacy is integral to the development of scientific literacy (Amran et al., 2018 & Wang et al., 2012). Science is intrinsically multimodal and heavily dependent on a variety of VSMs (Tang, 2013) in order to represent and communicate key scientific concepts and ideas. Therefore, pedagogical focus should emphasize not only content delivery, but shift towards a more integrated, and thus representational approach in order for students to develop visual literacies within science (Alper et al., 2017 & Mnguni, 2014 & Tippett, 2016). Students who are at an early stage in their schooling, should be introduced to a variety of VSMs, such as life cycles of different organisms from which they are expected to decode and apply their understanding too (Eilam, 2013 & Milner-Bolotin & Nashon, 2012).

Fernández & Ruiz-Gallardo (2017) tested if children are competent in producing anatomy cross-sections by testing graphic production skills in anatomy associated with nutrition. The children had to draw a diagram of a human cross section, integrating knowledge of anatomy acquired from longitudinal sections. The results showed that the children had very limited skills in producing the graphics. The results also indicated that an initial exposure to cross-sections in daily life is not enough evidence to draw them correctly, so this type of graphic production should be addressed from the earliest stages of education, since it contributes to the development of visual literacy. This is a crucial skill when it comes to learning science concepts and developing scientific literacy (Milner-Bolotin & Nashon, 2012 & Turiman et al., 2012).

When considering the application of VSR to biology education, Milner-Bolotin & Nashon (2012) highlighted the essence of VSR and the development of visual-spatial literacy. The spatial representations are especially important in all branches of biology (Hegarty, 2011), where 3-dimensional (3D) and 4-dimensional (4D) representations are crucial for understanding phenomena (Newcombe & Shipley, 2015 & Uttal & Cohen, 2012). The focus on the visualisation of the static and dynamic relationship between objects is important in biology education (Castro-Alonso et al., 2015 & McElhaney et al., 2015). By the time biology students get to tertiary level, research indicates that a small percentage of biology students have had the chance to develop VSR skills (Gabrieli & Norton, 2012 & Lufler et al., 2012 & Milner-Bolotin & Nashon, 2012). Therefore, without a visually rich pedagogical framework, students are unlikely to develop a conceptual understanding of VSMs (Kleiss, 2016 & Rose, 2016).

Rybarczyk (2011) compared the composition of visual representations, specifically representations of data generated from experimental research found in general biology and discipline-specific textbooks, to primary journal articles. Results showed that there is a mismatch between the types of scientific visualizations in the textbooks, compared with how science is documented in primary literature. Therein, Rybarczyk (2011) suggested that educators need to note this difference and integrate opportunities for the development of visual literacy skills in undergraduate courses. They can do this by supplementing textbooks with visual representations of experimental data from other sources as a form of primary literature.

2.5 Conclusion

The above sections highlighted how the brain processes information, how best to incorporate multimedia learning according to CTML as well as understanding the complexities of the cognitive process of visualization. This chapter explored the debates in literature of VSMs and the importance of instructional material to provide students with opportunities to develop cognitive elements such as VSR, by reducing cognitive load in order to promote cognitive abilities. Moreover, this chapter highlighted the need for instructional designers, as well as educators to consider developing instructional material that will benefit students of multiple learning styles, as well as incorporate the preferred students learning styles in teaching to develop the educator’s pedagogical skills during lesson delivery.

Chapter Three: Research Approach, Design and Methodology

3.1 Introduction

The previous chapter reviewed literature on the cognitive theory of multimedia leaning and the theoretical cognitive process of visualization, and their implications for teaching and learning sciences using visuo-semiotic models. The purpose of the current chapter is to describe the research approach, research design, research methods, sampling and sample description, data collection (instrument design, development and instrument description), data collection procedure and data analysis. As stated in Chapter 1, the current study aimed to investigate the relationship between learning styles, modes of content presentation and visuo-semiotic reasoning in biology, as a preliminary effort to understand how teaching and learning could be enhanced through VSMs. The objectives of the research were to determine the:

a. most preferred learning style amongst Grade 10, biology students.
b. effective mode of presentation for teaching the cell cycle among Grade 10, biology students.
c. extent of visuo-semiotic reasoning amongst Grade 10, biology students.

The research question guiding this study asked:

What is the relationship between learning styles, mode of presentation and visuo-semiotic reasoning amongst Grade 10, biology students?

3.2 Research paradigm

Research paradigm or worldview is defined by Guba & Lincoln as a "basic set of beliefs that guide action" (1994, p.17). A research paradigm is a set of fundamental assumptions and beliefs as to how the world is perceived (Jonker & Pennink, 2010 & Wahyuni, 2012). A research paradigm consists of the following philosophical dimension components, i.e. ontology, epistemology, methodology and methods (Iofrida et al., 2018 & Ivleva et al., 2016 & Scotland, 2012). Ontology is described as an explicit specification of conceptualization (Gruber, 2018) that is concerned with what constitutes a reality (Scotland, 2012 & Wahyuni, 2012). Epistemology is concerned with the nature and forms of knowledge. Epistemological assumptions are concerned with how knowledge can be created, acquired and communicated (Greco, 2017 & Lehrer, 2018 & Scotland, 2012 & Zagzebski, 2017). Since the ontological and epistemological differ in their philosophical underpinnings, neither one can be empirically disproven nor proven (Burkholder & Burbank, 2019 & Garner et al., 2016). However, their differences in assumptions of reality and knowledge, which underpin their particular research approach, are reflected in their methodology and methods (Klakegg, 2016 & Scotland, 2012). Methodology refers to the study of methods, it is characterized by asking, how, what, why, where, when and involves the process of data collection and analysis (Ginor, 2017 & Wahyuni, 2012). Methods refer to a specific application of techniques and procedures used in the process of data collection and analysis (Yin, 2017).

Creswell & Creswell (2017) proposed four widely accepted research paradigms, i.e. positivists, postpositivist, interpretivism and pragmatism (Kankam, 2019 & Makombe, 2017). The positivist researchers are concerned with uncovering the truth and presenting it by empirical means (Antwi & Hamza, 2015 & Cohen et al., 2002). Wahyuni (2012) describes the positivist researchers as those who "seek to obtain law-like generalizations by conducting value free research to measure social phenomena" (2012, p.71). Positivists assert that researchers observing the same factual problem will generate similar results (Creswell, 2009 & Winter, 2000). This is based on their belief that the existence of a universal generalization can be applied across all contexts, this is now called naïve realism (Kivunja & Kuyini, 2017 & Michell, 2003 & Wahyuni, 2012).

Postpositivist argue the notion of absolute truth stipulated by the positivist's researcher (Bisman, 2010 & Kelly et al., 2018). Postpositivist recognize that all observations are fallible, have error and that all theory is revisable (Sheikh & Sultana, 2016 & Trochim, 2006). Although the postpositivist believes in generalization, they admit that knowledge is a result of social conditioning. This is called the critical realist stance (Wagner, 2016 & Wahyuni, 2012) were understanding social reality needs to be framed in a certain context of relevant law or dynamic social structures, which have created the observable phenomena within the social world (Lune & Berg, 2016 & Panhwar et al., 2017).

Interpretivism subscribes to constructivism (Stelmach, 2016). Interpretivists believe that reality is constructed by social actors and people's perceptions of it (Lindlof & Taylor, 2017 & Scott, 2016). Interpretivists recognize that individuals contribute to the construction of reality, through social interaction (Creswell & Poth, 2017 & McNeill & Nicholas, 2017 & Nicotera, 2019). Therefore, interpretivists reject objectivism and a single truth as proposed in post-positivism (Kelly et al., 2018 & Samy & Robertson, 2017). Pragmatism arises out of actions, situations and consequences, rather than arising from antecedent conditions as in post-positivism (Andrews & Giesbrecht, 2016 & Haddadi et al., 2017). Pragmatism places emphasis on what works best to address the research problem at hand (Morales, 2017). Table 3.1 provides a summary of the research paradigms discussed.

Table 3.1: Fundamental Beliefs of Research Paradigms in Social Sciences

	Research Paradigms			
Fundamental Beliefs	*Positivism (Naïve realism)*	*Post positivism (Critical Realism)*	*Interpretivism (Constructivism)*	*Pragmatism*
Ontology: the position of the nature of reality	External, objective and independent of social factors.	Objective. Exist independently of human thoughts and beliefs or knowledge of their existence but is interpreted through social conditioning.	Socially constructed, subjective, may change, multiple.	External, multiple view chosen to best achieve an answer to the research question.
Epistemology: the view on what constitutes acceptable knowledge	Only observable phenomena can provide credible data, facts. Focus on causality and law-like generalisations reducing phenomena to simplest elements.	Only observable phenomena can provide credible data, focus on explaining within a context or contexts.	Subjective meanings and social phenomena. Focus upon the details of situation, the reality behind these details, subjective meanings and motivating actions.	Either or both observable phenomena and subjective meanings can provide acceptable knowledge dependent upon the research question. Focus on practical applied research, integrating different perspectives to help interpret the data.
Axiology: the roles of values in research and the researcher's stance	Value-free and etic. Research is undertaken in a value-free way, the researcher is independent of the data and maintains an objective stance.	Value-laden and etic. Research is value laden; the researcher is biased by world views, cultural experiences and upbringing.	Value-bond and emic. Research is value bond, the researcher is part of what is being researched, cannot be separated and so will be subjective.	Value-bond and etic and emic. Values paly a large role in interpreting the results, the researcher adopting both objective and subjective points of view.
Research methodology: the model behind the research process	Quantitative	Quantitative or Qualitative	Qualitative	Quantitative and Qualitative (mixed or multi-method design)
Based on Guba & Lincoln (2005), Hallebone & Priest (2009) and Saunders et al., (2009, p.119)				

The present study employed the positivist paradigm which postulates that true knowledge is based on experience of true senses and can be obtained via experiment or observation (Antwi & Hamza, 2015 & Caldwell, 2015). It enables the use of quantitative research, to illustrate within the process of studying the phenomena, the relationship between an independent and dependent variable (Creswell & Creswell, 2017). This paradigm helps positivist researchers to understand the objects by empirical tests and methods such as sampling, measurement, and questionnaires (Rahi, 2017). This suggests that insights provided by positivist researcher may have a high-quality standard of validity and reliability and can be generalized to a large scale of the population.

3.3 Research approach

Research has been afforded a number of different definitions as there has been more than one type of research approach. These research approaches are qualitative research approach, quantitative research approach and mixed methods research approach (Tuckman & Harper, 2012). Researchers have a choice of three methods when carrying out research, depending on the factors involved. Researchers may consider the quantitative research method to test a hypothesis and make predictions by using measured amounts; ultimately describing an event by using figures (Johnson & Christensen, 2019 & Nardi, 2018). This method enables the researcher to use numbers in statistical tests to ensure that the results have a statistical relationship and use numbers to explain their findings (McCusker & Gunaydin, 2015 & Yilmaz, 2013).

Alternatively, the researcher may use a qualitative research method, in which they describe the kind of quality of a subject, while interpreting and attempting to understand an event (Holloway & Galvin, 2016 & Maxwell, 2012 & Tracy, 2019). This method enables the researcher to use texts to explain their findings (Cho & Lee, 2014 & Ritchie et al., 2013 & Wahyuni, 2012 & Wolfswinkel et al., 2013 & Yilmaz, 2013). Also, the researcher may choose to employ a mixed method in which the researcher uses a combination of quantitative and qualitative methods to completely describe an event (Hollstein, 2014 & Morse, 2016 & Punch, 2013 & Yoshikawa et al., 2008). According to Creswell (2003), the decision of what method a researcher employs depends on (a) research problem, (b) the researchers experience, (c) the reporting audience, (d) whether the researcher wants to specify the kind of information to be collected and (e) whether data to be collected is numeric or in text (Creswell & Poth, 2017 & Creswell et al., 2007 & Creswell, 2003).

3.3.1 Qualitative research approach

Qualitative research is a research strategy that usually focused on exploring and understanding a human or social phenomenon, from the perspective of the individuals involved; as well as emphasizes words rather than quantifications in the collection and analysis of data (Bryman, 2008 & Glesne, 2016). Jackson et al., (2007) considered qualitative research as an understanding of the human experience in a humanistic, interpretive way by gaining a perspective of issues facing them. Research is usually investigated within their own specific context and the meaning of the research is what individuals bring or contribute towards it (Denzin & Lincoln, 2008). McCusker & Gunaydin (2015) characterize qualitative research by its aims, which relates to understanding some aspect of social life and its methods; which are used to generate words, rather than numbers for data analysis.

Qualitative research assumes two aspects. Firstly, it predisposes that reality is socially constructed and that the situational conditions are highly complex and difficult to measure (Chowdhury, 2015 & Grbich, 1998 & Silverman, 2013 & Szyjka, 2012). Secondly, qualitative research is applicable to studies that involve relationships between individuals, individuals and their environments, and motives that drive human behaviour and action (Gunnell, 2016 & Lehnert et al., 2016 & Tracy, 2019). Therein, the aim of qualitative research is to contextualize, understand and interpret a situation (Bendassolli, 2013 & Flood, 2010 & Gelo et al., 2008 & Szyjka, 2012). Qualitative research begins with inductive inquiry (Bansal et al., 2018 & Creswell & Poth, 2017 & Patton, 2005), where broad generalizations are made from specific observations (Best & Kahn, 2016 & Creswell & Cresswell, 2017 & Flick, 2018). Opposite to inductive inquiry is deductive inquiry, where a basic form of valid reasoning is inferred in order to reach a specific logical conclusion. This conclusion is reached by testing a hypothesis and/or theories (Coccia, 2018 & Ricco, 2017). Moreover, in qualitative research the researcher is considered to be the main instrument. (Lune & Berg, 2016 & Merriam & Grenier, 2019 & Rahi, 2017). The methods involved require a high level of descriptive writing and a significant amount of time is given to the collection and processing of data (Szyjka, 2012). The general types of qualitative methods are case studies, ethnographic studies, phenomenological studies and grounded theory (Mohajan, 2018). The following paragraphs will briefly describe the types of qualitative methods, together with their advantages and disadvantages.

Case studies allow an in-depth understanding of participants, events, behaviours, and feelings that occur during specific experiences and specific timeframes (Baxter & Jack, 2008 & MacNeill et al., 2016 & Ritchie, 2003 & Zucker, 2009). In a case study, the researcher explores a single entity or phenomenon which is regarded as a case (Dasgupta, 2015 & Duff, 2018 & Mills et al., 2017 & Soy, 2015). The case is bounded or influenced by time and activity and the researcher collects detailed information through a variety of data collection procedures over a sustained period of time (Butler, 2011 & Mills et al., 2010 & Pohjola et al., 2016 & Yin, 2012). The case study is a descriptive record of an individual's experiences and/or behaviours kept by the observer (De Massis & Kotlar, 2014 & Garner & Scott, 2013 & Hancock & Algozzine, 2016 & Tetnowski, 2015).

Case study research is categorized as either exploratory, descriptive or explanatory (Armour & Griffiths, 2012 & Arshad et al., 2013 & Gerring, 2006 & Stevenson, 2004 & Walker, 2016). Exploratory case studies sets out to explore any phenomenon in the data which serves as a point of interest to the researcher (Duff, 2018 & George, 2019 & Jebb et al., 2017 & Yin, 2017). A pilot study is considered as an exploratory case study (Becker et al., 2014 & Hallingberg et al., 2018). Second, descriptive case studies set to describe the natural phenomena which occur within the data in question (Baskarada, 2014 & De Massis & Kotlar, 2014 & George , 2019 & Gray, 2013 & Yin, 2012). Third, explanatory case studies examine the data closely both at surface and on a deep level, in order to explain the phenomena in the data (Aithal, 2017 & Gibbs, 2018 & Silverman, 2015). There are a number of advantages in using case studies. First, the examination of the data is most often conducted within the context of its use (Bryman, 2017 & Cronin, 2014 & Houghton et al., 2013 & Soy, 2015). Second, variations in terms of intrinsic instrumental and collective approaches to case studies allow for both qualitative and quantitative analyses of the data (Baskarada, 2014 & Hancock & Algozzine, 2016 & Harling, 2012 & Lune & Berg, 2016 & Punch, 2013). Third, the detailed qualitative accounts often produced in case studies, not only help to explore or describe the data in real-life environments but also help to explain the complexities of real-life situations which may not be captured through experimental or survey research (Baskarada, 2014 & Creswell & Poth, 2017 & Hastie & Hay, 2012 & Kumar, 2019 & Starman, 2013).

Despite the advantages, case studies face criticism (George, 2019). Yin (1984) discussed three types of arguments put forth against case study research. First, case studies are often accused of lack of rigour (Barratt et al., 2011 & Dattilio et al., 2010 & Larrinaga, 2017). Second, case studies provide very little basis for scientific generalization, since they use a small number of subjects (Boddy, 2016 & Starman, 2013 & Vissak, 2010 & Yin, 2012). Third, case studies are labelled as being too long, difficult to conduct and produce a massive amount of documentation (Krusenvik, 2016 & Starman, 2013 & Zainal, 2007). A common criticism is that case study research is considered 'microscopic', as it depends on a single case exploration; making it difficult to reach a general conclusion (Das & Singha, 2011).

Ethnographic studies involve a researcher collecting observational data of an intact cultural group in their natural setting over time (Angrosino, 2016 & Creswell & Creswell, 2017 & Creswell, 2003 & Williams, 2007). A cultural group can be any group of individuals who share a common social experience, location, or other social characteristics of interest (Foulkes, 2018 & Richerson et al., 2016 & Young, 2017). Ethnography has been described as the study of human cultures (Atkinson, 2016 & Taylor, 2017). Observation in ethnography is a comprehensive and ongoing process (Conroy, 2017 & Flick, 2018 & Nurani, 2008). There are two types of observation. participant observation and non-participant observation (Lavia et al., 2018 & Luen et al., 2018 & Parker, 2017). Participant observation requires the researcher to take part in the daily activities of the individuals being observed (Blomberg et al., 2017 & Jorgensen, 2015 & Spradley, 2016). Non-participant observation requires researchers to watch and record the participant(s) behaviour or actions (Bloomer et al., 2017 & Handley et al., 2019 & Laurier, 2016 & Morgan et al., 2015). Ethnography uses non-numerical, context specific data that cannot be reproduced (Fusch & Ness, 2017 & Gunnell, 2016 & Walford, 2018).

One of the main advantages of ethnographic research is that it provides a comprehensive perspective on phenomena (Hanson et al., 2011 & Queirós et al., 2017 & Suryani, 2013) and behaviours are observed in their natural setting (Blomberg et al., 2017 & Leite et al., 2012 & Sangasubana, 2011). Ethnographic research accounts for the complexity of group behaviour, reveals interrelationships among multifaceted dimensions of group interactions, and provides context for behaviours (Jayasekara, 2012 & McHale et al., 2012). Ethnographic research also has several disadvantages to be considered (Lewis & Russell, 2011 & Sangasubana, 2011). Ethnographic research is highly dependent on the researcher's observations and interpretation thereof (Jorgensen, 2015 & Leslie et al., 2014 & Oun & Bach, 2014); this makes the observer bias almost impossible to eliminate, and it is difficult to check the validity of the researcher's conclusions (Silverman, 2015 & Xu & Storr, 2012 & Yazan, 2015). Ethnography is time consuming and requires a well-trained researcher (Chrysochou, 2017 & Ortiz & Beach, 2013).

Phenomenological studies involve conducting research in a small group of people intensely over a long period of time (Cronin, 2014 & Hanson et al., 2011 & Yin, 2015). In a phenomenological study, human experiences are examined through a detailed description of the people being studied (Connelly, 2010 & Hossain, 2011 & Matua & Van Der Wal, 2015 & Smith & Shinebourne, 2012). The aim is to understand the 'lived experience' of the individuals being studied (Connelly, 2010). Phenomenology asserts that experience (Gunnell, 2016 & Williams, 2014) is more important than what the "physical senses can apprehend" (Budd, 2005, p.45). In phenomenological research, the researcher becomes a participant (Dempsey et al., 2016 & Glesne, 2016 & Reinharz, 2017 & Tetnowski, 2015). The advantage of phenomenological research is that it provides a unique perspective (Breidbach et al., 2015). This is because phenomenological research studies human experiences by focusing on how people perceive an event or phenomena, rather than simply how the phenomena exists in a 'vacuum' (Packer, 2017 & Rotter & Wertz, 2019 & Tracy, 2019). The disadvantage of phenomenological research is the concern of generalizing the data collected/analysed to the other situations (Rahman, 2017 & Smith, 2018) and it is difficult to replicate (King et al., 2018 & Morrell-Scott, 2018).

Grounded theory is a method in which "one step of the process predicates the actions of the next step" (Gunnell, 2016, p.4). The aim of grounded theory is to derive theory based on emerging patterns from the views of study participants (Creswell, 2003 & Khan, 2014). The focus of grounded theory is to uncover basic social processes. For example, a researcher may consider exploring integral social relationships, and the behaviour of groups where there has been little exploration of the contextual factors that affect the individuals' lives (Birks & Mills, 2015 & Charmaz, 2014). The advantage of grounded theory is that it provides a methodology to develop an understanding of social phenomena that is not pre-theoretically developed within existing theories and paradigms (Bryant & Charmaz, 2007 & Mahiya, 2015 & Star, 2011). Also, grounded theory is well suited for investigating social processes that have attracted little prior research attention (Stol et al., 2016 & Suddaby, 2006). In contrast, the disadvantage of ground theory is that it fails to recognize the placement of the researcher (Gligor et al., 2016 & Reay et al., 2019). Also, grounded theory tends to produce large amounts of data which are often difficult to manage (Glaser & Strauss, 2017 & Male, 2016 & Stol et al., 2016).

The advantages of qualitative research methods include; (a) provides a detailed perspective of a few people, (b) the voices of the participants can be heard, (c) the context of the participants can be understood, (d) it is built from views of participants and not from the researcher, and (e) people like stories. Its disadvantages include its limited generalizability, data includes a few participants that were studied, it is highly interpretive, and there is reliance on participants which minimizes the researcher's expertise (Creswell, 2013).

3.3.2 Quantitative research approach

Quantitative research is one that explains phenomena by collecting numerical data that are analysed using mathematically based methods (Johnson & Christensen, 2019 & Williams, 2007). According to Cohen et al. (2002), quantitative research employs empirical methods and empirical statements. An empirical statement is a descriptive statement about what "is" the case in the "real world", rather than what "ought" to be the case (Cohen et al., 2002 & Sukamolson, 2007). The use of quantitative research is a way of acquiring knowledge based on broad generalizations across greater populations (Polit & Beck, 2010).

A basic description of quantitative research is the concern for collecting and analysing data that is structured, and which can be represented numerically (Bryman, 2016 & Goertzen, 2017 & Rahman, 2017). Goertzen (2017) describes this point as quantitative research, making it "effective at answering the 'what' and 'how' of a given situation (2017, p.12). Quantitative research aims at establishing cause and effect relationships between two variables.

Three general types of quantitative methods are experiments, quasi-experiments and surveys (Jopling, 2019 & Mayton et al., 2015 & Xie, 2016). Experiments are often regarded as true experiments and are characterized by random assignment of subjects to experimental conditions and include the use of experimental controls (Fong et al., 2016 & Maxwell et al., 2017 & Montgomery, 2017). The advantage of experimental research is that the researcher has control over variables (Johnson et al., 2013 & Watson, 2015). However, its limitations lies in that the study can reproduce artificial results which may apply to only one situation and may be difficult to replicate (Crump et al., 2013 & Myers et al., 2013 & Nardi, 2018). Quasi-experimental studies share similar features of experimental designs, except that they involve non-randomized assignments of subjects to experimental conditions (Aloe et al., 2017 & Reeves et al., 2017 & Steiner et al., 2017). The advantage of quasi-experiments is that they are more practical and feasible to conduct where the sample size is small (Walser, 2014). Where true experiments cannot be conducted, quasi-experiments are preferable (Connelly et al., 2013 & Vine et al., 2014). The disadvantage of quasi-experiments is that the researcher does not have control over extraneous variables which are influencing the dependent variable (Blom-Hansen et al., 2015 & Grabbe, 2015 & Pierce, 2013). The absence of a control over the research setting makes the result of this research method less reliable and weak for establishment of causal relationships between independent and dependent variables (Dunning, 2012 & Haslam & McGarthy, 2014).

Surveys include cross-sectional and longitudinal studies using questionnaires or interviews for data collection, with the intent of estimating the characteristics of a large population of interest based on a smaller sample from that population (Heeringa et al., 2017 & Nardi, 2018). A survey is a process of gathering data that could involve a wide variety of data collection methods including questionnaires (Church & Waclawski, 2017 & Fan & Yan, 2010 & Young & Jamieson, 2001). The advantage of using questionnaires is that they are cost effective, practical, easy to analyze, and are scalable (Bird, 2009 & Brace, 2018 & Gillham, 2008 & Patten, 2016).

The advantages of quantitative research methods is that it draws conclusions for a large number of people, it employs efficient data analysis, examines probable cause and effect, controls the issue of bias and people generally prefer numbers/statistics as opposed to qualitative descriptions. Its limitations are that it is impersonal, words of the participants are not heard, there is limited understanding of the context of the participants and it is largely research driven (Creswell, 2013). The disadvantages include lack of personalization, accessibility, interpretation and analysis issues, unconscientious responses and respondents may skip questions (Rubin & Babbie, 2016 & Ruel et al., 2015).

3.3.3 Mixed-methods research approach

Mixed methods research combines quantitative and qualitative methods in the same study in order to get a full understanding of the phenomenon under investigation (Johnson & Onwuegbuzie, 2004 & Östlund et al., 2011 & Teddlie & Tashakkori, 2009). The assertion that mixed methods is a combination of quantitative and qualitative is recent, but quantitative and qualitative data have been collected by researchers for many years (Borrego et al., 2009 & Creswell, 2013 & Hanson et al., 2005 & Hussein, 2009 & Mertens, 2014). The main assumption for a mixed method approach, is that it focuses on collecting and analysing data of a single study by combining both quantitative and qualitative methods; it provides a better understanding of the problem than using either method alone (Almalki, 2016 & Halcomb & Hickman, 2015 & Morse, 2016 & Palinkas et al., 2015). When methods are combined, qualitative methods may provide an in-depth understanding of the variables that lead to quantitative numerical findings (Edmonds & Kennedy, 2016 & Frels & Onwuegbuzie, 2013 & Hurmerinta-Peltomäki & Nummela, 2006).

Mixed method studies may start with qualitative methodology to define questions (Creswell, 2014 & Patten & Newhart, 2017 & Zohrabi, 2013). Although there may be no prescribed process for employing a mixed method study, Creswell (2003) categorized six method variations of data collection. Firstly, the sequential explanatory strategy, which collects and analyses quantitative data; followed by collection and analysis of qualitative data (Creswell, 2003 & Gunnell, 2016 & Subedi, 2016 & Taguchi, 2018). Secondly, the sequential exploratory strategy collects, and analyses qualitative data; followed by the collection of quantitative data (Almeida, 2018 & Creswell, 2003 & Gunnell, 2016 & Warfa, 2016). Thirdly, the sequential transformative strategy provides input for data collection and analysis of either type of data, before combining the data during the interpretation phase of the study (Creswell & Clark, 2017 & Creswell, 2003 & Denzin, 2017 & Mayoh & Onwuegbuzie, 2015 & Venkatesh et al., 2016); this methodology is guided by a theoretical perspective (Gunnell, 2016). Fourthly, the concurrent triangulation strategy collects data concurrently and attempts to corroborate, confirm and cross-validate findings within a single study (Chemagos et al., 2016 & Creswell, 2003 & Gunasekare, 2015 & Gunnell, 2016 & Lunsford & Brown, 2019 & & Riazi, 2016). Fifthly, the concurrent nested strategy collects both data types concurrently, and embeds one methodology with a more predominant method over the other (Creswell, 2003 & Gunnell, 2016 & Kanga et al., 2015 & Rai, 2018 & Schoonenboom & Johnson, 2017). Sixthly, the concurrent transformative strategy collects each type of data concurrently and combines the findings during the analysis phase of the study (Alavi & Hąbek, 2016 & Bentahar & Cameron, 2015 & Creswell & Clark, 2017 & Creswell, 2003 & Gibson, 2017 & Gunnell, 2016 & Khoo-Lattimore et al., 2019).

Using a mixed methods study has several advantages. It compares quantitative and qualitative data, reflects the participants point of view, fosters scholarly interaction, provides methodological flexibility and collects rich and comprehensive data. The limitations of mixed methods approach are its challenge to be implemented; particularly when they are used to evaluate complex interventions. Mixed methods rely on a multidisciplinary team of researchers and requires an increased number of resources.

3.3.4 Justification for the choice of quantitative research approach

The present study adopted a quantitative, quasi-experimental research approach. The use of any approach depends on the researcher's method of data collection and data analysis. This is especially true since qualitative and quantitative research approaches and methods represent different research strategies and differ in their theoretical, epistemological and ontological issues (Antwi & Hamza, 2015 & Bell et al., 2018 & Bengtsson, 2016 & Creswell & Poth, 2017 & Eyisi, 2016 & Stage & Manning, 2015 & Yüksel & Yıldırım, 2015). Quantitative research methods deal with numbers and factors that are measurable in a systematic way to investigate phenomena and their relationships (Bernard, 2017 & Håkansson, 2013 & Walliman, 2015 & Whitehead et al., 2012). Quantitative research methods are used to answer questions on relationships within measurable variables, with an intention to explain, predict and control phenomena (Antwi & Hamza, 2015 & Bernard & Bernard, 2013 & Nardi, 2018). Therein, this type of approach was suitable for the present study, as it aimed to investigate the relationship between learning styles, modes of content presentation and visuo-semiotic reasoning in biology, as a preliminary effort to understand how teaching and learning could be enhanced through VSMs. A quantitative study is described as to either 'confirm' or 'not to confirm' the hypothesis tested (Johnson & Christensen, 2019 & Seawright & Gerring, 2008 & Wisdom et al., 2012). In this regard, researchers using the quantitative method identify one or few variables that they intend to investigate and proceed with data collection related to those variables.

3.4 Research designs

A research design is a framework of methods and techniques (Lune & Berg, 2016 & Marshall & Rossman, 2014 & Ulin et al., 2012) chosen by a researcher to combine various components of research in a reasonably logical manner; so that the research problem is efficiently handled (Denzin, 2017 & Hanington & Martin, 2012 & Sedlmair et al., 2012 & Wahyuni, 2012). It provides insights about how to conduct research using a particular methodology (Kelly et al., 2014 & Petty et al., 2012 & Yilmaz, 2013). Research design is different from the method by which data is collected (Neuman, 2016 & Terrell, 2012 & Wahyuni, 2012 & Zohrabi, 2013). Research design is concerned with the logical structure of inquiry and the mode of data collection is considered as the method (Creswell & Creswell, 2017 & Hakim, 2012 & Hughes & Sharrock, 2016 & Rovai et al., 2013). Failure to distinguish between design and methods leads to poor evaluation of designs (Sedlmair et al., 2012 & Stern et al., 2012). For example, a research design type could be a case study or an experiment and the method of collecting data could be a questionnaire.

3.4.1 Experimental research design

Experimental studies can either be a true experiment, a quasi-experiment or a single case study (Blom-Hansen et al., 2015 & Khaldi, 2017 & Kratochwill, 2015). Experimental research involves (Best, 2010 & Craig et al., 2012) experiments in which standardized procedures are used in order to hold all conditions constant, expect the independent variable which is measured (Maxwell et al., 2017 & Myers et al., 2016 & Salkind, 2010). Experimental research seeks to determine a relationship between two variables, the dependent variable and the independent variable (Ellis & Levy, 2009) and at the end of the study, a correlation between a specific aspect of the phenomena and the variable being studied is either supported or rejected (Hoy & Adams, 2015 & Walliman, 2015).

In a true experiment, the participants are subjected to a treatment or a condition, where the researcher tests whether differences in this outcome are related to the treatment (Berinsky et al., 2012 & Ross & Morrison, 2004). Participants are randomly assigned to either the treatment group or to the control group (Kuyken et al., 2015). Random assignment neutralizes factors other than the dependent or independent variable, making it possible to directly infer cause and effect (Pirlott & MacKinnon, 2016). In a quasi-experiment, there can be one or more control groups and experimental groups (Grabbe, 2015); a random assignment of subjects in both control and experiment groups (Ro & Khan, 2019); the pre-test of groups to check equality, the post-test of groups to identify the impacts on dependent variables (Arifin & Anwar, 2018); isolation, control and manipulation over independent variables and non-contamination between experimental and the control group (Asgari & Baptista Nunes, 2011 & Brous et al., 2016). Quasi-experiments are seen as an alternative to true experiments, since not all phenomena can be studied under laboratory conditions (Barrett & Hornbeck, 2018).

There are three types of quasi-experimental viz, non-equivalent, pre-test-post-test and interrupted time series (Fife-Schaw, 2006 & Krass, 2016). A non-equivalent groups design is one in which participants have not been randomly assigned to conditions (Abbuhl et al., 2014 & Wilson et al., 2005); who are most likely to be dissimilar. Unlike a between-subjects experiment, where participants are randomly assigned to conditions (Shim et al., 2007), the resulting groups are likely to be similar; thus, regarded as equivalent (Rovai et al., 2013). An example of a non-equivalent group would be for the researcher to have a treatment and a control group (Saha et al., 2010). In a school setting, learners are categorized into different grades; a researcher who wants to evaluate a new teaching method would then consider a treatment and a control group (Chebii et al., 2012). This design is regarded as non-equivalent, because the learners are not randomly assigned to classes by the researcher, which means there could be important differences between them (Bernard et al., 2004 & Wambugu & Changeiywo, 2008 & Wilder, 2015).

3.4.2 Non-experimental research design

Non-experimental research are investigations in which there is no manipulation of the independent variable by the researcher (Verma, 2019); the researcher can only observe and interpret phenomena (Curtis et al., 2016 & Swart et al., 2019 & Thomlinson, 2018). Non-experimental research includes the following; descriptive, causal-comparative, correlational, and surveys (Turner et al., 2013). Descriptive research aims to determine, identify or describe a condition, situation or events that occur in the present moment (West et al., 2017). The advantages of descriptive research is that it is effective to analyse non-quantified topics (Tiwari, 2018); as well as the possibility to observe the phenomenon in a completely natural and unchanged environment (Gray, 2013 & Merriam & Tisdell, 2015).

Causal-comparative research aims to investigate the relation between the variables under study, in order to identify possible causal relationships between them (Khaldi, 2017 & Mertler & Reinhart, 2016 & Turner et al., 2013). The advantages of a causal-comparative research is that it allows the study dealing with cause and effect relationships to occur under conditions where experimental manipulation is difficult or impossible (Baldwin, 2018 & Cohen et al., 2013 & Martella et al., 2013). The limitations is that it is difficult to establish causality on the basis of the data collected (Baldwin, 2018 & Cohen et al., 2013 & Reio Jr., 2016). Correlational research is concerned with the establishing of possible relationships between variables (Bryman & Cramer, 2012 & George, 2019 & Håkansson, 2013). The advantage of a correlational study is that it can be conducted on variables that can be measured and not manipulated (MacKinnon et al., 2012 & Wicherts et al., 2016); a correlation can demonstrate an absence or a presence of a relationship between two factors (Bishara & Hittner, 2012 & Cohen et al., 2014). Surveys are used to describe the views of a large group of people at a given point in time. Surveys do not attempt to establish a cause and effect relationship (Moser & Kalton, 2017 & Nardi, 2018). The advantage of survey research is that it provides a high level of general capability in representing a large population, it is cost effective and surveys can be administered to participants in a variety of ways, thus providing significant statistical results (Hair Jr. et al., 2015 & Sue & Ritter, 2012).

3.4.3 Research design used for the current study (Quasi-experimental)

The current research adopted a quasi-experimental research approach that resembles experimental research but is not as true as experimental research (Levy & Ellis, 2011 & Sullivan-Bolyai & Bova, 2014). It also included a non-experimental survey. Since random assignment of participants is difficult, quasi-experiments allows this type of study to be conducted at a school (Cook & Payne, 2002). Quasi-experiments are often conducted to evaluate the effectiveness of a treatment, such as an educational intervention (Cheung & Slavin, 2016). In the present study, learners were presented with different modes of content presentation: simulation (simulation of the cell cycle using bead-work), animation as well as static multimedia. The basis of quasi-experimental is that a test is conducted under controlled conditions, so as to demonstrate a known truth and to examine the validity of a hypothesis (Campbell & Stanley, 2015 & Vanderhoven et al., 2015). The researcher has control in quasi-experimental research, as he/she manipulates the variable that is supposed to affect the outcome of the experiment. In this instance (Campbell & Stanley, 2015 & Lager & Torssander, 2012), the different modes of content presentation and learning styles are used as variables that are manipulated to affect the outcome.

3.5 Research Method

3.5.1 Design

A quasi-experimental pre-test-post-test design, and a non-experimental survey were employed in the present study. In a pre-test-post-test, a dependent variable is measured once before the treatment is implemented, and once after it is implemented (Padmavathy & Mareesh, 2013 & Shek & Sun, 2012). The pre-test post-test design focuses on testing the participants, firstly under the control condition and then under the treatment condition (Norman, 2012 & Rendon et al., 2012). In the present study, the pre-test- post-test is summarized in Table 3.2:

Table 3.2: A description of the Pre-test-Post Test

Group	**Pre-test**	**Treatment**	**Post-test**
Group One **(Treatment group)**	✓	Multimedia Animation	✓
Group Two **(Control group)**	✓	2D Static model (Paper-Based)	✓
Group Three **(Treatment group)**	✓	Simulation of the Cell Cycle using Bead-work	✓

The pre-test-post-test generally works as follows; the participants were placed into three groups, where two groups made up the experimental group and one group was considered as the control group (Argaw et al., 2017 & Nitchot et al., 2012 & Shek & Sun, 2012). The experimental groups received the ‘treatment’ as an educational intervention group. Of the two groups, one watched an animation depicting the cell cycle, and the other group (group 3) had to simulate the cell cycle by using beads. The control group was the group that did not receive treatment i.e. there was no manipulation performed on their method of learning, unlike the experimental groups above. All the groups received a pre-test, which was used to assess the effect of the experiment before the actual 'treatment' was given and a post-test was given after the 'treatment' was employed (Chebii et al., 2012 & Lapkin et al., 2013). Therein, following the post-test, statistical analysis was carried out to see whether the 'treatment' had an effect on the learning of the students (Pandey et al., 2014).

3.5.2 Data collection

Data collection is a process of gathering information specifically on the variables of interest that enable the researcher to answer the proposed research question(s) (Cheng & Phillips, 2014 & Mertler, 2018 & Neuman, 2016). There are two types of data; that is primary and secondary data (Daas & Arends-Tóth, 2012 & Walliman, 2017). Data that is collected first-hand by the researcher and is known as primary data (Wahyuni, 2012). This data type is considered to be collected on purpose (Sutton & Austin, 2015) because there are no previous records of that particular data (Guest et al., 2013). Primary data can be collected using a range of methods like surveys, interviews, focus groups and is considered to be a highly reliable method of data collection (Rosenthal, 2016 & Sagoe, 2012). Secondary data is data that has been previously collected and compiled by someone else and is made accessible to the public (Johnston, 2017). The primary data that was once collected becomes secondary data when it is further used for another type of research (Wahyuni, 2012). Data that can be quantified and expressed numerically, for example, marks obtained in the form of a test grade for males and females becomes feasible as it is capable of being statistically evaluated (Cronk, 2017).

3.5.2.1 Quasi-experimental

A content knowledge test comprised of two sections (A and B). The content knowledge test has been attached as Appendix A. Section A comprises of the biographical information of the participants. Section B tested for the students understanding of the cell cycle. Section B consisted of 20 alternative close-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 Khan's Academy (https://www.khanacademy.org/science/biology/cellular-molecular-biology/mitosis/e/mitosis-questions). Khan's Academy based in the United States of America is a non-profit organization with a goal of creating a set of online tools that help educate students. Khan's Academy includes supplementary practice exercises and materials for educators. The content knowledge test was distributed to the participants in class during their biology lesson. There were three groups (see Table 3.1). The validation of the instrument will be discussed under 'validity'.

Questionnaires were distributed in class (in the presence of students) to ensure that all questionnaires were accounted for by each student. The lessons were normally 40-45 minutes in duration, and the questionnaire took about 40 minutes to complete. The process of distributing and collecting questionnaires was applied to both the control and experimental groups. Each item was explained to the students and students were given 10 minutes to read through the questionnaire. The students were also given the opportunity to ask questions and clarify any misunderstanding. The students were made aware that they were not writing a formal test. The students were informed that they were not forced to participate in the research and that only those who gave consent were to be included. They were given the choice to also withdraw at any given time of the research.

3.5.2.2 Survey

The VARK questionnaire was first developed by Fleming (1995) and was used to collect data regarding students preferred learning style. The VARK questionnaire is attached as Appendix B. It has 16 items which can be answered within a short time. The VARK questionnaire was structured as multiple-choice questions. For each question, students had to choose the statement that best explained their learning style preference (Fleming & Baume, 2006). If more than one choice matched their perception, then more than one statement could be selected. Depending on their responses or scores, they were classified as unimodal or multimodal (bimodal, trimodal or quad modal), according to their preference. The VARK questionnaire is easy to administer, with free online availability. The VARK questionnaire is a good tool to alert the student and teacher to the variety of learning preference in a classroom environment. The questionnaire has established preliminary validity and adequate reliability coefficients. The VARK questionnaire was distributed after the content knowledge test, and the results were analysed after the post-test.

3.5.3 Sampling

The primary goal of sampling is to get a representative sample from a much larger population (Acharya et al., 2013 & Etikan & Bala, 2017 & Robinson, 2014). There are two main types of sampling in quantitative research, viz probability sampling and non-probability sampling (Uprichard, 2013). Probability sampling is a sampling method that utilizes a form of random selection, it is based on the notion that each sample has an equal chance of being chosen (Saunders, 2012). This method of sampling gives the probability that a sample is a representative of a population (Acharya et al., 2013). The following methods are found in probability sampling:

i. ***Simple random sampling***: the objective of simple random sampling is to select a sample in which each element and each combination of elements in the population have an equal probability of being selected as a part of a sample (Suresh & Chandrashekara, 2012). It is considered as one of the simplest forms of random sampling; this method is a fair way to select a sample (Levy & Lemeshow, 2013).
ii. ***Stratified random sampling***: it's a form of random sampling in which the population is divided into two or more groups (strata), according to one or more attributes (Corrigan et al., 2009). Stratified random sampling intends to guarantee that the sample represents specific subgroups or strata (Boschetti et al., 2016).
iii. ***Systematic random sampling***: systematic sampling is an improvement over the simple, random sampling. This method requires the complete information about the population (Bellhouse, 2014 & Westfall, 2009).
iv. ***Cluster random sampling*****:** cluster sampling is one of the efficient methods of random sampling (Acharya et al., 2013). It is a technique in which clusters of participants that represent the population are represented, and the population are identified and included in the sample (Singh & Masuku, 2014). Cluster sampling involves the identification of a cluster of participants representing the population and their inclusion in the sample group (Meyer & Wilson, 2009).
v. ***Multi-stage sampling*****:** Multi-stage sampling, also regarded as multi-stage cluster sampling is a more complex form of cluster sampling which contains two or more stages in sample selection. (Kandola et al., 2014) In multi-stage sampling, large clusters of population are divided into smaller clusters in several stages in order to make primary data collection more manageable (Philpott & De Matos, 2012).

Advantages of probability sampling is that there is an increased accuracy of sampling error estimation; there is a higher level of reliability of research findings; there exists the absence of systematic error and sampling bias; there exists the possibility to make inferences about the population (Cascio, 2012 & Groves, 2011). The disadvantages of probability sampling is that it is time consuming, it is more expensive than non-probability sampling and there exists higher complexity compared to probability sampling (Bornstein et al., 2013).

Non-probability sampling, also known as non-random sampling, ensures that not all members of the population have the chance of participating in the study (Vehovar et al., 2016). Non-probability sampling methods include quota sampling, convenience sampling, purposive sampling and snowball sampling (Taherdoost, 2016).

i. ***Quota sampling***: is a non-random sampling method of gathering representative's data from a group, where the aim is to end up with a sample where the strata being studied is proportional to the population being studied (Landreneau & Creek, 2009 & Mujere, 2016).
ii. ***Convenience sampling***: relies on data collection from population who are conveniently available to participate in a study (Sedgwick, 2013a).
iii. ***Purposive sampling***: also known as judgemental, selective or subjective sampling (Boehnke et al., 2011). A non-probability sample is selected based on the characteristics of a population and on the objective of the study (Suen et al., 2014).
iv. ***Snowball sampling***: is a non-probability sampling technique in which samples have traits that are rare to find (Sedgwick, 2013b). Snowball sampling consists of two steps: Firstly, the researcher identifies potential subjects and secondly the researcher requests the subjects to recruit other participants for the study (Etikan et al., 2016).

Advantages of non-probability sampling is that it provides the possibility to reflect on the descriptive comments of the sample, its cost and time effectiveness compared to probability sampling (Tansey, 2009 & Vehovar et al., 2016). Non-probability sampling is effective when it is not feasible or impractical to conduct probability sampling (Yang & Banamah, 2014). The disadvantages of non-probability sampling are the difficulties in estimating sampling variability and identifying possible bias. Research is less generalized compared to probability sampling (Singh, 2015). Also, the unknown proportion of the entire population is not included in the sample group, i.e., there is a lack of representation of the entire population (Williams, 2018).

The present study employed a non-probability, purposive sampling method where data was collected from a public school and a private school in Gauteng, West of Johannesburg. The public school is a co-educational school which provides education to learners from different backgrounds, and it is well resourced in terms of facilities. For example, computer laboratories with internet access and a library is made accessible to students, while the Private school is under-resourced. The students in Grade 10 are between 15-17 years and are represented by a diverse cultural community.

3.5.4 Data analysis

3.5.4.1 Descriptive statistics

Descriptive statistics are used to describe the basic features of the data in a study (Ho & Yu, 2015). Descriptive statistics are used to present quantitative descriptions in a manageable form (Al-Hattami & Al-Ahdal, 2015). For the purpose of describing properties, it uses measures of central tendency, i.e. mean, median, mode and the measures of dispersion i.e. range, standard deviation, quartile deviation and variance (Ali & Bhaskar, 2016). The data is summarised by the researcher in a useful way, with the help of numerical and graphical tools such as charts, tables, and graphs, to represent data in an accurate way (Chambers, 2017). Moreover, the text is presented in support of the diagrams to explain what they represent.

3.5.4.2 Inferential statistics

Inferential statistics is about formulating generalisations of the sample and relating the results to the population (Holcomb, 2016). This means that the results from the analysis of the sample can be deduced from the larger population, from which the sample was taken (Schreier & Flick, 2017). The sample is chosen to be a representative of the entire population; therefore, it should contain important features of the population (Gibbs et al., 2017). Inferential statistics is used to determine the probability of properties of the population on the basis of the properties of the sample by employing probability theory (Gibbs et al., 2015). The major inferential statistics are based on the statistical models such as Analysis of Variance (ANOVA), chi-square test, student's t distribution and regression analysis (Robby & Gitsaki, 2015 & Vieira Jr., 2017). Researchers are more interested in what the data indicates for the population.

Inferential statistics indicate whether or not the results based on the sample are significant enough to be applied to the larger population or if the results were most likely to be caused by chance (Mertler & Reinhart, 2016). Researchers evaluate the differences in the dependent variable, between the control and the experimental groups (Hartas, 2015). If a difference in the dependent variable between the two groups is statistically significant, it means that the results were not likely to have happened by chance (Watson, 2015). Statistical significance indicates a high probability that the independent variable caused the change in the dependent variable (Garson, 2012 & Hair et al., 2013). Statistical significance does not refer to how important the results are (Hair et al., 2013). Results are likely to be statistically significant when there is a large difference between the means of the two frequency distributions; when their standard deviations (SD) are small and when the samples are large (Bluman, 2013). Researchers can use a variety of inferential statistics to determine statistical significance (chi square tests, t-tests, ANOVAs) (Lehman et al., 2013). Each of these methods generate a probability value (p-value) that indicates how likely it is that the difference between the control and experimental groups is caused by chance and not by the independent variable (Leech et al., 2013). The p-value must be $\leq .05$ for statistical significance to exist (Sullivan & Feinn, 2012). The lower the p-value, the more significant the results and the less likely they are caused by chance (Wood et al., 2014).

3.5.5 Validity

Validity refers to whether the research truly measures that which it intended to measure or how truthful the results are (Nardi, 2018 & Yilmaz, 2013). In other words, will the study enable the researcher to achieve their objective ? (Golafshani, 2003). Validity in quantitative research considers the accuracy of the measurement and whether the research has measured that which it was intended for (Roberts et al., 2006). Validity has three distinct aspects, all of which are important (Rolfe, 2006). They are content validity, face validity, criterion validity and construct validity. Content validity refers to whether or not the content of the variables are correct

(Cappelleri et al., 2014). For example, whether the items of a questionnaire are correct to measure the latent concept that the researcher is intending to measure (Colliver et al., 2012 & Drost, 2011). Moreover, there is an important role of theory in determining content theory (Wolming & Wikström, 2010). Therein, the main judgement of whether an instrument is content valid, is its accordance to a theory of how the concept works and what it is (Lakshmi & Mohideen, 2013).

Face validity involves setting up a panel of experts to comment on the instrument from 'face' value as to whether the instrument looks valid (Janssen et al., 2013 & Suen, 2012). One disadvantage of face validity is that lay users may not be fully cognisant of the theoretical background (Barnett et al., 2015). Criterion validity is closely related to theory as with content validity (Lahey et al., 2015). There are two types of criterion, that is, predictive validity and concurrent validity. Predictive validity refers to whether or not the instrument predicts the outcomes theoretically expected to be achieved (Drost, 2011 & Oluwatayo, 2012). Concurrent validity questions whether or not the items on the instrument agree with the scores on other factors (LoBiondo-Wood & Haber, 2014). Construct validity relates to the internal structures of the instrument and the concept it intends to measure; this also relates to the theoretical framework of the concept that is to be measured (Oluwatayo, 2012).

3.5.7.1 Validation of the instrument

The validity of the questionnaire was checked through face validation and content validation. Face validation involves the use of an expert in a specific field of study to check if the instrument measures that which it intends to measure (Christmann & Badgett, 2009). Four experts were involved in the validation of the instrument. Face validation is also subjective judgement of an instrument that may be used for purposes of the research (Bolarinwa, 2015). In the present study, the appropriateness of the instrument was considered to ensure that students would be able to understand what is asked of them and provide the appropriate responses. Content validation refers to the theoretical concept which focuses on the extent to which the instrument of measurement shows evidence of fair and comprehensiveness coverage of the topic that it intends to cover (Hassan & Marston, 2010). The instrument covered the content knowledge on the cell cycle for Grade 10 biology students.

3.5.6 Reliability

A second element that determines the quality of the measurement of the instrument is known as reliability (Miller, 2019). Reliability refers to the extent to which scores are free from measurement error (Scholtes et al., 2011). For quantitative research, consistency and repeatability of the results or observations over time, and the similarity of measurements are all important in determining the degree of reliability of the research (Bruton et al., 2000 & Drost, 2011).

3.5.6.1 Reliability of the instrument

Joppe (2000) defines reliability as "the extent to which results are consistent over time and which provide an accurate representation of the total population under study" (2000, p.1). The questionnaire was given to the Grade 10 biology students, simultaneously. Administration procedure of the questionnaire was accounted for in order to maintain consistency between the groups. 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 score (*p* value) was used to ascertain validity and reliability of results from data collected through the content knowledge test, while Cronbach's alpha score was used to ascertain validity and reliability of results from data collected through questionnaires. This is because Cronbach's alpha is the most commonly used test and ascertain validity and reliability, wherein a reliability score of 0.7 and higher is regarded as acceptable (Gelman & Carlin, 2017). The *p* value is a continuous measure of evidence into determining the data as either highly significant when $p \leq 0.01$, marginally significant when $p \leq 0.05$ and not statistically significant when $p > 0.10$ (Gelman & Carlin, 2017).

3.6 Ethics

Ethics relates to the application of moral principles to prevent harming (Orb et al., 2001) others during the research study, as well as to promote goodness and to be respectful and fair (Ryen, 2016). The researcher considered the ethical implications for this study in terms of the University's policy on Research Ethics. Ethical clearance certificate from the College of Education, from a University has been attached as Appendix C. The researcher adhered to the rules and requirements stipulated by the Ethics Policy. A lletter requesting permission to conduct research has been attached as Appendix D (p.187); a letter requesting parental consent for minors to participate in a research project has been attached as Appendix E (p.188-189); a participant information sheet has been attached as Appendix F (p.190); consent to participate in this study has been attached as Appendix G (p.191); a letter requesting consent from learners in a secondary school (high school) to participate in a research project has been attached as Appendix H (p.192- 193), and a cover letter for the questionnaire has been attached as Appendix I (p.194).

3.7 Conclusion

This chapter explored research paradigms: qualitative, quantitative, and mixed methods approaches to research. Quantitative methods help to identify the hypothesis and statistically test variables against such a hypothesis. Statistical tests try to find patterns in the data, describe the data or try to draw inferences about the population from a sample. Such methods are usually generalizable to a larger population. In contrast, qualitative methods use techniques such as narratives, phenomenologies, ethnographies, ground theory and case studies. Such methods try to understand the deeper meaning of events, behaviours, emotions and relationships. The mixed methods approach is a combination of both qualitative and quantitative research approach. Mixed methods have the potential to lessen the researcher's bias and criticism that is pointed out at each methodology. The current research adopted a quasi-experimental research approach that resembles experimental research but is not as true as experimental research (Levy & Ellis, 2011 & Sullivan-Bolyai & Bova, 2014). It also included a non-experimental survey. Since random assignment of participants is difficult, quasi-experiments allows this type of study to be conducted at a school (Cook & Payne, 2002). A quasi-experimental pre-test-post-test design, and a non-experimental survey were employed in the present study

Chapter Four: Data Presentation and Analysis

4.1 Introduction

This chapter describes the analysis of the data, followed by a discussion of the research findings. The findings relate to the research questions that guided the study. Data were analysed to identify, describe and explore the relationship between learning style, modes of content presentation and visuo-semiotic reasoning. Data was obtained from self-administered questionnaires, completed by 76 biology students (n=76). A total of 76 questionnaires were received.

The questionnaire comprised of two sections and data generated will be presented as follows:

i. the first section comprises of demographic data such as age, sex, channels through which students learn about biology.
ii. The second section comprises of data which tests the content understanding of the cell cycle, in conjunction with the mode of content presentation used to teach the cell cycle.

4.2 Methods of data analysis and presentation of data

Descriptive, statistical analysis was used to identify frequencies and percentages to answer all of the questions in the questionnaire. Not all respondents answered, therefore percentages reported may vary per group per question. The statistical significance of relationships among selected variables was determined using Analysis of Variance (ANOVA). The level of significance of the *p* value was set at 0.05.

4.3 Student performance in the pre-test and post-test

In Group 3, pre-test results showed that students generally had a poor understanding of content knowledge related to the cell cycle. For example, 82.4% of the participants could not correctly list the contents of the nucleus (Table 4.1). Similarly, 94.1% of the participants failed to provide a correct definition of the genome. A majority of the participating students were however able to correctly provide a definition of a cell, list the causes of cancer, describe the characteristics of a normal (cancer free) cell and the characteristics of a cancer cell as well as describe the prerequisite processes for anaphase. While these students performed well in these items, the overall average pass rate was however low (i.e. 37.5%). This suggests that students did not have sufficient content knowledge related to the cell cycle, as probed in the current research.

In the post-test, student performance improved to 43.4%. This improvement was observed in selected items, but not all. For example, the pass rate on their knowledge of nucleus contents improved from 18% in the pre-test to 23.5% in the post test. Similarly, the pass rate on the item that asked for the definition of the genome went from 35% to 59%. However, in some items the pass rate dropped. For example, on the item that asked for the definition of the cell, the pass rate went from 100% in the pre-test to 64.7% in the post-test. In some items however, no change was observed. For example, in the items that probed for the causes of cancer and characteristics of a normal cell, the pass rates were 76% in both the pre-test and post-test (Table. 4.1).

Table 4.1: Performance of the students from Group 3 in the pre-test and post-test

Test Group		Nucleus contents	Genome definition	Genotype definition	Cell definition	Mitosis definition	Causes of cancer	Characteristics of a normal	Characteristics of a cancer	Difference between	Cell cycle process	Chromosome alignment during anaphase
Pre-test	Mean	0,18	0,06	0,35	1,00	0,47	0,76	0,76	0,71	0,12	0,24	0,29
	Median	0,00	0,00	0,00	1,00	0,00	1,00	1,00	1,00	0,00	0,00	0,00
	Mode	0,00	0,00	0,00	1,00	0,00	1,00	1,00	1,00	0,00	0,00	0,00
	Std. Deviation	0,39	0,24	0,49	0,00	0,51	0,44	0,44	0,47	0,33	0,44	0,47
	Variance	0,15	0,06	0,24	0,00	0,26	0,19	0,19	0,22	0,11	0,19	0,22
	Skewness	1,87	4,12	0,68		0,13	-1,37	-1,37	-0,99	2,61	1,37	0,99
	Std. Error of Skewness	0,55	0,55	0,55	0,55	0,55	0,55	0,55	0,55	0,55	0,55	0,55
	Kurtosis	1,67	17,00	-1,77		-2,27	-0,15	-0,15	-1,17	5,44	-0,15	-1,17
	Std. Error of Kurtosis	1,06	1,06	1,06	1,06	1,06	1,06	1,06	1,06	1,06	1,06	1,06
	Mean	0,24	0,00	0,59	0,65	0,71	0,76	0,76	0,76	0,12	0,53	0,29

Post-test	Median	0,00	0,00	1,00	1,00	1,00	1,00	1,00	1,00	0,00	1,00	0,00
	Mode	0,00	0,00	1,00	1,00	1,00	1,00	1,00	1,00	0,00	1,00	0,00
	Std. Deviation	0,44	0,00	0,51	0,49	0,47	0,44	0,44	0,44	0,33	0,51	0,47
	Variance	0,19	0,00	0,26	0,24	0,22	0,19	0,19	0,19	0,11	0,26	0,22
	Skewness	1,37		-0,39	-0,68	-0,99	-1,37	-1,37	-1,37	2,61	-0,13	0,99
	Std. Error of Skewness	0,55	0,55	0,55	0,55	0,55	0,55	0,55	0,55	0,55	0,55	0,55
	Kurtosis	-0,15		-2,11	-1,77	-1,17	-0,15	-0,15	-0,15	5,44	-2,27	-1,17
	Std. Error of Kurtosis	1,06	1,06	1,06	1,06	1,06	1,06	1,06	1,06	1,06	1,06	1,06

Test Group		Describe metaphase	Identifying early	Describe prerequisite	Identify late prophase	Identify G2 in cell division	Identify early prophase	Differentiate between	Identify anaphase	Identify early prophase	Differentiate between chromosomes and chromatics
Pre-test	Mean	0,12	0,29	0,65	0,24	0,29	0,35	0,29	0,18	0,35	0,18
	Median	0,00	0,00	1,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
	Mode	0,00	0,00	1,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
	Std. Deviation	0,33	0,47	0,49	0,44	0,47	0,49	0,47	0,39	0,49	0,39
	Variance	0,11	0,22	0,24	0,19	0,22	0,24	0,22	0,15	0,24	0,15
	Skewness	2,61	0,99	-0,68	1,37	0,99	0,68	0,99	1,87	0,68	1,87
	Std. Error of Skewness	0,55	0,55	0,55	0,55	0,55	0,55	0,55	0,55	0,55	0,55
	Kurtosis	5,44	-1,17	-1,77	-0,15	-1,17	-1,77	-1,17	1,67	-1,77	1,67
	Std. Error of Kurtosis	1,06	1,06	1,06	1,06	1,06	1,06	1,06	1,06	1,06	1,06
Post-test	Mean	0,41	0,71	0,47	0,35	0,35	0,29	0,06	0,53	0,29	0,24
	Median	0,00	1,00	0,00	0,00	0,00	0,00	0,00	1,00	0,00	0,00
	Mode	0,00	1,00	0,00	0,00	0,00	0,00	0,00	1,00	0,00	0,00
	Std. Deviation	0,51	0,47	0,51	0,49	0,49	0,47	0,24	0,51	0,47	0,44

Variance	0,26	0,22	0,26	0,24	0,24	0,22	0,06	0,26	0,22	0,19
Skewness	0,39	-0,99	0,13	0,68	0,68	0,99	4,12	-0,13	0,99	1,37
Std. Error of Skewness	0,55	0,55	0,55	0,55	0,55	0,55	0,55	0,55	0,55	0,55
Kurtosis	-2,11	-1,17	-2,27	-1,77	-1,77	-1,17	17,00	-2,27	-1,17	-0,15
Std. Error of Kurtosis	1,06	1,06	1,06	1,06	1,06	1,06	1,06	1,06	1,06	1,06

However, a t-test showed no significant difference between the students' pass rate in the pre-test compared to the post-test (*p* >.05) (Table 4.2). The variances were also not statistically different (p = .825). These results suggest that the simulation of the cell cycle by bead-work (as a teaching and learning resource) did not have a statistically significant impact on learner performance and pass rate.

Table 4.2: T-test results comparing the performance in the pre-test and post-test in Group 3

		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
Average Score	Equal variances assumed	0,050	0,825	-1,547	32	0,132	-0,05882	0,03803	-0,13630	0,01865
	Equal variances not assumed			-1,547	31,962	0,132	-0,05882	0,03803	-0,13630	0,01865

A pattern similar to that found in Group 3 was observed in Group 2, albeit with some differences. For example, the average pre-test pass rate in Group 2 was 48.1% (Table 4.3). As shown on Table 4.3, the majority of the students in this Group (2) were able to correctly respond to items that probed their knowledge of the definition of a genome (70.4%), definition of the cell (74%), definition of mitosis (67%), causes of cancer (85%), characteristics of a normal cell

(100%), characteristics of a cancer cell (100%), identifying early telophase (52%), as well as differentiating between chromosomes and chromatids (63%). In the post-test, the pass rate was 52.9%, suggesting that there was some improvement. For example, the pass rate improved on the items that asked students to describe the metaphase plate (from 14.8% to 22.2%), identify late prophase (from 29.6% to 59.3%), identify anaphase (from 22.2% to 44.4%). The performance dropped however on items that asked students to differentiate between chromosomes and chromatids (from 63% to 55.5%) and describe prerequisite processes for anaphase (from 22.2% to 14.8%).

Table 4.3: Performance of the students from Group 2 in the pre-test

Test Group		Nucleus contents	Genome definition	Genotype definition	Cell definition	Mitosis definition	Causes of cancer	Characteristics of a normal cell	Characteristics of a cancer cell	Difference between DNA and Genome	Cell cycle process	Analyse chromosome alignment during anaphase
Pre-test	Mean	0,37	0,04	0,70	0,74	0,67	0,85	1,00	1,00	0,30	0,44	0,33
	Median	0,00	0,00	1,00	1,00	1,00	1,00	1,00	1,00	0,00	0,00	0,00
	Mode	0,00	0,00	1,00	1,00	1,00	1,00	1,00	1,00	0,00	0,00	0,00
	Std. Deviation	0,49	0,19	0,47	0,45	0,48	0,36	0,00	0,00	0,47	0,51	0,48
	Variance	0,24	0,04	0,22	0,20	0,23	0,13	0,00	0,00	0,22	0,26	0,23
	Skewness	0,57	5,20	-0,95	-1,16	-0,75	-2,10			0,95	0,24	0,75
	Std. Error of Skewness	0,45	0,45	0,45	0,45	0,45	0,45	0,45	0,45	0,45	0,45	0,45
	Kurtosis	-1,82	27,00	-1,20	-0,70	-1,56	2,59			-1,20	-2,11	-1,56
	Std. Error of	0,87	0,87	0,87	0,87	0,87	0,87	0,87	0,87	0,87	0,87	0,87

	Kurtosis											
Post-test	Mean	0,37	0,15	0,70	0,81	0,59	0,81	0,93	0,93	0,22	0,56	0,48
	Median	0,00	0,00	1,00	1,00	1,00	1,00	1,00	1,00	0,00	1,00	0,00
	Mode	0,00	0,00	1,00	1,00	1,00	1,00	1,00	1,00	0,00	1,00	0,00
	Std. Deviation	0,49	0,36	0,47	0,40	0,50	0,40	0,27	0,27	0,42	0,51	0,51
	Variance	0,24	0,13	0,22	0,16	0,25	0,16	0,07	0,07	0,18	0,26	0,26
	Skewness	0,57	2,10	-0,95	-1,72	-0,40	-1,72	-3,45	-3,45	1,42	-0,24	0,08
	Std. Error of Skewness	0,45	0,45	0,45	0,45	0,45	0,45	0,45	0,45	0,45	0,45	0,45
	Kurtosis	-1,82	2,59	-1,20	1,02	-1,99	1,02	10,67	10,67	0,00	-2,11	-2,16
	Std. Error of Kurtosis	0,87	0,87	0,87	0,87	0,87	0,87	0,87	0,87	0,87	0,87	0,87

Test Group		Describe metaphase plate	Identifying early telophase	Describe prerequisite processes for anaphase	Identify late prophase	Identify G2 in cell division	Identify early prophase	Differentiate between chromosomes and chromatics	Identify anaphase	Identify early prophase	Differentiate between chromosomes and chromatics
Pre-test	Mean	0,15	0,52	0,22	0,30	0,33	0,33	0,63	0,22	0,30	0,67
	Median	0,00	1,00	0,00	0,00	0,00	0,00	1,00	0,00	0,00	1,00
	Mode	0,00	1,00	0,00	0,00	0,00	0,00	1,00	0,00	0,00	1,00
	Std. Deviation	0,36	0,51	0,42	0,47	0,48	0,48	0,49	0,42	0,47	0,48

	Variance	0,13	0,26	0,18	0,22	0,23	0,23	0,24	0,18	0,22	0,23
	Skewness	2,10	-0,08	1,42	0,95	0,75	0,75	-0,57	1,42	0,95	-0,75
	Std. Error of Skewness	0,45	0,45	0,45	0,45	0,45	0,45	0,45	0,45	0,45	0,45
	Kurtosis	2,59	-2,16	0,00	-1,20	-1,56	-1,56	-1,82	0,00	-1,20	-1,56
	Std. Error of Kurtosis	0,87	0,87	0,87	0,87	0,87	0,87	0,87	0,87	0,87	0,87
Post-test	Mean	0,22	0,56	0,15	0,59	0,30	0,52	0,56	0,44	0,59	0,63
	Median	0,00	1,00	0,00	1,00	0,00	1,00	1,00	0,00	1,00	1,00
	Mode	0,00	1,00	0,00	1,00	0,00	1,00	1,00	0,00	1,00	1,00
	Std. Deviation	0,42	0,51	0,36	0,50	0,47	0,51	0,51	0,51	0,50	0,49
	Variance	0,18	0,26	0,13	0,25	0,22	0,26	0,26	0,26	0,25	0,24
	Skewness	1,42	-0,24	2,10	-0,40	0,95	-0,08	-0,24	0,24	-0,40	-0,57
	Std. Error of Skewness	0,45	0,45	0,45	0,45	0,45	0,45	0,45	0,45	0,45	0,45
	Kurtosis	0,00	-2,11	2,59	-1,99	-1,20	-2,16	-2,11	-2,11	-1,99	-1,82
	Std. Error of Kurtosis	0,87	0,87	0,87	0,87	0,87	0,87	0,87	0,87	0,87	0,87

A t-test showed that there was no significant difference in the students' pass rate in the pre-test compared to the post-test (Table 4.4; p = .186). However, Levene's test for equality of variances shows that there were significant differences between the variances in the two tests (p = .022). These results, however, suggest that the paper-based worksheet intervention did not have a significant impact on student performance.

Table 4.4: T-test results comparing performance in the pre-test and post-test in Group 2

		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
Average Score	Equal variances assumed	5,568	0,022	-1,339	52	0,186	-0,04762	0,03555	-0,11896	0,02372
	Equal variances not assumed			-1,339	46,249	0,187	-0,04762	0,03555	-0,11917	0,02394

Performance in the pre-test for group 1 was also similar to the other two groups. Here the pass rate was 43.2% (Table 4.5). The students in Group (1) performed the worst in the items that probed for their knowledge of the definition of the genome, where no student was able to provide a correct answer. Similarly, only 11% of the participating students were able to provide a correct answer for the item that asked the students to list the content of the nucleus. A similar number of students (11%) were able to describe the metaphase plate and identify late prophase. These results suggest that a majority of the student may not have had sufficient content knowledge of concepts related to the cell cycle.

The pass rate in the post-test was 44.9%, which is just over 1% improvement from the pre-test. Here, data showed that slight improvement was observed in selected items. For example, the pass rate on the item that asked students to define a genotype improved from 59.3% to 61.5%. On the item that asked for a definition of a cell, the pass rate improved from 88.9% to 92.3%. However, there were instances were no change was observed in the pass rate. For example, the pass rate remained 0.00% for the item that asked for the genome definition. In some cases, however the pass rate increased significantly. For example, on the item that asked for the contents of the nucleus, the pass rate went from 11.1% in the pre-test to 42.3% in the post test. Furthermore, the pass rate did drop in some items. For example, in the item that asked students to define mitosis, the pass rate went from 70.4% to 65.4%. For the item that asked for the differences between DNA and genome, the pass rate went from 29.6% to 11.5%.

Table 4.5: Performance of the students from Group 1 in the pre-test

Test Group		Nucleus contents	Genome definition	Genotype definition	Cell definition	Mitosis definition	Causes of cancer	Characteristics of a normal cell	Characteristics of a cancer cell	Difference between DNA and Genome	Cell cycle process	Analyse chromosome alignment during anaphase
Pre-test	Mean	0,11	0,00	0,59	0,89	0,70	0,89	0,93	0,93	0,30	0,33	0,37
	Median	0,00	0,00	1,00	1,00	1,00	1,00	1,00	1,00	0,00	0,00	0,00
	Mode	0,00	0,00	1,00	1,00	1,00	1,00	1,00	1,00	0,00	0,00	0,00
	Std. Deviation	0,32	0,00	0,50	0,32	0,47	0,32	0,27	0,27	0,47	0,48	0,49
	Variance	0,10	0,00	0,25	0,10	0,22	0,10	0,07	0,07	0,22	0,23	0,24
	Skewness	2,62		-0,40	-2,62	-0,95	-2,62	-3,45	-3,45	0,95	0,75	0,57
	Std. Error of Skewness	0,45	0,45	0,45	0,45	0,45	0,45	0,45	0,45	0,45	0,45	0,45
	Kurtosis	5,27		-1,99	5,27	-1,20	5,27	10,67	10,67	-1,20	-1,56	-1,82
	Std. Error of Kurtosis	0,87	0,87	0,87	0,87	0,87	0,87	0,87	0,87	0,87	0,87	0,87
Post-test	Mean	0,42	0,00	0,62	0,92	0,65	0,81	0,85	0,85	0,12	0,23	0,35
	Median	0,00	0,00	1,00	1,00	1,00	1,00	1,00	1,00	0,00	0,00	0,00
	Mode	0,00	0,00	1,00	1,00	1,00	1,00	1,00	1,00	0,00	0,00	0,00
	Std. Deviation	0,50	0,00	0,50	0,27	0,49	0,40	0,37	0,37	0,33	0,43	0,49
	Variance	0,25	0,00	0,25	0,07	0,24	0,16	0,14	0,14	0,11	0,18	0,24
	Skewness	0,33		-0,50	-3,37	-0,69	-1,66	-2,04	-2,04	2,56	1,36	0,69

	Std. Error of Skewness	0,46	0,46	0,46	0,46	0,46	0,46	0,46	0,46	0,46	0,46	0,46
	Kurtosis	-2,06		-1,90	10,16	-1,66	0,81	2,33	2,33	4,91	-0,18	-1,66
	Std. Error of Kurtosis	0,89	0,89	0,89	0,89	0,89	0,89	0,89	0,89	0,89	0,89	0,89

Test Group		Describe metaphase plate	Identifying early telophase	Describe prerequisite processes for anaphase	Identify late prophase	Identify G2 in cell division	Identify early prophase	Differentiate between chromosomes and chromatics	Identify anaphase	Identify early prophase	Differentiate between chromosomes and chromatics
Pre-test	Mean	0,11	0,44	0,30	0,11	0,33	0,33	0,52	0,41	0,33	0,15
	Median	0,00	0,00	0,00	0,00	0,00	0,00	1,00	0,00	0,00	0,00
	Mode	0,00	0,00	0,00	0,00	0,00	0,00	1,00	0,00	0,00	0,00
	Std. Deviation	0,32	0,51	0,47	0,32	0,48	0,48	0,51	0,50	0,48	0,36
	Variance	0,10	0,26	0,22	0,10	0,23	0,23	0,26	0,25	0,23	0,13
	Skewness	2,62	0,24	0,95	2,62	0,75	0,75	-0,08	0,40	0,75	2,10
	Std. Error of Skewness	0,45	0,45	0,45	0,45	0,45	0,45	0,45	0,45	0,45	0,45
	Kurtosis	5,27	-2,11	-1,20	5,27	-1,56	-1,56	-2,16	-1,99	-1,56	2,59
	Std. Error of Kurtosis	0,87	0,87	0,87	0,87	0,87	0,87	0,87	0,87	0,87	0,87
Post-test	Mean	0,50	0,58	0,19	0,38	0,12	0,35	0,27	0,54	0,46	0,23
	Median	0,50	1,00	0,00	0,00	0,00	0,00	0,00	1,00	0,00	0,00
	Mode	.00[a]	1,00	0,00	0,00	0,00	0,00	0,00	1,00	0,00	0,00
	Std. Deviation	0,51	0,50	0,40	0,50	0,33	0,49	0,45	0,51	0,51	0,43
	Variance	0,26	0,25	0,16	0,25	0,11	0,24	0,20	0,26	0,26	0,18
	Skewness	0,00	-0,33	1,66	0,50	2,56	0,69	1,11	-0,16	0,16	1,36

	Std. Error of Skewness	0,46	0,46	0,46	0,46	0,46	0,46	0,46	0,46	0,46	0,46
	Kurtosis	-2,17	-2,06	0,81	-1,90	4,91	-1,66	-0,85	-2,14	-2,14	-0,18
	Std. Error of Kurtosis	0,89	0,89	0,89	0,89	0,89	0,89	0,89	0,89	0,89	0,89

Similar to Groups 3 and 2, a t-test comparing performance in the pre-test and post-test in Group 1 (Table 4.6) showed that there was no significant difference in the pass rate in the pre-test and post-test (p > .05). There was also no significant difference in the variances (p = .923). These results also suggest that the multimedia animation used, did not have any significant impact on student performance.

Table 4.6: T-test results comparing performance in the pre-test and post-test in Group 1

		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
Average Score	Equal variances assumed	0,009	0,923	-0,544	51	0,589	-0,01662	0,03056	-0,07797	0,04473
	Equal variances not assumed			-0,544	50,971	0,589	-0,01662	0,03055	-0,07795	0,04471

In light of these observations, the researcher compared the performance within the tests (pre- and post-test) to determine if there was a statistical difference on student performance between groups. An Analysis of Variance (ANOVA) showed that there was a significant difference in the pre-test in student performance between the Groups (Table 4.7, $p < .010$). Comparing Group 3 and 2 showed that there was a significant difference ($p = .003$). However, there was no significant difference between Group 3 and Group 1 ($p = .110$). There was also no significant difference between Group 2 and Group 1 ($p = .101$). These results confirm that there was a significant difference in the variances between the groups, but the mean scores were not significantly different.

Table 4.7: ANOVA results comparing performance in the pre-test for Group 1, 2 and 3

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	0,119	2	0,059	4,939	0,010
Within Groups	0,817	68	0,012		
Total	0,936	70			

In the post-test, however and ANOVA, showed that there was a significant difference in the pre-test in student performance between the groups (Table 4.8, *p* = .027). The t-test here showed that there was a significant difference between student performance in Group 3 and Group 2 (p = .031). Similarly, the difference was significant between Group 2 and 1 (p = .033). However, the difference was not significant between Group 3 and 1 (p = .673).

Table 4.8: ANOVA results comparing performance in the post-test for Groups 1, 2 and 3

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	0,125	2	0,063	3,832	0,027
Within Groups	1,095	67	0,016		
Total	1,220	69			

4.4 Student preferred learning styles

The current study found slight variations regarding the preferred learning styles (Table 4.9). To this end, it was found that a majority students in Group 3 (47%) selected the reader learning style as their preference; whereas in Group 2 the most preferred learning style was the kinaesthetic learning style, which was selected by 50% of the students. In Group 1, the kinaesthetic learning style was also preferred by the majority of the students (59.5%). The least preferred learning style in Group 3 was the visual learning style, were only 25% of the participating students identified themselves as visual learners. Similarly, in Group 2, 38% of the learners identified themselves as visual learners and 41% in Group 1 identified themselves as visual learners.

Table 4.9: Learning styles preferred by students in Groups 1, 2 and 3

Group 3		Visual learner	Auditory learner	Reader learner	Kinaesthetic learner
	Median	25,00	31,00	47,00	38,00
	Mode	25,00	25,00	50,00	38,00
	Std. Deviation	20,65	15,96	15,57	20,49
	Variance	426,39	254,64	242,57	419,90
	Skewness	2,34	0,61	-0,48	0,26
	Std. Error of Skewness	0,64	0,64	0,64	0,64
	Kurtosis	6,99	-0,16	-0,98	-1,08
	Std. Error of Kurtosis	1,23	1,23	1,23	1,23

Group 2		Visual learner	Auditory learner	Reader learner	Kinaesthetic learner
	Median	38,00	41,00	41,00	50,00
	Mode	25,00	38.00	31,00	50.00
	Std. Deviation	19,15	16,39	20,06	19,90
	Variance	366,57	268,52	402,37	396,15
	Skewness	-0,07	0,01	0,54	0,07

	Std. Error of Skewness	0,44	0,44	0,44	0,44
	Kurtosis	-0,90	0,19	-0,89	-0,82
	Std. Error of Kurtosis	0,86	0,86	0,86	0,86

Group 1		Visual learner	Auditory learner	Reader learner	Kinaesthetic learner
	Median	41,00	56,50	47,00	59,50
	Mode	50,00	50,00	25.00	69,00
	Std. Deviation	18,14	18,10	19,49	18,69
	Variance	329,08	327,52	379,84	349,31
	Skewness	0,07	-0,22	0,11	-0,25
	Std. Error of Skewness	0,49	0,49	0,49	0,49
	Kurtosis	0,08	-1,10	-1,04	-0,46
	Std. Error of Kurtosis	0,95	0,95	0,95	0,95

Data were analysed to determine if there were correlations between preferred learning styles within Groups. In Group 3, results showed that there was no significant correlation between the different learning styles (Table 4.10). Notably, however, the slight (insignificant) correlation between some learning styles were negative. For example, the correlation between auditory learning style and visual learning style, as well as reader learning style and visual learning style were both negative.

Table 4.10: Correlation between learning styles in Group 3

		Visual learner	Auditory learner	Reader learner	Kinaesthetic learner
Visual learner	Pearson Correlation	1	-0,209	-0,444	0,463
	Sig. (2-tailed)		0,515	0,148	0,130
	N	12	12	12	12
Auditory learner	Pearson Correlation	-0,209	1	0,483	0,557
	Sig. (2-tailed)	0,515		0,112	0,060
	N	12	12	12	12
Reader learner	Pearson Correlation	-0,444	0,483	1	-0,136
	Sig. (2-tailed)	0,148	0,112		0,673
	N	12	12	12	12
Kinaesthetic learner	Pearson Correlation	0,463	0,557	-0,136	1
	Sig. (2-tailed)	0,130	0,060	0,673	
	N	12	12	12	12

In Group 2, some significant correlations were observed (Table 4.11). For example, there was a significant correlation between the auditory learning style, reader learning style, kinaesthetic learning style and visual learning style. This result was the opposite of the observed results in Group 3 (see Table 4.10). Furthermore, the reading learning style and kinaesthetic learning styles correlated significantly with the auditory learning style.

Table 4.11: Correlation between learning styles in Group 2

		Visual learner	Auditory learner	Reader learner	Kinaesthetic learner
Visual learner	Pearson Correlation	1	.563**	.520**	.671**
	Sig. (2-tailed)		0,002	0,005	0,000
	N	27	27	27	27

Auditory learner	Pearson Correlation	.563**	1	.592**	.447*
	Sig. (2-tailed)	0,002		0,001	0,019
	N	27	27	27	27
Reader learner	Pearson Correlation	.520**	.592**	1	0,320
	Sig. (2-tailed)	0,005	0,001		0,103
	N	27	27	27	27
Kinaesthetic learner	Pearson Correlation	.671**	.447*	0,320	1
	Sig. (2-tailed)	0,000	0,019	0,103	
	N	27	27	27	27

As shown in Table 4.12, in Group 1 however, the strongest correlation was observed between the kinaesthetic learning style and the auditory learning style. The correlation between kinaesthetic learning style, and visual learning style; reading learning style and auditory learning style, as well as kinaesthetic learning style and reading learning style were significant, but not strong.

Table 4.12: Correlation between learning styles in Group 1

		Visual learner	Auditory learner	Reader learner	Kinaesthetic learner
Visual learner	Pearson Correlation	1	0,141	0,247	.391*
	Sig. (2-tailed)		0,483	0,214	0,044
	N	27	27	27	27
Auditory learner	Pearson Correlation	0,141	1	.430*	.630**
	Sig. (2-tailed)	0,483		0,025	0,000
	N	27	27	27	27
Reader learner	Pearson Correlation	0,247	.430*	1	.395*
	Sig. (2-tailed)	0,214	0,025		0,041
	N	27	27	27	27

Kinaesthetic learner	Pearson Correlation	.391*	.630**	.395*	1
	Sig. (2-tailed)	0,044	0,000	0,041	
	N	27	27	27	27

Correlation between post-test results from each group and their preferred learning styles were also explored. Results here showed that performance did not correlate with any learning style (Table 4.13).

Table 4.13: Correlation between learning styles and performance

		Visual learner	Auditory learner	Reader learner	Kinaesthetic learner
Group 3	Pearson Correlation	0,140	0,461	0,351	0,538
	Sig. (2-tailed)	0,665	0,132	0,263	0,071
	N	12	12	12	12
Group 2	Pearson Correlation	0,210	-0,099	0,150	0,071
	Sig. (2-tailed)	0,293	0,623	0,454	0,726
	N	27	27	27	27
Group 1	Pearson Correlation	0,080	-0,111	-0,078	0,019
	Sig. (2-tailed)	0,693	0,581	0,700	0,925
	N	27	27	27	27
	*. Correlation is significant at the 0.05 level (2-tailed).				
	**. Correlation is significant at the 0.01 level (2-tailed).				

4.5 Conclusion

This chapter presented data, followed by a discussion of the research findings. The findings related to the research questions that guided the study. Data were analysed to identify, describe and explore the relationship between learning style, modes of content presentation and visuo-semiotic reasoning. Pre-test results showed that students generally had a poor understanding of content knowledge related to the cell cycle. Similarly, in the post-test students showed a slight improvement, however, it was not significant. The current study found slight variations regarding the preferred learning, where Group 3 selected reader or writer and Group 1 an 2 selected kinaesthetic. The least preferred learning style across the Group (1, 2 and 3) was the visual learning style.

Chapter Five: Discussion of Results

5.1 Introduction

The purpose of this chapter is to discuss, interpret and describe the results presented in chapter four. The results will be discussed through the lens of the theoretical framework discussed in chapter two, i.e., the theoretical cognitive process of visualisation by Mnguni (2014) and Mayer's (2005a) CTML. Additionally, the findings of the study are discussed in light of the problem statement presented in chapter one, which addressed the dearth in research regarding the relationship between learning styles, modes of content presentation and visuo-semiotic reasoning. Also, chapter one described the increase in the integration of VSMs in biology education in order to promote more effective learning of visually and spatially complex topics, such as molecular biology. However, the effectiveness of VSMs could be limited if the related learning styles are not accommodated and they could also be limited if students experience learning difficulties due to lack of visual literacy and VSR to work with VSMs. The present study aimed to investigate the relationship between learning styles, modes of content presentation and visuo-semiotic reasoning, as a preliminary effort to understand how teaching and learning could be enhanced through VSMs. The research question guiding this study was:

What is the relationship between learning styles, modes of content presentation and visuo-semiotic reasoning?

As a result, the sub-questions that guided the present study were as follows:

a. *What are the most preferred learning styles amongst Grade 10 Biology students, to learn the cell cycle?*
b. *What could be the most effective mode of content presentation for teaching and learning the cell cycle?*
c. *What is the level of visuo-semiotic reasoning amongst Grade 10 Biology students?*

5.2 Discussion of findings

5.2.1 What is the level of visuo-semiotic reasoning amongst Grade 10 Biology students?

Results showed that although students were able to respond correctly in the pre-test to items such as what is the definition of a cell, were able to list the causes of cancer, describe the characteristics of a normal vs. cancer cell, describe pre-requisite processes for anaphase, define a genome, define mitosis, identify early telophase, differentiate between chromosomes and chromatids, describe the metaphase plate and identify late prophase, students still had a generally poor understanding of the cell cycle. Similarly, in the post-test students showed slight improvement, however, it was not significant. Improvement was observed on selected items such as their knowledge of the nuclei content, definition of genome, description of metaphase, identification of late prophase, anaphase and the definition of the cell. Working memory involves simultaneous attention to task relevant information, as well as manipulation, processing and storage (Camos et al., 2018 & Myers et al., 2017 & Nyberg & Eriksson, 2016).

The general poor performance of students may have been a result of cognitive load experienced by the students. Cognitive load theory describes variables that hinder schema development (acquisition of knowledge) (Paas & Sweller, 2014). Wherein, the intrinsic load which is concerned with the intrinsic complexity of information which must be learned and understood, provides the ultimate determinant of both intrinsic and extraneous cognitive load (Leahy & Sweller, 2019). Extraneous cognitive load is concerned with the manner in which instructional material is designed (Sithole, 2017), the findings suggest that the mode of content presentation used for each group was not compatible with their preferred learning styles, this increase on extraneous load affected the germane cognitive load. The germane cognitive load is concerned with the acquisition of knowledge (Kirschner et al., 2018). Generally, a decrease in extraneous cognitive load results in the increase in the germane (Klepsch et al., 2017). Consequently, an increase in the extraneous cognitive load will result in a decrease in the germane cognitive load. The findings of the study suggest that the mode of content presentation which is related to extraneous cognitive load used for each Group (1, 2 and 3) was not compatible with their preferred learning, which implies an increase on extraneous cognitive load and affected germane cognitive load which is observed in their low level of VSR.

Working memory provides a major cognitive differences between biologically primary and biologically secondary knowledge (Sweller, 2016a). Biologically primary knowledge pertains to knowledge that has been acquired overtime and innate in nature (Hota & Barhwal, 2017 & Sweller, 2016a) such as learning how to listen and speak or recognise faces; this knowledge does not require explicit instruction (Sweller, 2016b), such as multimedia instruction, however, it is the foundation of biologically secondary knowledge. Biologically secondary knowledge consists of the wide variety of disparate knowledge, that is considered to be domain specific knowledge (Sweller & Paas, 2017 & Sweller, 2016a), such as Chemistry, Biology, Mathematics. Biologically secondary knowledge requires primary knowledge for its acquisition (Sweller, 2016c), for example, the ability to listen and speak influences our ability to read and write. All secondary concepts and skills have the underlying bed of primary concepts and skills (Lespiau & Tricot, 2018). These underlying primary concepts and skills are likely to influence individual differences in secondary concepts and skills (Sweller, 2016a).

When working with domain-specific information, working memory is severely constrained in both capacity and duration (Cowan, 2016 & Oberauer et al., 2016). As a result, these constraints have instructional consequences (Archibald, 2017). Working memory capacity is important for many cognitive processes including problem solving (Funke & Frensch, 2017 & Menon, 2016), and essentially VSR. Individual differences in working memory capacity appear to arise from firstly, the ability to maintain information in primary memory (Nęcka et al., 2016) and secondly, the ability to manipulate the focus of attention from information stored in long-term memory (Cowan, 2017 & Myers et al., 2017). Therefore, instructional implications flow from biologically secondary domain specific characteristics of knowledge (Ruppert et al., 2019).

Cimer (2012) investigated the biological topics that students have difficulties in learning, the reasons why secondary school students have difficulties in learning biology and ways to improve effectiveness of student's biology learning. The findings showed that there were five topics that students had difficulty learning and these included matter cycle, endocrine system and hormones, aerobic respiration, cell division and genes and chromosomes. Similarly, the findings of the current study are supported by the findings of Cimer (2012) suggesting that students experience difficulties with the following biological topics; cell division (mitosis), genes and chromosomes. The study also suggested the following reasons for why students had difficulties in learning the topics in biology; the nature of the topic, teachers' style of teaching biology, students learning and study habits, students negative feeling and attitudes towards the topic and lack of resources (Cimer, 2012). To overcome these difficulties and make the students learning biology effective, the participants (students) suggested that teachers teach biology through the use of visual material, conducting practical experiments, connecting the topics with daily life, making biology teaching interesting and for students to use various study techniques in order to be successful in biology (Cimer, 2012). The student's views reported in this study contain valuable information for teachers, schools, policy makers and researchers to consider in instructional design, curricula design and other educational processes.

Chattopadhyay (2012) examined the understanding of cell division (mitosis and meiosis) amongst higher secondary students (junior college level). The study found that students had a wide range of misconceptions related to cell division and these results corroborated with a similar study conducted in middle school, where findings suggested that students understanding of cell division was limited from middle school, therein Chattopadhyay (2012) suggested that misconceptions and poor understanding of cell divisions among higher secondary students have been carried from their school level. The current study observed a similar particularly to cell division mitosis, where students indicated misconceptions between concepts such as gene, chromosome, chromatid. In support of Chattopadhyay (2012), Osman et al. (2017) investigated the claims that middle school students exhibit poor understanding of genetics due to misconceptions and difficulties that hinder progression in conceptual understanding of major genetics concepts and phenomena across different grade levels. The findings showed that students had an inadequate understanding of basic genetic concepts which were persistent across levels. Furthermore, findings indicated that students across grade levels exhibited a low level of genetic literacy.

Williams et al. (2012) examined students understanding of the normative connections between key concepts of cell division and underlying biological principals that are critical for an in-depth understanding of genetic inheritance. Findings from a confirmatory factor analysis supplemented with an analysis of student's responses revealed a strong relationship between concepts of genetic inheritance and cell division and provided evidence of the nature of the difficulties that students had when trying to understand these concepts. Williams et al. (2012) distinguished students as either one who possesses normative or non-normative ideas in understanding the biological process and purpose of cell division. The findings suggested that student's difficulty in delineating the purpose of cell division most likely depends on their ideas and links about the cell division processes and products and their ability to develop criteria that helps them identify key distinguishable features.

Cellular processes that rely on knowledge of molecular behaviour are difficult for students to comprehend (Newman et al., 2012 & Tibell & Rundgren, 2010 & van Mil et al., 2013). Newman et al. (2012) argued that research should be conducted not only on the limits and misconceptions of students conceptual understanding but also the applicability of known concepts to unfamiliar concepts; this is described as the definition of 'transfer'. In addition, Newman et al. (2012) suggested that students do not transfer their knowledge about Deoxyribose Nucleic Acid (DNA) between different levels of representation that they may encounter, for example, images of whole chromosomes either depicted through photographs or diagrams; sub-microscopic images of DNA replication or symbolic images of a gene representation. Newman et al. (2012) suggested that in order to improve student conceptual understanding of topics related to genetic information, educators should use pedagogies and activities that prime students for making connections between chromosome structure and cellular processes (Brigandt, 2013 & Weber, 2016).

5.2.2 What are the most preferred learning styles amongst Grade 10 Biology students, to learn the cell cycle?

Results showed that the most preferred learning style was kinaesthetic, seconded by reader/writer learning style. The least preferred learning style across all three groups was the visual learning style. The results from the analysis to determine if there was correlation between post-test results from each Group (1, 2 and 3) indicated that students' performance did not correlate with any learning style. Correlation refers to a relationship between two variables; this is to figure out which variables are connected (Akoglu, 2018 & Bryman & Cramer, 2012 & Kim, 2015 & Mukaka, 2012). This could be because VARK learning styles accounts for the way students prefer delivery of instruction or input mode of accessing information and does not account for the preference of the learning style on working memory. VSR in working memory allows one to be able to generate, recognize, transform, store and retrieve visuospatial information (Castro-Alonso & Atit, 2019 & Ness et al., 2017).

In addition, the VARK learning styles suggest that to learn, we depend on our senses to process information around us. However, research suggests that more multiple styles of learning capabilities have greater significance in other words, we all learn through more than one style (Chen & Wu, 2015 & Truong, 2016 & Willingham et al., 2015). Gardner's theory of multiple intelligences (Gardner, 2015 & Gardner & Hatch, 1989 & Helding, 2009) describes the different ways students learn and acquire information. These multiple intelligences can be differentiated into eight modalities; Visual-spatial intelligence, makes it possible for students to perceive visual or spatial information, such as to transform acquired information and to re-create visual images from memory (Staley, 2015). Interestingly, while this intelligence is usually tied to the visual modality, spatial intelligence can also be exercised to a high level by individuals who are visually impaired (Brokaw, 2012). Verbal-linguistic intelligence, these type of students communicate and make sense of the world through language (Maftoon &

Sarem, 2012 & Mehrabian, 2017). Musical-rhythmic intelligence, allows students to create, communicate and understand meanings out of sounds (Sulaiman et al., 2013). Logical-mathematical, enables students to use and appreciate abstract relations (Hanafiyeh, 2013 & Korkmaz, 2018). Interpersonal intelligence describes the ability to understand and interact effectively with others (Beheshtifar & Roasaei, 2012). It involves effective verbal and non-verbal communication; these students work effectively in groups as they possess an ability to engage with multiple perspectives (Kostelnik et al., 2014). Intrapersonal intelligence, these students are drawn towards understanding one's own interest and goals, they are independent and tend to build accurate mental modes of themselves (Zeidner et al., 2012 & Zimmerman, 2013). Naturalistic intelligence helps students to recognize and categorize plants, animals and other objects in nature (Maftoon & Sarem, 2012 & Maxilom, 2016). Bodily kinaesthetic intelligence allows students to use all or part of the body to create products or solve problems, for examples, athletes, dancers, artistic individuals (Blue, 2015). The current study did not account for multiple intelligences. The theory implies that educators should recognize and teach to a broader range of talents and skills (Alviárez et al., 2014). Also, educators should structure the presentation of material in a style which engages most or all of the intelligences (Hanafin, 2014).

The results of the learning styles found in this study will be discussed and are supported through the work of Graf & Lin (2008) who aimed to identify interactions between learning styles by using the Felder-Silverman learning style model and cognitive traits (working memory). The Felder-Silverman learning style model is based on the notion that students have preferences in terms of the way they receive and process information (Ibrahim & Hamada, 2016). The model presents four different dimensions that are indicative of learning preferences (Crockett et al., 2017). The first dimension distinguishes between active and reflective dimension, which is concerned with the way learners process information (Yang et al., 2013). Learners are distinguished between those who learn best by 'doing' and to those who prefer to 'think' (Graf & Liu, 2010). Active learners prefer to work in groups and engage with classroom activities because it helps them to process information, whereas reflective learners process information better when they work individually, since they prefer to think about and reflect on the material (Zhan et al., 2011).

The second dimension covers the sensing and intuitive learners. This dimension is concerned with the preferred source of information, opposite to the active-reflective dimension which looks at the process of transforming the perceived information into knowledge (Bidarra &

Rusman, 2015 & Dung & Florea, 2012a). Sensing learners prefer to work with theoretical or conceptual ideas for example, facts and concrete learning material. Intuitive learners are more drawn to abstract ideas and hypothetical scenarios, for example, they like to discover possibilities and relationships between variables and tend to be more innovative and creative then sensing learners (Rüütmann & Kipper, 2012). The third dimension, visual and verbal considers the preferred input mode of information (Dung & Florea, 2012b). Visual learners process information better when it is delivered with images, graphics or illustration and verbal learners respond better to words (Mahmoudi et al., 2015 & Omar et al., 2015). In the fourth dimension, sequential and global learners are characterized according to their understanding (Hsiung & Lin, 2012). Sequential learners learn in scaffolds and have a linear learning progress, whereas global learners use a holistic thinking process (Demirkan, 2016 & Radwan, 2014). Graf & Lin (2008) showed that students with low working memory capacity tend to prefer an active, sensing, visual and global learning style. On the other hand, learners with a high working memory capacity students tend to be reflective, verbal or visual, intuitive and sequential.

The results from the numerous studies suggests that teaching pedagogy that is orientated towards students preferred learning style, tends to be more effective when compared with pedagogy where teaching and learning styles conflict (Manolis et al., 2013 & Uğur et al., 2011). However, Uğur et al. (2011) examined student's opinions on blended learning and its implementation in relation to their learning styles. The results showed that there was no difference between student's views on blended learning and its implementation regarding their learning styles.

In a study to examine the relationship between student preferred learning style and academic achievement, the results showed that the reported preferred learning style did not correlate to what and how much was learnt (DeCoux, 2016). Udeani & Adeyemo (2011) examined the relationship among teacher's problem solving abilities, students learning styles and student's achievement in biology. The findings of the study showed that the relationship between students learning styles and their academic achievement in biology was positive and significant. This suggests that adequate knowledge about learning styles for both the teacher and students provides an opportunity for better planned instructional material and for students to adopt appropriate modes of study techniques (Huang et al., 2012 & Quesada-Pineda et al., 2018).

On the contrary, learning styles are assumed to be a predictor of academic achievement (Diseth, 2011), Kirschner (2017), argues the following, firstly, that there is a difference between the way individuals learn and that which actually leads to effective and efficient learning (Kirschner & van Merriënboer, 2013). Secondly, preference for how one studies is different from learning style (Gilakjani, 2012 & Liew et al., 2015). Kirschner (2017), criticizes the concept of learning styles on the underlying position that there is no real scientific basis for the proposition. Firstly, how could students have an optimal learning style? Secondly, do students understand the preferred learning style. Thirdly, the proposed optimal learning and instruction entails that the learning style needs to be determined and aligned with instruction. Knoll et al. (2017) concluded that learning styles are associated with subjective aspects of learning, but not with the objective aspects of learning (Passarelli, 2016).

5.2.3 What could be the most effective mode of content presentation for teaching and learning the cell cycle?

The current study found that the use of multimedia animation, simulation of the cell cycle by bead-work and 2D static model (paper-based) had no significant impact on student performance. The findings might be a result of the conflict between the preferred learning style and the type of content presentation used, for example, students in Group 1 selected the kinaesthetic learning style and the mode of content presentation used for this group was the multimedia animation; Group 2 selected the kinaesthetic learning style and the type of content presentation used for this group was the 2D static model (paper-based); and Group 3 selected reader/ writer learning style and the mode of content presentation used for this group was to simulate the cell cycle by bead work. CTML attempts to explain how to structure multimedia instructional practices, and how to implement more effective teaching strategies to help students learn efficiently (Mayer & Massa, 2003 & Sorden, 2012).

There is ample research on the effectiveness of computer based simulations (Leemkuil & De Jong, 2012). For example, Rutten et al. (2012) investigated the effectiveness of computer based simulations in order to improve learning processes and outcomes as well as how the use of computer based simulations can enhance traditional instruction. The findings showed that computer simulations can enhance traditional instruction, however, improved visualizations do not necessarily translate to better learning. Surprisingly, there is a dearth in literature concerning the effectiveness of using simulation by beadwork to learn the cell cycle. Ekmekci

& Gulacar (2015) compared the effectiveness of computer based activities and hands-on activities in the context of electric circuits, their findings suggested that both instructional activities did not differ from one another in terms of learning processes.

Thomas & Israel (2014) investigated the effectiveness of animations and multimedia teaching on students' performance in science subjects; the findings showed that multimedia animations had a positive impact on student performance. Contrary to the current study the use of multimedia animation did not improve student performance. The findings of this study are supported by Taukobong (2017) and Schönborn & Anderson (2009) who stipulated that VSMs have the potential to accommodate various learning styles, thereby increasing learners understanding of content (Schönborn & Anderson, 2009). However, the effectiveness of VSMs could be limited if the related learning styles are not accommodated, and if students fail to have the necessary visual literacy and VSR skills to work with VSMs (Taukobong, 2017).

While multimedia instructions have been sought to be beneficial than traditional teaching methods, Dai & Fan (2012) argue that although multimedia instruction can make content more imaginable and comprehensive, it should not lead pedagogical instructors to have a general impression that it is not necessary to scaffold content. Scaffolding is usually conceptualized in terms of informational or coordinative support behaviours (Bickhard, 2013). In support of Dai & Fan (2012), Vekiri (2002), stated that for visualisations to be effective, students must process pictorial-textual material by educators scaffolding the verbal material. This means that educators should still endeavour to explain by providing examples in order to foster conceptual understanding (Ndlovu, 2016). A fundamental hypothesis underlying research on multimedia learning, is that multimedia instructional messages that are designed on the basis of how the human mind works (Salomon, 2012) are more likely to lead to meaningful learning than those that are not (Clark & Mayer, 2016 & Mayer, 2005a; 2009; 2011).

The modes of content presentation employed in this study did not follow principles on instructional design and organization of multimedia presentation, which provides strategies that may reduce extraneous cognitive load and increase germane cognitive load. Therefore, the modes of content presentation used in this study may have resulted in an increase on extraneous cognitive load in turn affecting working memory capacity. Pratt et al. (2011) examined the effect of working memory load on visual selective attention. Working memory and attention interact in a way that enables individuals to focus on relevant items (Gazzaley & Nobre, 2012

& Roux & Uhlhaas, 2014). The influence of working memory on attention has been studied using dual task designs (Fraser et al., 2015 & Morrison & Chein, 2011). Multitasking increases the demands on working memory and reduces the amount of resources available for cognitive control function such as resolving stimuli conflict (Fischer & Plessow, 2015).

Ahmed & De Fockert (2012), found that working memory plays a major role in the control of selection attention, where distractibility is greater under conditions of high concurrent working memory load and in individuals with a low working memory capacity. This means, individuals with a low working memory capacity are most likely to be distracted under conditions that require high working memory as a result this affects spatial distribution of attention. Therefore, the impact of VSM is affected by working memory capacity, for example, working memory selects information from sensory memory for processing and integration (Myers et al., 2017).

According to CTML, learning from multimedia presentation takes place when students engage in five cognitive processes (1) selecting relevant words for verbal working memory; (2) organizing selected words into a verbal model; (3) organizing selected images into pictorial model; (4) integrating the verbal and pictorial representations with each other; (5) and with prior knowledge. Therefore, the five cognitive processes (Mayer, 2010) of working memory determine which information is selected, which knowledge is retrieved from long term memory (prior knowledge) and integrated with the new information. Essentially, the five cognitive processes describe the high working memory, but if students have low working memory capacity, the communication of the VSM may not benefit the student. Learning with VSMs involves processing of the VSM in order to construct an internal representation (Evagorou et al., 2015 & Gordo et al., 2017).

5.2.4 What is the relationship between learning styles, modes of content presentation and visuo-semiotic reasoning?

The findings of this study suggests that a relationship exists between learning styles, modes of content presentation and visuo-semiotic reasoning associated with learning difficulties related to conceptual understanding of the cell cycle. The learning difficulties related to this study will be discussed through the lens of the theoretical cognitive stages of visualization (Mnguni, 2014). The cognitive process of visualization stipulates that the availability of VSR skills and the ability of students operating within various stages of visualization, that is IVM, CVM and EVM may influence student's visual literacy which in turn impacts their conceptual understanding of content related knowledge (Avgerinou & Pettersson, 2011 & Nitz et al., 2014).

VSR skills are necessary for students to comprehend content presented with VSMs. IVM in this study is observed through learning style preferences which were self-reported by the students through the VARK questionnaire. IVM refers to a process wherein sense organs such as eyes work with the brain to absorb information and cognitive effort is applied to comprehend visual information (Mnguni, 2014). IVM is parallel to the notion of learning styles wherein students have a preference in the way they perceive, process and retain information. The impact of IVM is observed in CVM and EVM, where CVM relates to the integration of prior knowledge with new knowledge and EVM considers students ability to communicate knowledge from their working memory by way of externalizing cognitive models (Mnguni, 2014). EVM was observed in this study from the availability of VSR skills amongst students to comprehend visual information from VSMs. The integration process of prior knowledge with new knowledge requires VSR skills (Mnguni, 2014). The prior knowledge observed from the pre-test results from students across all three groups, showed that their conceptual understanding of the cell cycle was generally low and efforts of different VSMs used as teaching and learning resources respectively, as observed in the post-test suggested that they did not have a significant impact on student performance. As such it is apparent that EVM can be affected by lack of VSR skills.

5.3 Recommendations for further research

The findings of the study suggest that there is a relationship between learning styles, modes of content presentation and visuo-semiotic reasoning. The author believes that this study has presented a strategy to be considered in teaching and learning. By understanding the relationship between learning styles, modes of content presentation and visuo-semiotic reasoning, a study could be conducted at different school levels (at foundation phase, intermediate phase and senior phase) Similar research should be conducted in other provinces to investigate the above mentioned relationship. The author recommends using a mixed methods approach, as characterized by triangulation, that is, the use of several means (methods, data sources and researchers) to examine the same phenomenon could be explored. These may include focus group discussions and interviews with respondents. A longitudinal study should be considered in order to obtain a better reflection of data over a longer time period.

5.4 Conclusion

Learning biology in the 21st century requires a set of VSR skills. These VSR skills include the ability to understand, reason and to remember by processing visual stimuli in order to comprehend spatial relationships between objects and to visualize different scenarios or images. The findings of this study accept the hypothesis for this study which stated there exists a relationship between learning styles, modes of content presentation and visuo-semiotic reasoning amongst Grade 10 biology students and these students prefer to learn the cell cycle theory in biology, using a specific style of learning through the use of an effective mode of presentation. This relationship stipulates that when learning style preferences do not align with mode of content presentation, this will have an impact on visuo-semiotic reasoning.

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APPENDIX A: CONTENT KNOWLEDGE TEST

Dear Learner

You are invited to participate in my survey in the investigation of the effectiveness of using computer-based visual models in molecular Life Sciences as part of my master's Degree in Natural Science Education from the College of Education, University of South Africa (UNISA). It will take approximately 20-30 minutes to complete. Your participation in this study is voluntary. There are no foreseeable risks associated with this project. However, if you feel uncomfortable answering any questions, you can withdraw from the survey at any point. It is important for me to learn your opinions. Your survey responses will be strictly confidential and data from this research will be reported only in the aggregate. Your information will be coded and will remain confidential. If you have questions at any time about the survey or the procedures you may email me on: masikanek93@gmail.com or my Supervisor on: mngunle@unisa.ac.za. Thank you for your time and support.

SECTION A

Please answer the following questions by writing or crossing (X) in the appropriate box:

A. What is your age, as at your last birthday?

B. What is your gender?

MALE	FEMALE

C. In the following list, please mark the channels through which you learn about Life Sciences?

1. Peers	
2. Television	
3. Radio	
4. Academic textbooks	
5. Educators//Tutors	
6. Internet	
7. Other *(specify)*	

SECTION B

In the following questions, please mark your responses by crossing (X) in the correct box next to your answer. Choose only one answer.

1. In most cells of your body, the nucleus contains….
   a. the instructions to make the entire organism;
   b. some of the instructions needed to make different parts of the organism;
   c. all the molecules needed to make different parts of the organism;
   d. the instruction needed to make small parts of the organism.

2. The complete set of genes of an organism is known as:
   a. Genetics;
   b. Genome;
   c. DNA;
   d. Chromosome.

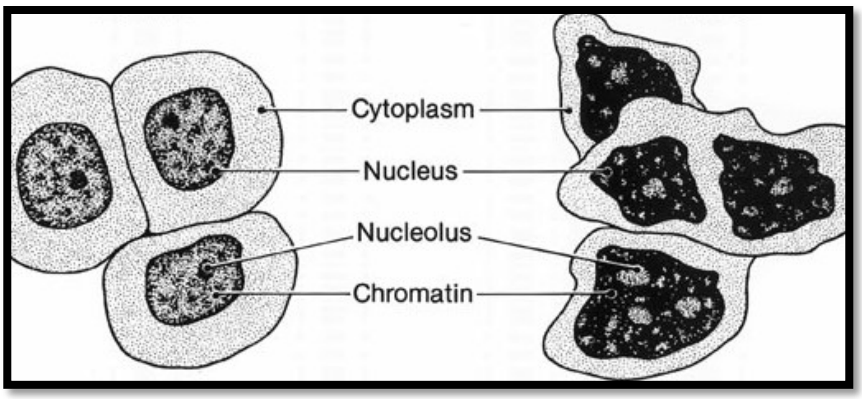
3. Genetic information is also known as:
   a. Science Technology;
   b. Genotype;
   c. DNA;
   d. Mitosis.

4. A cell is…
   a. used for stem cell harvesting;
   b. used to produce an animal with the same DNA as another animal;
   c. the structural and functional unit of an organism;
   d. used for biological synthesis.

5. Mitosis is...
   a. the process that uses living organisms and their biological processes to make or modify products;
   b. the process of natural sciences concerned with living organisms and their function;
   c. the process that results in variation and heredity in a living organism;
   d. the process that results in two daughter cells each having the same number and kind of chromosomes.

6. Cancer results from…
   a. the genetic composition of an organism;
   b. a malignant growth resulting from an uncontrolled division of cells;
   c. the new cells formed for growth.
   d. Bio-physiology.

7. Use the picture below to answer the questions.

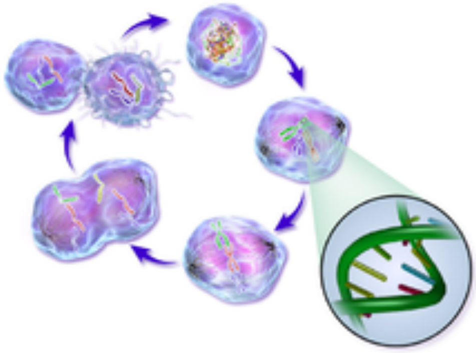


A B

7.1 Which cell represents a:
   a. Normal Cell…………………
   b. Cancer Cell………………….

8. How can a person's muscle cells have the same exact DNA sequences as their nerve cells even though they look and perform completely differently?
   a. The genome of the different cells changes;
   b. The proteins expressed in each cell are different;
   c. There are different DNA in the two types of cells;
   d. The two different cells become mutated.

9. Refer to the image below to answer the questions that follow.



9.1 What is represented?____

9.2 What is the process mentioned in 9.2?____

9.3 Does the image represent an animal cell or plant cell? Give a reason for your answer.____

APPENDIX B: VARK QUESTIONNAIRE

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Choose the answer which best explains your preference and circle the letter(s) next to it. Please circle more than one if a single answer does not match your perception. Leave blank any question that does not apply.

1. **You are helping someone who wants to go to your airport, the centre of town or railway station. You would:**

a. go with her.
b. tell her the directions.
c. write down the directions.
d. draw, or show her a map, or give her a map.

2. **You are not sure whether a word should be spelled `dependent' or `dependant'. You would:**

a. see the words in your mind and choose by the way they look.
b. think about how each word sounds and choose one.
c. find it online or in a dictionary.
d. write both words down and choose one.

3. **You are planning a vacation for a group. You want some feedback from them about the plan. You would:**

a. describe some of the highlights they will experience.
b. use a map to show them the places.
c. give them a copy of the printed itinerary.
d. phone, text or email them.

4. **You are going to cook something as a special treat. You would:**

a. cook something you know without the need for instructions.
b. ask friends for suggestions.
c. look on the Internet or in some cookbooks for ideas from the pictures.
d. use a good recipe.

5. **A group of tourists want to learn about the parks or wildlife reserves in your area. You would:**

a. talk about or arrange a talk for them about parks or wildlife reserves.
b. show them maps and internet pictures.
c. take them to a park or wildlife reserve and walk with them.
d. give them a book or pamphlets about the parks or wildlife reserves.

6. **You are about to purchase a digital camera or mobile phone. Other than price, what would most influence your decision?**

a. Trying or testing it.
b. Reading the details or checking its features online.
c. It is a modern design and looks good.
d. The salesperson telling me about its features.

7. **Remember a time when you learned how to do something new. Avoid choosing a physical skill, e.g. Riding a bike. You learned best by:**

a. watching a demonstration.
b. listening to somebody explaining it and asking questions.
c. diagrams, maps, and charts - visual clues.
d. written instructions – e.g. a manual or book.

8. **You have a problem with your heart. You would prefer that the doctor:**

a. gave you a something to read to explain what was wrong.
b. used a plastic model to show what was wrong.
c. described what was wrong.
d. showed you a diagram of what was wrong.

9. **You want to learn a new program, skill or game on a computer. You would:**

a. read the written instructions that came with the program.
b. talk with people who know about the program.
c. use the controls or keyboard.
d. follow the diagrams in the book that came with it.

10. **I like websites that have:**

a. things I can click on, shift or try.
b. interesting design and visual features.
c. interesting written descriptions lists and explanations.
d. audio channels where I can hear music, radio programs or interviews.

11. **Other than price, what would most influence your decision to buy a new non-fiction book?**

a. The way it looks is appealing.

b. Quickly reading parts of it.
c. A friend talks about it and recommends it.
d. It has real-life stories, experiences and examples.

12. You are using a book, CD or website to learn how to take photos with your new digital camera. You would like to have:

a. a chance to ask questions and talk about the camera and its features.
b. clear written instructions with lists and bullet points about what to do.
c. diagrams showing the camera and what each part does.
d. many examples of good and poor photos and how to improve them.

13. Do you prefer a teacher or a presenter who uses:

a. demonstrations, models or practical sessions.
b. question and answer, talk, group discussion, or guest speakers.
c. handouts, books, or readings.
d. diagrams, charts or graphs.

14. You have finished a competition or test and would like some feedback. You would like to have feedback:

a. using examples from what you have done.
b. using a written description of your results.
c. from somebody who talks it through with you.
d. using graphs showing what you had achieved.

15. You are going to choose food at a restaurant or cafe. You would:

a. choose something that you have had there before.
b. listen to the waiter or ask friends to recommend choices.
c. choose from the descriptions in the menu.
d. look at what others are eating or look at pictures of each dish.

16. You have to make an important speech at a conference or special occasion. You would:

a. make diagrams or get graphs to help explain things.
b. write a few key words and practice saying your speech over and over.
c. write out your speech and learn from reading it over several times.
d. gather many examples and stories to make the talk real and practical.

APPENDIX C: ETHICAL CLEARANCE CERTIFICATE

10. Miss K
Masikane.pdf

APPENDIX D: LETTER REQUESTING PERMISSION TO CONDUCT RESEARCH

Request for permission to conduct research at:

Title of the research: The relationship between learning styles, modes of content presentation and visuo-semiotic reasoning in Biology.

Dear: **Date:**

I, Khanyisile Masikane am conducting research under the supervision of Lindelani Mnguni, a Professor in the Department of Science and Technology towards a Master's Degree in Natural Sciences Education at the University of South Africa. We have funding from the National Research Foundation (NRF) for purpose of this study. We are inviting you to participate in a study entitled: **The relationship between learning styles, modes of content presentation and visuo-semiotic reasoning in Biology.**

The present study aims to investigate the relationship between learning styles, modes of content presentation and visuo-semiotic reasoning in Biology, as a preliminary effort to understanding how teaching and learning could be enhanced through visuo-semiotic models and to highlight the challenging aspects of teaching and learning molecular life science and to establish a foundation for future education research and practice in the discipline and the possible benefits of the study are the improvement of the teaching and learning process in molecular sciences as well contribute to the knowledge and understanding of the educational challenges and provide tools that can assist teachers and the educational system to meet these challenges.

The study will comprise of Grade 10 learners in Life Sciences .The benefits of this study will contribute to the knowledge and understanding of the educational challenges and provide tools that can assist teachers and the educational system to meet these challenges. This study poses no harm or damage to the participants. There will be no reimbursement or any incentives for participation in the research. Feedback procedure will be adhered to upon request, the findings of the study may be emailed to you.

Yours sincerely

_____________________________ **(Signature of researcher)**

_____________________________ **(Name of the above signatory)**

_____________________________ **(Signatory's position)**

APPENDIX E: LETTER REQUESTING PARENTAL CONSENT FOR MINORS TO PARTICIPATE IN A RESEARCH PROJECT

UNISA university of south africa

Dear Parent,

Your child is invited to participate in a study entitled "The relationship between learning styles, modes of content presentation and visuo-semiotic reasoning in Biology."

I am undertaking this study as part of my Master's research at the University of South Africa. The present study aims to investigate the relationship between learning styles, modes of content presentation and visuo-semiotic reasoning in Biology, as a preliminary effort to understanding how teaching and learning could be enhanced through visuo-semiotic models and to highlight the challenging aspects of teaching and learning molecular life science and to establish a foundation for future education research and practice in the discipline and the possible benefits of the study are the improvement of the teaching and learning process in molecular sciences as well contribute to the knowledge and understanding of the educational challenges and provide tools that can assist teachers and the educational system to meet these challenges. I am asking permission to include your child in this study because they are a pivotal agent to this study. I expect to have 150 other children participating in the study.

If you allow your child to participate, I shall request him/her to:

Take part in a survey, the questionnaires will be distributed to the participants (learners) in class during their Life Sciences period. This is to avoid unreturned questionnaires. The lessons are normally 40-45min and the questionnaire will take +/- 40-450min. This method will be applied for the controlled and experimental groups. Each teacher will be given clear written instructions upon distribution and the administration process. Each question will be explained to the learners and they will be given 10 minutes to read through the questionnaire. The learners will also be given the opportunity to ask questions and clarify any misunderstanding. The learners will be made fully aware that they are not writing a test. Learners will be informed that they will not be forced to participate in the research and that only those who gave consent will be included.

- 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. Your confidentiality may be compromised as the questionnaire will be distributed amongst other learners. However, his/her responses will not be linked to his/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. 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 with the prior approval of the school and your child's teacher. However, if you do not want your child to participate, he/she will in class and will not be issued a survey to complete.

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. There are no potential risks in relation to this study. There will be no reimbursement or any incentives for participation in the research.

If you have questions about this study please ask me or my study supervisor, Prof L.E Mnguni, Department of Science and Technology, College of Education, University of South Africa. My contact number is 081 454 3500 and my e-mail is masikanek93@gmail.com. The e-mail of my supervisor is mngunle@unisa.ac.za. Permission for the study has already been given by the Principal and the Ethics Committee of the College of Education, UNISA.

You are deciding 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:____

Yours Faithfully,

______________________________	______________________________	________________
Parent/guardian's name (print)	Parent/guardian's signature:	Date:
__________________________	__________________________	_______________
Researcher's name (print)	Researcher's signature	Date:

APPENDIX F: PARTICIPANT INFORMATION SHEET

This letter is an invitation to consider participating in a study I, Miss Khanyisile Masikane, am conducting as part of my research as a Master's student entitled "The relationship between learning styles, modes of content presentation and visuo-semiotic reasoning in Biology." at the University of South Africa. Permission for the study has been given by the University and the Ethics Committee of the College of Education, UNISA. I have purposefully identified you as a possible participant because of your valuable experience and expertise related to my research topic.

I would like to provide you with more information about this research and what your involvement would entail if you should agree to take part. The importance of " The relationship between learning styles, modes of content presentation and visuo-semiotic reasoning in Biology " in education is not substantially and documented. In this questionnaire I would like to have your views and opinions on this topic.

Your participation in this study is voluntary and you may decide to withdraw at any time without any negative consequences. All information you provide is considered completely confidential. Your name will not appear in any publication resulting from this study and any identifying information will be omitted from the report. However, with your permission, anonymous quotations may be used. Data collected during this study will be retained on a password protected computer for 12 months in my locked office, there are no known or anticipated risks to you as a participant in this study. If you have any questions regarding this study or would like additional information to assist you in reaching a decision about participation, please contact me at 0814543500 or by email at masikanek93@gmail.com.

I look forward to receiving your responses and thank you in advance for your assistance in this project. If you accept my invitation to participate, I will request you to sign the consent form which follows on (the next page).

Yours Sincerely,

____

APPENDIX G: CONSENT/ ASSENT TO PARTICIPATE IN THIS STUDY

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

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

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

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

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

I agree to the recording of the questionnaire.

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

Participant Name & Surname (please write in print) ____________________________________

____________________________ ____________________________________

Participant Signature Date

Researcher's Name & Surname <u>Khanyisile Masikane</u>

____________________________ ____________________________________

Researcher's signature Date

APPENDIX H: A LETTER REQUESTING ASSENT FROM LEARNERS IN A SECONDARY SCHOOL TO PARTICIPATE IN A RESEARCH PROJECT

UNISA university of south africa

The relationship between learning styles, modes of content presentation and visuo-semiotic reasoning in Biology.

Dear Learner, **Date:**

I am conducting a study on "The relationship between learning styles, modes of content presentation and visuo-semiotic reasoning in Biology" as part of my studies with the University of South Africa. Your principal has granted me permission to conduct this study in your school. I would like to invite you to be a very special part of my study. I am conducting this study so that I can find ways that your teachers can use to mitigate the challenges in teaching and learning molecular biology. This may 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 to ask you to complete a questionnaire about molecular studies. Answering the questionnaire/ completing the questionnaire will take no longer than 40 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. Participation is voluntary, and 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 without penalty. 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.
The are no potential risks involved.
You will not be reimbursed or receive any incentives for your participation in the research.
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 0814543500. Do not sign the form until you have all your questions answered and understand what I would like you to do.
Researcher: ____________________________ Phone number: ________________________

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

WRITTEN ASSENT

I have read this letter which asks me to be part of a study at my school. I have understood the information about my study, and I know what I will be asked to do. I am willing to be in the study.

___________________________	___________________________	___________________________
Learner's name (print):	Learner's signature:	Date:

___________________________	___________________________	___________________________
Witness's name (print)	Witness's signature	Date:

(The witness is over 18 years old and present when signed.)

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

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

APPENDIX I: COVER LETTER FOR QUESTIONNAIRE

UNISA university of south africa

Dear respondent,

This questionnaire forms part of my master's research entitled: "The relationship between learning styles, modes of content presentation and visuo-semiotic reasoning in Biology" for the degree MEd at the University of South Africa. You have been selected by a purposive sampling strategy from the population of Grade 10 learners. Hence, I invite you to take part in this survey.

The present study aims to investigate the relationship between learning styles, modes of content presentation and visuo-semiotic reasoning in Biology, as a preliminary effort to understanding how teaching and learning could be enhanced through visuo-semiotic models and to highlight the challenging aspects of teaching and learning molecular life science and to establish a foundation for future education research and practice in the discipline and the possible benefits of the study are the improvement of the teaching and learning process in molecular sciences as well contribute to the knowledge and understanding of the educational challenges and provide tools that can assist teachers and the educational system to meet these challenges.

You are kindly requested to complete this survey questionnaire, comprising of 2 sections as honestly and frankly as possible and according to your personal views and experience. No foreseeable risks are associated with the completion of the questionnaire which is for research purposes only. The questionnaire will take approximately +/- 40-45 minutes to complete.

You are not required to indicate your name or organisation and your anonymity will be ensured; however, indication of your age, gender, occupation position etcetera will contribute to a more comprehensive analysis. All information obtained from this questionnaire will be used for research purposes only and will remain confidential. Your participation in this survey is voluntary and you have the right to omit any question if so desired, or to withdraw from answering this survey without penalty at any stage. After the completion of the study, an electronic summary of the findings of the research will be made available to you on request.

Permission to undertake this survey has been granted by the school principal and the Ethics Committee of the College of Education, UNISA. If you have any research-related enquiries, they can be addressed directly to me or my supervisor. My contact details are: 081 454 3500 e-mail: masikanek93@gmail.com and my supervisor can be reached at 012 429 4614 Department of Science and Technology, College of Education, UNISA, e-mail: mgunle@unisa.ac.za By completing the questionnaire, you imply that you have agreed to participate in this research.