The visual literacy of Grade 10 Life Sciences learners in cytology

by

Tshegofatso Martha Taukobong

Submitted in partial fulfilment of the requirements for the degree

MAGISTER EDUCATIONIS

in the Faculty of Education

at the

UNIVERSITY OF PRETORIA

Supervisor:	**Prof JJR de Villiers**
Co-supervisors:	**Prof WJ Fraser**
	Dr MA Graham

AUGUST 2017

Ethical Clearance Certificate

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA
Faculty of Education

RESEARCH ETHICS COMMITTEE

CLEARANCE CERTIFICATE	CLEARANCE NUMBER: **SM 15/07/01**
DEGREE AND PROJECT	MEd
TITLE	The visual literacy of Grade 10 Life Sciences learners in cytology
INVESTIGATOR	Ms Tshegofatso Taukobong
DEPARTMENT	Department of Science, Mathematics and Technology Education
APPROVAL TO COMMENCE STUDY	11 December 2015
DATE OF CLEARANCE CERTIFICATE	2 August 2017

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Declaration

I declare that the thesis, which I hereby submit for the degree Maters of Education at the University of Pretoria, is my own work and has not previously been submitted by me for a degree at this or any other tertiary institution.

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Tshegofatso Martha Taukobong

29 August 2017

Ethics statement

The highest ethical standards were maintained in this thesis. The ethical considerations for this study are discussed in detail in Section 3.8.

Dedication

I dedicate this research to

Anna Mmamalebo Malapane and Lesego Deborah Manganye, my grandmother and soul mate friend, who passed on during the course of my study.

Acknowledgements

To have achieved this milestone in my life, I would like to express my sincere gratitude to the following people:

My Heavenly Father, who provided me with the strength, knowledge and perseverance to complete this study. It was not according to my will but to His will.

I owe special thanks to my supervisor, Professor J.J.R. de Villiers, and co-supervisors, Professor W.J. Fraser and Dr. M.A. Graham. I am deeply grateful for your commitment and patience towards my completion of this dissertation. I have learnt a lot from all of you. I am truly thankful.

I would also like to thank Professor L.E. Mnguni for introducing the phenomenon of visual literacy to me, his assistance and believing in me.

It is also essential for me to extend my appreciations to my colleagues and friends, those words of encouragement when I felt like giving up, kept me going.

I would like to thank all my participants, their teachers and principals at their schools for their willingness to assist and co-operation throughout this research.

Last but not least, I wish to extend my humble gratitude to a number of individuals, without whom this would have not been possible, particularly my mom, best friend Prudence and my family.

Thank you very much.

Abstract

In Life Sciences Education, the use of educational external representations (ERs) such as diagrams, models and animations are increasingly appearing in learning and teaching resources. However, their effectiveness is limited if learners experience learning difficulties due to lack of visual literacy and spatial ability skills to work with ERs. The study explored the level of visual literacy of 225 Grade 10 Life Sciences learners in cytology across six secondary schools in Pretoria, Gauteng. It was theorised that ERs need to be integrated in the Life Sciences curricula to develop learners' visual literacy and spatial ability skills. With this theory, the study aimed to explore the visual literacy of Grade 10 Life Sciences learners and the influence of gender and school location on the visual literacy and spatial ability skills of the learners. Through a quantitative research method a Life Sciences visual literacy questionnaire and a spatial ability test were used to collect data. Collected data was analysed descriptively and inferentially through Statistical Package Social Sciences Version 23. The results showed that most Grade 10 Life Sciences learners lack average visual literacy skills. Furthermore, the results showed that gender doesn't play a role on the learners' performance in visual literacy skills as both genders performed equally in both tests, On the other hand, the results showed that the location of the school (urban, rural or township) has an effect on the learners' performance in visual literacy skills. Teachers need to incorporate different ERs that would stimulate different senses and which will also enhance learners' visual literacy and spatial ability skills in their lessons. A conclusion and some recommendations for future research are given.

Key Terms:

Cytology, external representations, Life Sciences, spatial ability skills, visual literacy, visual literacy skills.

Language editor

Member South African Translators' Institute

28 18th Street
Menlo Park
Pretoria 0081
https://www.language-services.biz
21 August 2017

TO WHOM IT MAY CONCERN

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Anna M de Wet

BA Hons (Cum Laude), University of Pretoria

List of abbreviations

2D	Two-dimensional
3D	Three-dimensional
ANOVA	Analysis of variance
ER	External representation
LS	Life Sciences
LSD	Fisher's least significant difference
LSVLT	Life Sciences visual literacy test
SAT	Spatial ability test
SPSS	Statistical Package for Social Sciences
VL	Visual literacy

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CHAPTER 1: GENERAL ORIENTATION

The skills needed to learn and communicate visually are no longer optional.

- Bette Fetter

1.1. INTRODUCTION

The utilisation of educational external representations (ERs) such as diagrams, physical models and videos in science education, particularly in the Life Sciences, are increasingly being utilised as learning and teaching resources. ERs are a phenomenon that is illustrated pictographically and contains spatial relationships in the external world (Schönborn & Anderson, 2009).

In the past years, learners were taught using textbooks and they are dependent on the teacher to bring abstract biological concepts into concrete ones. However, in the 21st century learning, learners are exposed to different technological devices such as computers with computerised software games and videos, digital devices such as camcorders and smart phones creating more room for visual literacy to be an area of critical importance in education.

Learners of today are more acquainted with the new drastic change in technology. Such acquaintance offers teachers a platform to use the educational technological devices as an advantage to create a positive learning atmosphere and enhance learning in a classroom. Research showed that ERs have a greater advantage comparing to text only for teaching and learning (McTigue & Flowers, 2011).

In Life Sciences there are a lot of concepts that are abstract and not possible to see with the naked eye. Such concepts become very intricate for learners to understand if they are not taught using ERs. However, it is not only learners who come across this difficulty of comprehending the abstract concepts discussed, such as cell division. For example teachers might also experience a problem of unfolding the abstract concepts to concrete ones for learners to understand, because if they haven't learnt how to, then how can they possibly teach it (Luke, 2003). The invention of educational technological devices (such as web-based materials, multimedia as print outs and/or transparencies) and methods that aim to make abstract concepts more visual and concrete to learners, is acknowledged as an attempt to address learning difficulties using ERs.

As mentioned above learners of this era are more acquainted and depended on visual image and more familiar with visual concepts, the use of ERs for educational purposes has elevated a number of concerns. These concerns emanate from the mode of presentation (the nature of the ER, that is, graphics, colour and/or visual cues of the ER) and the interpretation of the ER by learners. Schönborn and Anderson (2006) have identified the main causes of learning difficulties learners experience when learning with ERs and, amongst others, visual literacy is one of them. The other learning difficulties learners may experience in interpreting ERs are the mode of representation, reasoning ability (cognitive process that a learner employs when decoding and perceiving visual markings on the ER with his/her own existing knowledge relevant to the ER) and conceptual knowledge (understanding and prior knowledge that exist before exposure to the ER question) of the ER.

This study therefore aims to re-visit the subject as presented in literature in an attempt to explore the level of visual literacy of the Grade 10 Life Science learners.

1.2 PROBLEM STATEMENT

Literature reveals that visualization is not a simple process of observing an object. It is, however, a process that involves active construction of meaning where promoters of visual literacy state that if perception involves active construction then the act of interpreting what is seen requires a critical observer (Purves & Lotto, 2003).

The problem in the past years in Life Sciences curricula was that learners experienced learning difficulties when dealing with ERs used to teach a certain phenomenon. They experienced difficulties to link 2D diagrams with 3D in reality and most commonly failed to relate ERs in assessment papers to the ones used in their textbooks. They also encountered difficulty in realizing that ERs were only an exemplary that represented reality, and not reality. However, such learning difficulties were somewhat side-lined as explicit teaching of visual literacy was not the main focus because teachers failed to address the strong points and limitations of ERs (Schönborn & Anderson, 2009).

In addition there is also a problem of the influence of gender on the level of visual literacy and spatial abilities of learners in Life Sciences curricula. Literature reveals that females' performance is inferior to that of males in mathematics, science education and spatial ability skills (Piraksa, Srisawasdi & Koul, 2014). This may result from a difference in spatial visualisation skills. This difference is due to a structure of the brain called the parietal lobe that is known to differ between males and females. The parietal lobe controls the spatial visualisation skills like mental rotation and it is found that females perform these tasks slower than males, hence the difference in performance (Koscik, O'Leary, Moser, Andreasen & Nopoulos, 2009). Furthermore, the environment in which the schools are located may be associated with the learners' performance in visual literacy and spatial ability tests. According to Acar, Büber and Tola (2015) learners from schools in high socio-economic environments outperform learners from schools in low socio-economic environments.

The potential difficulties learners experience in learning, communicating and thinking visually, that is, being able to select and effectively use a set of cognitive skills for perceiving, processing and expressing ERs in response to scientific knowledge, may be due to a lack of visualization skills, differences in spatial visualisation skills due to gender and the environments in which the schools are located. Therefore, the aim of the study was to explore the visual literacy of Grade 10 Life Sciences learners and the influence of gender and school location on the visual literacy and spatial ability skills of the learners. This was done in order to inform the researcher of the level of visual literacy Grade 10 Life Sciences learners possess and what need may exist for visual literacy development. The study suggested possible guidelines to enhance and promote pedagogy using ERs, to develop learners' skills needed to create mental images and minimize challenges that could inhibit creating such mental images, so that learners are empowered to effectively learn, think and communicate visually.

However, constraints such as the lack of research done regarding the use of ERs in Life Sciences, visual literacy, visualization skills, lack of teaching strategies and resources to teach visual literacy and the ever changing technology are limiting factors to address the difficulties learners experience when dealing with ERs (Mnguni, 2014). The proposed guidelines to improve learners' visual literacy skills are believed to address the difficulties that affect the visual learning, visual thinking and visual communicating of the learners. The assessment in the present study was done by conducting a visual literacy assessment questionnaire for Grade 10 Life Sciences learners to determine their levels of visual literacy. Then their performances in Life Sciences were collected to stipulate how they responded to questions that have ERs.

1.3 AIMS OF THE STUDY

There are a vast number of visual literacy skills a learner needs to understand Life Sciences concepts. For example visualization (visual thinking), perception, observation and conceptualization are some of the essential skills needed to understand Life Sciences concepts. The relationship between these mentioned skills is that one has to be able to observe (see or notice different visualization tools), perceive (interpret what is seen), visualize the visual mode in another form not presented to the eye, and lastly form concepts about the visual mode and interpret them in a conceptual way. It is a systematic process needed to interpret and understand ERs. The levels of visual literacy form part of a theory in which the author proposes to stipulate different levels of visual literacy. The table of cognitive complexity (Appendix A) is adapted from (Mnguni, 2014) and Blooms taxonomy cognitive levels and tasks where the author explains the process of visualization and levels of visualization. According to Mnguni (2014) visual mode is a representation of a phenomenon that cannot be seen in reality due to size and magnitude, while mental visual mode is a picture or image, formed mentally, of a specific phenomenon not presented to the eye. External visual mode is the construction of an external visual model through the expression of cognitive representation while internal visual mode is the process where sensory organs collaborate with the intellectual capacity to interpret data from the external environment.

Most biological concepts are very difficult to understand if they are limited to abstract concepts (text only). An intervention of converting such critical abstract concepts to concrete ones to enhance understanding must be implemented. Therefore, ERs like models, drawings, graphs, photos, illustrations, diagrams and so forth are usually used to assist learners to understand and be able to apply knowledge acquired in Life Sciences.

The Life Sciences curriculum does not necessarily call for teachers to explicitly develop visual literacy within its context, therefore, teachers end up assuming that the learners know what the visuals represent, failing to bridge the gap of knowledge between them and learners. It is as if they automatically think learners know and are able to associate the content with the ERs by osmosis. However, images are essential to our daily lives and it is time they become fundamental in a curriculum (Elkins, 2008, p.8).

This study serves to encourage teachers to explicitly develop learners' visual literacy skills and notify teachers of the negligence occurring in our learning environment that fails to allow learners to perform at their utter most best. The study focused specifically on Grade 10 learners because Grade 10 is a level where the learners choose their subjects based on their future career plans and most importantly it is a grade where Life Sciences is very distinctive and detailed. Therefore, the findings of the study aim to provide insights regarding the specific skills and knowledge related to visual literacy that should develop and provide awareness of the significance of visual literacy in Life Sciences and other related subjects.

1.4 PURPOSE OF THE STUDY

The motive of this study was to explore the visual literacy of Grade 10 life Sciences learners in cytology. To attain this, the researcher theorised that ERs needs to be integrated in the Life Sciences curricula to develop learners' visual literacy and spatial ability skills. Given this theory, the specific aims of this study are mentioned below:

- To explore the visual literacy in Grade 10 Life Sciences learners.
- To explore an influence of gender on the visual literacy and spatial ability skills of the learners.
- To explore the correlation between the location of the schools and the learners level of visual literacy.

1.5 RESEARCH QUESTIONS UNDER INVESTIGATION

Primary research question

What is the visual literacy of Grade 10 Life Sciences learners in cytology?

Secondary research questions

a) What is the difference between the visual literacy of males and females in cytology?
b) What is the correlation between school location and the learners' level of visual literacy?

1.6 HYPOTHESES

A hypothesis is a tentative, testable answer to a scientific question. It is a theory that is made on the basis of reasoning without assuming the truth and it is tested through a study (Merriam-Webster, 2004). In this study the following hypotheses were generated based on the research questions:

Table 1.1: Hypotheses generated based on research questions

Research question	Null hypothesis	Alternative hypothesis
What is the visual literacy of Grade 10 Life Sciences learners in cytology?	The mean score of the Life Sciences visual literacy test is not statistically significantly different to the mean score of the spatial ability test.	The mean score of the Life Sciences visual literacy test is significantly different to the average scores of the spatial ability test.
What is the difference between the visual literacy of males and females in cytology?	The mean score of males is not statistically significantly different to the mean score of females in the Life Sciences visual literacy test.	The mean score of males is statistically significantly different to the mean score of females in the Life Sciences visual literacy test.
	The mean score of males is not significantly different to the mean score of females in the spatial ability test.	The mean score of males is significantly different to the mean score of females in the spatial ability test.
How does the school location of learners influence their level of visual literacy?	The mean score of the urban, township and rural school locations in the Life Sciences visual literacy test is not statistically significantly different to each other.	The mean score of the urban, township and rural school locations in the Life Sciences visual literacy test is statistically significantly different to each other.
	The mean score of the urban, township and rural school locations in the spatial ability test is not statistically significantly different to each other.	The mean score of the urban, township and rural school locations in the spatial ability test is statistically significantly different to each other.

1.7 KEY THEORETICAL CONCEPTS

The definitions provided below are to ensure uniform understanding of these terms throughout the study.

Visualization skills: Set of abilities used to successfully encode and decode messages presented by external representations and learn from them (Mnguni, 2007).

Visual literacy: The ability to select and effectively use a set of cognitive skills for perceiving, processing and expressing ERs in response to scientific knowledge (Mayer, 2003).

Life Sciences: The study of biotic organisms from the level molecules to their ecology (interrelations between organisms and their environment) (CAPS, 2011).

Cognition: The process by which inputs from sense organs are transformed, condensed, explained, stored, recovered and used (Schönborn & Anderson, 2006).

Conceptualize: The ability to make meaning of a given concept (Schönborn & Anderson, 2006).

Perception: The ability to identify, organise and interpret using sensory information in order to represent and understand the environment around you (ability to interpret what is seen) (Schönborn & Anderson, 2006).

Visualization: The ability to mentally generate visual images of objects that are not present to the eye (Schönborn & Anderson, 2006).

Spatial ability: The ability to identify, organise, interpret or solve problems that are related to relationships between objects. Relationships may be about position, direction and size (Schönborn & Anderson, 2006).

Visuospatial: Relating to denoting the visual perception of the spatial relationship of objects (Schönborn & Anderson, 2006).

1.8 VALUE OF RESEARCH

The research aimed to explore the visual literacy of Grade 10 Life Sciences learners in cytology, that is, the visual and spatial skills learners possess and need to successfully work with different ERs. Therefore, this study explored the ERs learners prefer to better understand cytology. It also indicated the impact of teachers' choice on ERs used to teach certain phenomena and the learners' response to ERs.

1.9 OUTLINE OF THE DISSERTATION

To present a well-structured research report in which the content flows in a chronological manner and the research objectives and problems are addressed, the chapters are outlined as follows:

Chapter 1: General orientation

This chapter has outlined a perspective of this study, its purpose and objectives. A background has been provided along with a brief background of the problem statement that is related to the study, the research questions, the rationale and assumptions that were made.

Chapter 2: Review of related literature

This chapter focuses on the important aspects of reviewing literature. It will provide the conceptual framework that describes the significance of visual literacy in Life Sciences and create effectiveness of developing visual literacy and spatial ability skills of learners.

Chapter 3: Research method

This chapter outlines the research design and elaborate on the research methodology used for sampling strategy, data collection method, instruments and analysis methods engaged in the study.

Chapter 4: Data presentation, analysis and discussion

The fundamentals of this chapter are to present the results and statistical analysis processes of the collected data.

Chapter 5: Summary, recommendations and conclusions

This chapter provides a summary of the study, where the conclusions and the future recommendations are given. It indicates the limitations encountered during the study and the possibilities for future research.

The next chapter presents the literature that is relevant to the study and the conceptual framework that guided this study.

CHAPTER 2: REVIEW OF RELATED LITERATURE

“If people are not taught the language of sound and images, shouldn’t they be considered illiterate as if they left college without being able to read and write?”

- Unknown

2.1 INTRODUCTION

A review of literature is conducted to create an image of what has been researched about a particular phenomenon and share with readers the findings of the other studies related to the study being reported (Creswell, 2008).The literature review provides the theoretical framework that describes the significance of visual literacy in Life Sciences and creates effective responses to assessments incorporated with ERs in learners.

The 21st century is facing a transition with the explosion in technology in the usage of images where external ERs are broadly used for communication, including scientific journals and textbooks (McTigue & Flowers, 2011). At a scholarly level an effective learner, to fully function in this image rich world, must be able to efficiently communicate verbally, visually, in texting and in a second language (Oblinger, Oblinger & Lippincott, 2005). As part of this transition, we as science teachers expect learners to be able to work with ERs that illustrate biological phenomena and have visual and spatial ability skills to scientifically reason and interpret scientific information. We also desire that learners should have skills in scientific reasoning such as drawing conclusions from data, integrating conclusions with prior knowledge and applying the knowledge to other science problems. Such expectancy fosters learners to develop a number of learning capabilities so that they may productively function in a technology centred education system. These capabilities include enhancement of the 21st century skills, content literacy, academic communication literacy, scientific literacy, visual literacy and scientific visualization. Visual literacy is one of the most crucial capabilities in Life Sciences because phenomena (e.g. Cytology) and processes (e.g. cell division) exist at complex microbiological levels which cannot be perceived with an un-aided eye (Mnguni, 2007).

ERs such as videos and physical models are then utilised to convey these phenomena and processes at larger scale to assist learners to build up content knowledge (Dori & Barak, 2001). However, Schönborn and Anderson (2006) contend that learners and teachers need to develop visual literacy skills in order to effectively work with ERs. Regardless of the range of possibly confusing ERs used in Life Sciences, their significance in science literature is well documented. Literature reviewed indicated that not a lot of research has been conducted on the role of ERs in Life Science instruction. Therefore, this results in a lack of research being done to investigate if there is any significance of using ERs to develop visual literacy in Life Sciences curricula. The failure to question the importance of using ERs to convey meaning is because experts' (teachers', authors' and researchers') assumptions on the learning and teaching material they chose to use in Life Sciences is that they would necessarily be good for developing visual literacy and understanding of concepts amongst learners.

The assumptions mentioned above are resonated by McTigue and Flowers (2011), namely, that learners' preferences on accessible ERs e.g. illustrations such as drawings and diagrams and experts' choices on grade-level diagrams are not well aligned. This study explores the visual literacy abilities of Grade 10 Life Sciences learners, the difference between visual literacy level amongst males and females and the influence of the schools' locations on learners' visual literacy development. The research question framing this is: "What is the visual literacy of Grade 10 Life Sciences learners in cytology", therefore, this literature review will give an indication of the following aspects:

i) What is visual literacy?
ii) The role of visual literacy skills in Life Sciences curricula.
iii) Can visual literacy skills be improved and how?
iv) Implications of explicitly teaching visual literacy.

The following sections provide a detailed account with respect to the above areas.

2.2 WHAT IS VISUAL LITERACY?

In order to develop visualization skills it is important for teachers and learners to understand what visual literacy is. The literature has raised a number of issues concerning definition of visual literacy. One issue surrounds defining, as well as measuring visual literacy. Definition of the concept 'visual literacy' is a multifarious matter. This perplexity is created due to literature not containing a single accepted definition of visual literacy thus causing and emphasizing the eclectic nature of it (Buckley, 2000). Debes (1969) demarcated visual literacy as a collection of visual skills a person can cultivate by seeing and simultaneously integrating other sensory experiences. Conversely numerous scholars define visual literacy from a generic perspective in relation to different forms of ERs. Valcke (2002) focuses on extraction of information from ERs; Buckley (2000) focuses on mental processing while Burton (2004) focuses on the production of ERs. Regarding current definitions for visual literacy, most are yet to be confirmed and agreed on by way of international unanimity.

Seels (1994) defines visual literacy as the ability to conduct visual thinking, visual learning and visual communication. Visual thinking according to Kovalik and King (2011) refers to the ability of a person to communicate their views and ideas using colour and pictorials. Visual communication is using visual cues to express ideas and convey meaning (Seels, 1994, p.108). Then, visual learning refers to the construction of knowledge through interaction with visual representations (Seels, 1994, p.107). Seels also offers four possibilities for depicting the relationships between these as shown in Figures 2.1 - 2.3. Figure 2.1 offers a hierarchical structure of subcategories while Figure 2.2 shows what Seels positions as a more “holistic” conceptualization (Seels, 1994, p.104). Figure 2.3 points to the internal and external processes involved in visual literacy.

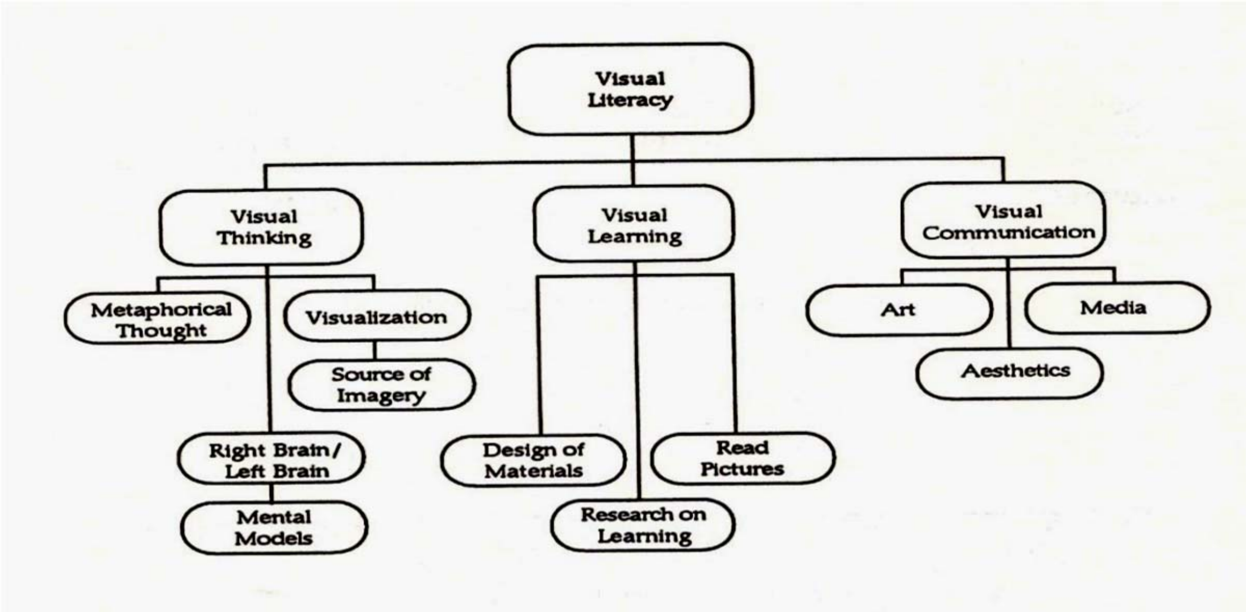

Figure 2.1: Relationship of areas of study in visual literacy (Seels, 1994, p. 105)

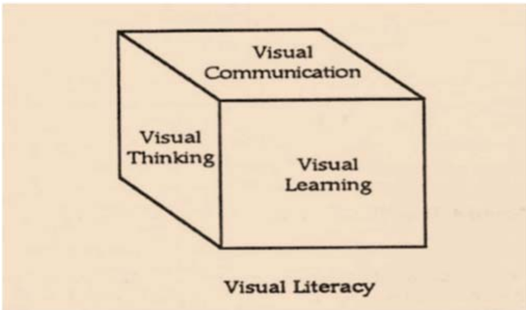

Figure 2.2: The visual literacy cube (Seels, 1994, p. 105)

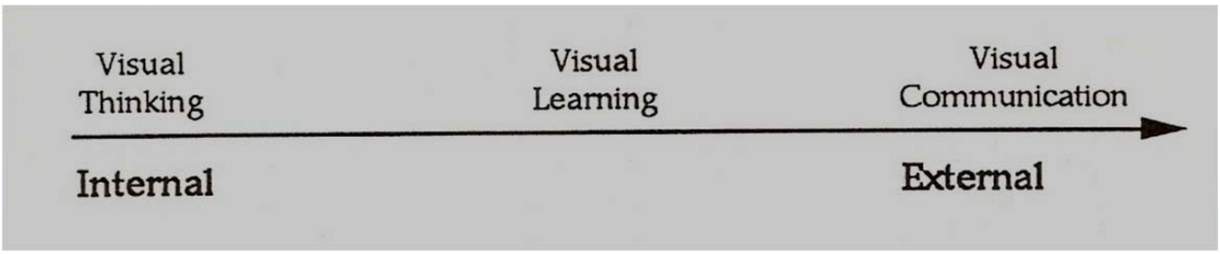

Figure 2.3: The visual literacy continuum (Seels, 1994, p. 106)

2.3 THE ROLE OF VISUAL LITERACY SKILLS IN LIFE SCIENCE CURRICULA

A very high percentage of all sensory learning is visual (Cook, 2006). Science culture is increasingly dependent on ERs to present phenomena that is not tangible and cannot be seen by the naked eye due to size and magnitude as well as trying to communicate knowledge and discovery generated from experimental research. How learners interact and interpret scientific ERs to successfully construct meaning is essential in undergraduate science education because if learners cannot accurately decode visual representations they would struggle with 40% of the content in assessment tasks. Therefore incorporating both pictures and text in learning can increase students learning outcomes (McTigue & Flowers, 2011).

According to Schönborn and Anderson (2009) the role of visual literacy skills in the Life Sciences curricula is to be able to read (decode and encode), create own ERs (draw) and communicate visually (understanding, interpreting and expressing of information using images). However, the curriculum does not call for explicitly developing visual literacy skills to learners which will empower them to effectively work with ERs i.e. explain symbols or interpret diagrams. Unlike cognitive skills (e.g. thinking, reasoning, creativity, synthesis) visual literacy skills are not habitually acquired during the process of teaching and learning using ERs, they have to be explicitly addressed. ERs have the impact of stimulating long attention span and uphold motivation. They have a way of representing information in a manner so that knowledge is more effectively gained and stored than when information is represented as text. More specifically, ERs enhance retention of information, improves problem solving and assist with assimilation of new and prior knowledge (Cook, 2006).

Schönborn and Anderson (2006) shows that for most learners to improve their visualization skills, they have to be exposed to different ERs that will stimulate their visual literacy. Cook (2006) specifies that to understand the significance of ERs in science teaching and learning, one should not only take into consideration the way they are designed, but also consider the manner in which different learners will interpret them. Since learners learn differently, they may have more learning difficulties in understanding or interpreting ERs than initially assumed. For argument sake, a concept map may be designed to be a useful ER to illustrate the association between a plant and an animal cell; however, if a learner cannot understand and interpret the concept map in order to gain knowledge on the association between a plant and an animal cell, then the concept map may turn out to be functionally useless.

Cognitive load theory has a principle of balancing text with pictures to enhance learning. However; this design principle is not usually applicable because of different learning styles learners have. Learners do not enter a classroom as an empty vessel but, rather, they contain prior knowledge. Prior knowledge can help or hinder learning; therefore it is important in determining the impact of that and of the ERs on learners' learning abilities. Schönborn and Anderson (2006) have identified factors that may affect learners' ability to interpret ERs. These factors are reasoning ability, understanding of the concepts related to the ER and the nature of the mode in which the anticipated phenomenon was represented. The factors are based on a Venn diagram representing a model of seven factors that determine learners' ability to interpret ERs (Figure 2.4).

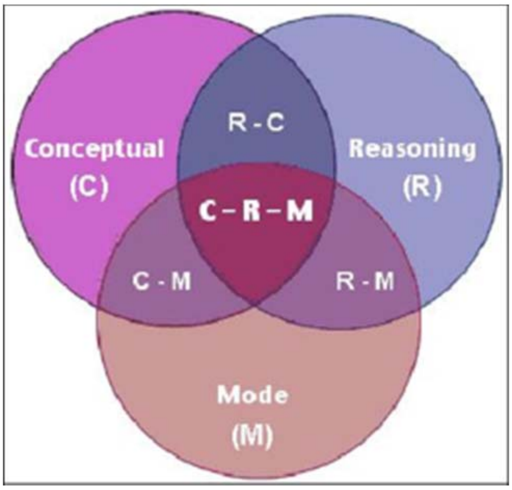

Figure 2.4: A Venn diagram representing factors that affect learners' ability to interpret ERs (Schönborn, 2005).

The Conceptual knowledge (C) factor represents the learners' prior knowledge of all the concepts that are represented by the ER, before exposure to the ER. The Mode (M) factor represents the nature of the ER and how well or poorly its features represent the concept, structure or processes it is designed to represent. Lastly the Reasoning (R) factor represents the total reasoning capacity the learner contains for interpreting the ER. The difficulty comes in where the learner has to successfully engage all factors when learning using ERs. This difficulty may result in learners not being able to:

- To link 2D drawings with 3D reality.
- Realize that diagrams are only a model, and do not represent reality.
- Relate diagrams in exams papers to how they are represented in their textbooks.
- Relate different ERs to what is shown in their textbooks.
- Understand scale and magnification.
- See colour as a salient feature.

These difficulties learners experience leads to consequences of poor learner performance in assessment tasks, therefore an intervention is needed to improve visual literacy and interpretation of biological diagrams (Salters-Nuffield Advanced Life Sciences, n.d.).

The researcher submitted a questionnaire to South African Grade 10 learners on the significance of visual literacy in Life Sciences education for an honours project. The results revealed that most teachers and learners use textbooks and exercise books to teach and study Life Sciences and there is less use of other ERs. These arguments manifest that visual literacy is not promoted in our classes. These practices of teaching and learning may cause cognitive overload in a learner.

According to Cook (2006) cognitive load theory provides a theoretical foundation for designing instructional materials to best enhance learning. The basic premise of this theory is that learning will be hindered if the instructional materials overwhelm learners' cognitive resources. According to this theory, the hindrance placed on working memory can be reduced by either increasing its capacity or reducing its cognitive load. Working memory has two components, a visuospatial sketchpad and a phonological loop, that initially process visual and verbal information independently. Therefore, combining text with ERs for teaching can increase capacity of working memory and enhance learning (Chandler & Sweller, 1992).

2.4 CAN VISUAL LITERACY SKILLS BE IMPROVED AND HOW?

To improve the visualization skills of learners, schools have to reduce placing the primary emphasis on textual literacy and scientific literacy. Rather emphasis should be on textual, scientific and visual literacy to empower learners (Luke, 2003). This stipulates that it is time visual literacy plays a significant role in the Life Sciences curriculum and teachers should be urged to explicitly teach learners visual literacy to help them interpret existing visual material, as well as guidelines in presenting visual material, so that learners' interpretation is as hoped. Schönborn and Anderson (2009) has identified ten fundamental guidelines for teaching and learning with visualization tools that arose in his thinking about the pedagogical implications of visualization in the Life Sciences curriculum. The formulated guidelines are approaches that could promote teaching and learning of visual literacy and its incorporation in Life Sciences curricula and eradication of learner difficulties with visualization tools and visualization skills.

PAUSE AND WONDER….

Where in our current South African curriculum are learners explicitly taught visual literacy skills?

Guidelines to improve learners' visual literacy skills:

• *Becoming aware of current theories on how individuals learn from, and visualize external representations*.

According to Montessori (1946) the dominance of theories on how people are thought to learn science is that of constructivism. The theory stipulates that knowledge and images cannot be transferred passively from the educator into learners' brains in an intact form as an identical copy. Based on the cognitive theory of multimedia learning and the theory of constructivism the author suggests that visual literacy in Life Sciences should be defined as the ability to select and effectively use a set of cognitive skills for perceiving, processing and expressing external representations in response to scientific knowledge in Life Sciences. Therefore, visualization can be divided into four stages; namely, visual perception, visual imagery, integration and expression of visual models as a means of expression. Visual perception refers to the process where the eye and brain work together to take in information about the outside world, whereas Visual imagery is the process of creating meaning from perceived visuals (Burton, 2004). The theory of multimedia learning and constructivism indicate that the important factors influencing learning is what the learner already knows and being mentally engaged in an active visualization process. This involves tasks such as group work to actively interpret an animation and critique its strengths and limitations with respect to its effectiveness in representing a particular phenomenon or concept.

• *Address the key factors affecting learners' ability to visualize external representations.*

In order to address the key factors affecting learners' ability to visualize external representations, one has to identify them first then incorporate them in the lesson plans dealing with visual literacy. Factors include learners' general reasoning ability to interpret external representation, to read and make sense of external representation, to select and retrieve conceptual knowledge of relevance to the ERs, the nature of the mode in which the desired phenomenon is represented by the ER and the learners' understanding (or lack of) of the conceptual knowledge represented by the ER. Other factors that affect learners' visual interpretation are the salient characteristics on the external representation which obscure learners' focus. These factors are prerequisites for sound visualization and interpretation of ERs and should be properly addressed to enhance the visual literacy of our learners' (Schönborn & Anderson, 2009). To address these factors the teacher should aim tasks at developing reasoning skills with either the external representation or with learners' own conceptual knowledge. To avoid misconception of the external representation, teachers should design tasks that require students to identify and explain the meaning of external representation. That is, explain which part of the external representation represents which phenomena and what it means. These kinds of tasks will unconsciously induce development of learners' conceptual knowledge of the content at hand. Therefore, challenging learners and giving them complex tasks to abstractly use their brains to revert, enlarge or downscale external representations and boost their visualization skills to analyse and interpret external representations.

• *Make the conceptual knowledge depicted by external representations explicit to learners.*

When teaching a Life Sciences topic (e.g. electron chain transfer), and making use of external representations, it is vital for the educator to follow the same approach used with other lessons. This should be done for lessons without external representations, and should explain and clarify for learners what particular conceptual knowledge the external representation does and does not represent (Schönborn & Anderson, 2009). Therefore, the educator should explain the purpose of the external representation and the conceptual understanding that it implies. This will limit confusion and correct any incorrect conceptual knowledge assumptions related to the visualisation tool.

• *Impart knowledge of the visual language and conventions used by external representations.*

Life Sciences curricula are bombarded with terminologies that are represented using symbols, diagrams and so forth, therefore teachers should explicitly teach the learners these representations so that they could gain the necessary visual vocabulary and external representation processing skills (Schönborn & Anderson 2009).

• *Make learners aware of the limitations of each external representation.*

It is important for both teachers and learners to consciously analyse, critique and discuss each scientific external representation used during the lessons by identifying what conceptual knowledge the external representation represents but also ascertain the limitations of the external representation in terms of what it is not representing. Help learners realize that representations are not an exact copy of reality but a partial representation of how the phenomenon looks in real life. It is important to give learners tasks with external representations that make them realize that external representations are just limited models of a particular phenomenon, which can vary in their usefulness for promoting learning and understanding.

• *Empower learners with the necessary skills needed to process biological external representations.*

Literature has shown that there is a lack of attention directed at explicitly training learners to process external representations. A learner should know how to read, which is an abstract visualization skill itself, and needs to be mastered. Therefore, teachers should encourage learners to adopt a strategic approach to visualization processing since evidence suggests that in some cases, different skills are required to interpret different types of external representations (O'Neil, 2011). For example a visualization portraying quaternary protein structure requires three-dimensional visualization skills, whereas an external representation that depicts an upside down diagram requires 'image reverting' skills. Thus, to develop such skills learners should be exposed to simpler representations then ascend to more complex ones that represent the same phenomenon. This will help them develop such skills and get them to perform a multitude of tasks with external representations requiring a wide range of processing skills.

2.5 IMPLICATIONS OF EXPLICITLY TEACHING VISUAL LITERACY

According to Pavlinic, in Schönborn and Anderson (2006), visualization skills can be strengthened by allowing learners to generate their own diagrams as this is a powerful tool for improving scientific visual literacy. The diagrams may be concept maps or flow charts which will enable them to structure, organize and compare concepts graphically. The planning, organizing and comparing of skills unconsciously strengthens their processing skills of other abstract external representations and stimulates their metacognitive thinking skills.

Given the complex nature of visual literacy as discussed above, the study concur with Metros and Woolsey (2006) who argue that there needs to be a conscious and systematic integration of visual literacy into curricula. Their views are echoed by Schönborn and Anderson (2006) who indicate that students must be explicitly taught visual literacy instead of relying on an osmotic random process of acquiring it serendipitously. While much research has been done to explore the nature of visual literacy, the researcher believes that the significance and extent to which visual literacy is integrated into curricula needs further investigation. Such research would firstly establish empirically the extent to which visual literacy is integrated into Life Sciences curricula, including assessment. This will give an indication as to whether arguments for an explicit integration of visual literacy into curricula are worth considering.

Schönborn and Anderson (2006) demonstrate the significance of visual literacy in biochemistry. They state that biochemical phenomena taught to students appear within the macroscopic, microscopic and sub microscopic levels of organization. Students are then expected to construct and produce knowledge by functioning effectively within each of these levels of organization. To facilitate this process, scholars have developed an array of a visual vocabulary, symbolism and visual models with varying aesthetic features (e.g. colour and shape) appearance and levels of abstraction over the years.

Some of these abstracts are more stylized than others, and differ in the realistic appearance. The mode of representation also differs with some models appearing at two-dimensional and three-dimensional static, dynamic and multimedia modes. This complicated nature of visual modelling in biochemistry demonstrates the significance of visual literacy.

While Schönborn's and Anderson's (2006) views are generally accepted within tertiary education, one wonders about the nature of visual models in high school Life Sciences, which is the foundation of all fields of Life Sciences. The researcher therefore believes that it is imperative to characterize the nature of visual literacy in the high school Life Sciences, in order to inform the formal integration of visual literacy into curricula.

The pedagogical importance of visual literacy and visualization education has been side lined for some time now. Given the diversity and confusing nature of visualization tools used in Life Sciences to convey meaning and understanding and the related visualization and conceptual difficulties identified by research done, learners require a high level of visual literacy to successfully respond to assessment task in Life Sciences. The above mentioned guidelines support the motive behind the question of the significance of visual literacy in education of Life Sciences learners and how visual literacy has become an issue for advanced Life Sciences with the rapid changing technology.

2.6 THEORIES OF LEARNING AND THE ACQUISITION OF VISUAL LITERACY

This study looks at visual literacy from an academic perspective which entails the cognitive abilities which learners need in order to function efficiently within an academic setting, particularly in Life Sciences. Metros and Woolsey (2006) highlight that learners need multimodal fluency with skills to decode and encode visual images that represent scientific phenomena. Visual literacy therefore is proposed to be the ability to select and effectively use a set of cognitive skills for perceiving, processing and expressing external representations in response to scientific knowledge in Life Sciences. This definition is based on Mayer's (2003) cognitive theory of multimedia learning.

According to Mayer (2003) visualization is a cognitive process that involves a number of mental processes as explained in the cognitive theory of multimedia learning. According to this theory, external pictures first enter the cognitive system through the eyes during the visualization process. The learner then attends to some aspects of the visual model which leads to the construction of a mental pictorial image within the working memory. Following subsequent construction of mental images, the learner arranges the set of images into a coherent mental representation called a pictorial model (Figure 2.5). The process involves the selection, organization and integration of images and is commonly referred to as visuospatial thinking (Mayer, 2003). In other words, learning from ERs consists of a number of cognitive processes. When the learning process takes place, the ERs with objects that stimulate different senses, in this case ERs with pictures and or words, firstly register in the cognitive system through the eyes and ears. Then the learner engages in relevant cognitive processing, for instance, attending to relevant materials of the external visualization, mentally organizing the material into coherent cognitive representations in the working memory and lastly the mental integration of the material with prior knowledge in the long term memory (Mnguni, 2014).

Mayer's (2003) cognitive theory of multimedia learning is related to a constructivist epistemology of learning. According to constructivism, learners actively develop their own understanding of the world, rather than having such understanding delivered to them. Such an outlook requires learners to be active participants in the visualization process, rather than merely absorbing the information presented to them in its entirety. Learners construct concepts from prior knowledge. However, prior knowledge not only influences subsequent conceptual learning, but also influences perception and attention. Therefore, variations in how learners interpret visual representations are also largely due to their existing knowledge. Learners use prior knowledge to select relevant information from graphics, add information to that knowledge, and ultimately, develop a mental model (Mnguni, 2014). It is important to note that during cognitive processing of information, learners tend to select salient characteristics (e.g. colour) which are easiest to comprehend and manage mentally, as important (Cook, 2006).

Information-processing theories assume that learners have a restricted working memory, and when overloaded, learning will not take place. Primarily, it is the prior knowledge of the learner that determines how much information can be held simultaneously in working memory.

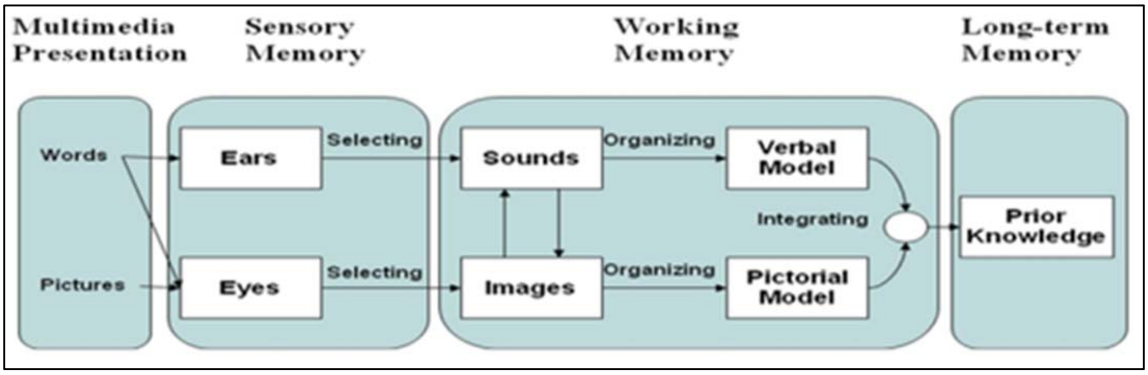

Figure 2.5: An illustration of the cognitive theory of multimedia learning (adapted from Mayer, 2003)

One particular information-processing theory in which prior knowledge can easily be integrated into its conceptual framework is the cognitive load theory. Cognitive load theory provides a theoretical foundation for designing instructional materials to best enhance learning. The basic premise of this theory is that learning will be hindered if the instructional materials overwhelm a learner's cognitive resources. It is based on a cognitive architecture, consisting of a limited working memory that interacts with an unlimited long-term memory (Cook, 2006). According to this theory, working memory has two components, a visuospatial sketchpad and a phonological loop, that initially process visual and verbal information independently. The components work independently and information load might overwhelm one of these processing systems hence the information overload may be managed by dividing the information across these two systems. Therefore, using more than one presentation modality can increase the capacity of working memory (Kirschner, 2002).

Instructional presentations, which are of the form of, say, text / audio, and have the benefit of both visual and verbal modalities, are more valuable than presentations that rely on either verbal or visual information only. The facilitation of visual representations on learning from text can be explained through dual coding theory. According to dual coding theory, visual and verbal information are processed in independent subsystems of working memory (Cook, 2006). The visuospatial sketchpad takes the visual input and ultimately creates a visual mental model; the phonological loop takes the verbal input and ultimately creates a verbal mental model. The two different kinds of mental models are finally mapped onto each other (Mayer, 2003). By using the capacity of both systems, more information can be processed than would otherwise be possible with only one of those systems. Therefore, learning from text with visual representations will be richer than learning from text alone or visual representations alone.

The theoretical framework suitable for this study is the cognitive theory of multimedia learning. The suitability is enhanced by how learning is active when information is presented in both pictures and words, enabling learners to integrate acquired knowledge with existing knowledge; it is the prior knowledge of the learner that determines how much information can be held simultaneously in working memory.

2.7 SUMMARY AND CONCLUSION

According to literature above, it is clear that there is a need to practise beyond measure and find strategies to develop visual literacy in Life Sciences curricula, through designed instruction and activities that will inform learners of the nature and modes of visualizations used in Life Sciences education aimed at developing their knowledge and skills for envisaging external representations. Therefore in conclusion, these calls for development of visual literacy in Life Sciences education will help our learners acquire skills that will help them interpret visualizations as hoped and convey meaning and understanding to be able to respond positively and successfully to assessment tasks.

Such skills can be used in everyday life and in future as in this century: pictures, images, diagrams and other visualizations are used for learning, communication, understanding and conveying meaning in social networks. The next chapter will outline the research design that was followed in this study.

CHAPTER 3: RESEARCH METHODOLOGY

The illiterate of 21st century will not be those who cannot read and write but those who cannot think, communicate and learn visually
- T. Taukobong

3.1 INTRODUCTION

This chapter focuses on the nature of the research and an account is given of the methods used in carrying out the study and the research design. The chapter presents the population under consideration, the sampling techniques engaged, data collection procedures, instruments and analysis techniques used in the study. The purpose for conducting this research was to explore the visual literacy of Grade 10 Life Sciences learners in cytology. The main research question for this study was:

- ✓ What is the visual literacy of Grade 10 Life Sciences learners in cytology?

Other research questions that guided this study were:

- ✓ What is the difference between the visual literacy of males and females in cytology?
- ✓ What is the correlation between school location and the learners' level of visual literacy?

3.2 RESEARCH APPROACH AND DESIGN

This study used a quantitative research method. A quantitative approach refers to the research methods where findings are observed through the use of statistical means of quantifying information (Field, 2014). Quantitative research is an objective and systematic process which is used to describe and test relationships between variables. In the quantitative approach a survey may be used for descriptive, explanatory or exploratory research (Creswell, 2013). An exploratory survey was used. A survey is used to collect data for describing a population from a sample of people by means of people responding to a set of questions posed by the investigator (Creswell, 2013). In this study data was collected through questionnaires distributed personally to the learners by the researcher.

The researcher used an exploratory survey because it provides an accurate portrayal or account of the characteristics, for example opinions, abilities and knowledge of a particular individual (Creswell, 2013). This design was selected to meet the objectives of the study, namely to explore the visual literacy of Grade 10 Life Sciences learners in cytology.

3.3 POPULATION AND SAMPLE

Population

Population is defined as all elements (individuals, objects and events) that meet the sample criteria for inclusion in a study (Merriam-Webster, 2004). The study population consisted of Grade 10 learners taking Life Sciences as a subject in Pretoria, Gauteng.

Sample

The research methodology involved a convenient sample of 225 Grade 10 learners who took Life Sciences as a subject. The researcher used convenience sampling to select six schools around Pretoria, Gauteng, where each school consists of one or two classes that take Life Sciences as one of their school subjects (refer to Table 3.1). A convenient sampling was used because the researcher resides in Pretoria which makes schools easily and conveniently available. Then the researcher stratified the schools to gain access to a presentation of schools that were chosen and to ensure a high degree of representatives of all the strata.

The sampling criteria

The selection of the schools for the study was based on the following aspects:

- Schools' locations (urbanized, township or rural location).
- The socio-economic environments of these locations and schools. A high socio-economic status in this study refers to a well-resourced school located in a suburb mostly identified as a "historically module C school" while a middle socio-economic status refers to a school surrounded by media centres, facilities and resources. A low socio-economic status would refer to a school that is located in a township, with very limited resources and limited access to resources and facilities.
- Classes were randomly selected.

Table 3.1: Schools' location and their socio-economic environments

School	Location	Socio-economic environment
School A	Arcadia (Urbanised)	High
School B	Pretoria Central (Urbanised)	Middle
School C	Soshanguve (Township)	Low
School D	Laudium (Urbanised)	Middle
School E	Hatfield (Urbanised)	High
School F	Olievenhoutbosch (Rural)	Low

Unit of analysis

Unit of analysis is the 'what' or 'who' that is studied. Therefore, it is the major entity that is analysed in the study. In this study the unit of analyses was visual literacy of the participants and the ability to apply it.

3.4 DATA COLLECTION INSTRUMENTS

Two instruments were subsequently used to empirically collect data. The visual literacy questionnaire was constructed and piloted by the researcher. The visual literacy questionnaire consisted of two sections of which the first section (refer to Appendix B) was based on the respondents learning background and study orientations. The second section investigated the Life Sciences visual literacy in cytology. The second instrument, a visual spatial ability test adopted from Newton and Bristol (2009) was based on visual recognition which measured the spatial abilities of learners (refer to Appendix C).

Section B of the Life Sciences visual literacy questionnaire was composed of seven structured-open questions that required respondents to apply skills and knowledge acquired in Life Sciences classes on cytology and cellular processes. The respondents had to compare and relate diagrams and schematic representations, interpret and perceive colours, detect patterns, discriminate, complete diagrams cognitively, perform mental rotation, predict, analyse and solve schematic and diagrammatic representations, illustrate, sketch, draw ground perception and depth perception, analyse, find and imagine.

3.5 DATA COLLECTION AND DOCUMENTATION

As mentioned above, two instruments were subsequently used to empirically collect data in this study. These instruments were utilized due to their effect of minimal interaction between respondents and the researcher, therefore allowing respondents freedom of expression (Creswell, 2013). The instruments focused on assessing the learners' level of visual literacy, the relationship between the performances and schools' locations, and the relationship between gender and learner performances. The researcher administered the instruments which took learners at least 60 minutes to complete.

A pilot study is a small scale research carried out prior to embarking on the full-scale research investigation to explore grey areas that need more development and refinement (Thapliyal, Shukla, Kumar, Upadhyay & Jain, 2005). They further state that the purpose of a pilot study is to detect possible errors in the measurement of procedure and to identify vaguely formulated questions.

According to Saunders, Lewis and Thornhill (2003) a pilot study can be done on a minimum number of 10 people who possess similar abilities and background to the targeted population. This is for assessment of the validity of the questions and the reliability of the data to be collected.

In this study, the researcher went through the following steps:

- Firstly, the questionnaire was circulated to the research supervisors who were requested to make recommendations for amendments in the layout, contents and instruction.
- Secondly, the questionnaire was piloted with a group of 17 Grade 11 respondents. The necessary amendments were made to the questionnaire in correspondence with the feedback.
- Thirdly, variables were coded for entry into the Statistical Package for Social Sciences (SPSS) version 23.

3.6 DATA ANALYSIS AND INTERPRETATION

Field (2014) states that quantitative analysis of the questionnaire responses need to be summarised and portrayed clearly on a statistical basis to offer the researcher an opportunity to quantify the data and infer generalisations. The processing of raw data was statistically done through the use of SPSS.

Data collected was analysed descriptively and inferentially to establish if there was any correlation between the study orientations and the performance in the visual literacy tests. Furthermore, gender related variables and schools' related locations were pursued. In order to establish whether there were any statistical differences between variables the probability value of 0.01 (referred to as sig. in the SPSS output tables) was used. The probability of value is calculated using Bonferroni's adjustment which refers to dividing the significance value by the number of hypotheses the researcher has hypothesised, thus we used 0.05/5 = 0.01 (Armstrong, 2014).

Table 3.2: Summary of the data collection and data analysis methods

Research sub-questions	Data collection method	Data source	Data analysis method
What is the difference between the visual literacy of males and females in cytology?	Survey	Grade 10 learners from 6 sampled schools	Inferential and descriptive statistics. Correlation, one sample test, independent sample test.
What is the correlation between the school location and the learners' level of visual literacy?	Survey	Grade 10 learners from 6 sampled schools	Inferential and descriptive statistics. Correlation, t-test, Analysis of variance (ANOVA), post-hoc Fisher's least significant difference (LSD) test.

3.7 VALIDITY AND RELIABILITY

In order to have confidence in the research methodology and its findings, the measure of reliability is of importance. This refers to the estimated probability of consistency of given measurements over time (Libarkin & Kurdziel, 2002). In other words, reliability predicts the probability of obtaining the same results if the research method is repeated under the same conditions on a different occasion.

Reliability

In this study, the reliability was estimated using the internal consistency method referred to as Cronbach's alpha. This is a check for consistency of the questionnaire and any Cronbach alpha value less than 0.5 is unacceptable (Goforth, 2015). In this study a Cronbach alpha value of 0.517 is attained which is acceptable.

Validity

Validity is a measure to which an instrument measures what it was intended to measure (Thapliyal et al., 2005). A pilot study and a critique done by a panel of Life Sciences education experts were used to ensure content validity. Content validity is defined as a measure of how appropriate the items seem to a set of experts on the subject matter (Libarkin & Kurdziel, 2002) or, stated differently, to what extent all aspects of the construct are measured.

3.8 ETHICAL CONSIDERATIONS

Regarding the autonomy of participants, a consent form (Appendices E, F and G) was signed by the principal, learners, parents / guardians and the researcher. This consent form indicates the following:

- The purpose of this research.
- The details of the researcher and the supervisors and their association with the University of Pretoria.
- The right to withdraw from the study at any given time.
- Participation is voluntary.
- Anonymity and confidentiality will be exercised.
- That anonymity will be guaranteed (e.g. coded / disguised names of participants / respondents / institutions).
- There will be no direct benefits for participation in the research.
- Minimal disruption of classes. Questionnaire to be conducted outside the normal school time table.
- Data collected in this study will be destroyed after a period of 15 years.

3.9 SUMMARY

In this chapter the researcher has outlined the research methods used to explore the visual literacy of Grade 10 Life Sciences learners in cytology through administering questionnaires as a data collection method. The next chapter presents the results of the collected data and the processes of analysis.

CHAPTER 4: DATA PRESENTATION, ANALYSIS AND DISCUSSION

Learning to see and create visual images must also be recognised as an essential to the learning process.

- Bette Fetter

4.1 INTRODUCTION

The purpose of this chapter is to present the results of the collected data and to explain the processes of analysis. The aim of the study was to explore the level of visual literacy of Grade 10 Life Sciences learners in cytology. Reporting of the results is done according to the structure which has been described in the research methodology section. The SPSS version 23 was used for all data analyses which included descriptive statistics, Levenes' test to test for homogeneity of variance, the t-test to test for differences between means, ANOVA, the post-hoc Fisher's least significant difference (LSD) test and correlations.

The percentage of people who respond to a questionnaire is referred to as a response rate. A high response rate is desirable and, in this study, of the 250 questionnaires that were distributed 225 questionnaires were completed. This gives a response rate of 90% that shows that the survey had a high reliability. The structure of this chapter has been outlined in the following manner:

- Learners' biographical data.
- Learners' understanding of Life Sciences when using different ERs.
- Use of ERs when studying Life Sciences.
- Learners' preference of ERs to study Life Sciences.
- Opinions of learners regarding teachers' use of ERs to teach Life Sciences.
- Learners' description of their teachers' use of visual examples in Life Sciences.

- Learners’ preferences on external representation that can best enhance their knowledge of an animal cell.
- Learners’ preferences on external representation that can best enhance their knowledge of a plant cell.
- Learners’ expressions when requested to draw and label mitochondria organelle.
- Diagnostic analysis of Life Sciences visual literacy test and spatial abilities test.
- Comparisons of means between groups in the life sciences visual literacy test and the spatial ability test.

4.2 BIOGRAPHICAL INFORMATION

The study constituted of 225 respondents who were Grade 10 Life Sciences learners from six different secondary (high) schools in Pretoria. The following biographical information was captured on the learners: age, location of the school, reasons why Life Sciences was chosen as an elective subject and home language. A detailed summary of each is given below. It should be noted that some of the questions, and other questions in the questionnaire, had some missing values. Missing values are a common occurrence due to nonresponse and there are a few ways of dealing with missing data which include imputing the missing values with replacement values (such as the mean) or making use of statistical models that allow for missing data and analysing only the available data. The latter approach was used in this study, i.e. missing values were ignored since there weren’t many missing data entries.

Age

The minimum and maximum ages were 14 and 19, respectively, with an average age of 16.07 years (SD = 0.991). The results indicated that less than half of the learners (45%) were female and more than half of the learners (55%) were male.

Learners' school location

The learners' school location may have an influence on the level of visual literacy of the learners. Therefore, the researcher explored this variable and the results indicated that the majority of schools (39%) are located in a high socio-economic area (urban) closely followed by 32% of the learners' schools located in a low socio-economic area (rural) and only 29% of the schools are located in a medium socio-economic area (township).

Reasons why learners chose Life Sciences as an elective subject

Life Sciences could be perceived to be a difficult subject; this is stipulated by the low enrolled number compared to the high number of learners enrolled for other subjects such as history. This study showed that 43% of the learners indicated that they chose to enrol for Life Sciences as a subject because they needed it for further education, closely followed by the 31% who were curious about the Life Sciences content. Only 5% had intrinsic interest in the Life Sciences and were driven by its content. Furthermore 2% chose to enrol for Life Sciences as a subject because they perceive it to be easy while parents (2%) and teachers (2%) also influenced respondents to enrol in the subject.

Learners' home language

Since visual literacy could be considered as a language on its own, inquiring learners' home language came as a necessity, to explore whether home language has an impact on the level of visual literacy of the learners. Findings revealed that most learners' home language was Sepedi (42%) followed by Setswana (15%), Zulu (12%), South Sotho (7%) and Xhosa (6%). The other home languages included Afrikaans, English, Ndebele, Swati, Tsonga and Venda (2%).

4.3 RESULTS OF THE LIFE SCIENCES VISUAL LITERACY TEST

4.3.1 Learners' understanding of Life Sciences when presented in different ERs

In Life Sciences there are a lot of concepts that are abstract and not possible to see with the unaided (naked) eye. Such concepts become very intricate for learners to understand if they are not taught using ERs. In that regard, learners were asked if they understood Life Sciences better if presented using different modes of ERs. The majority of the learners indicated that they understood Life Sciences better when presented as diagrams (58%), closely followed the presentation of real life examples (57%) as well as drawings (49%). Almost three quarters of the learners stated that they did not understand Life Sciences phenomena when presented as text only (74%), videos only (74%), physical models only (73%) or photos only (65%) (see Figure 4.1).

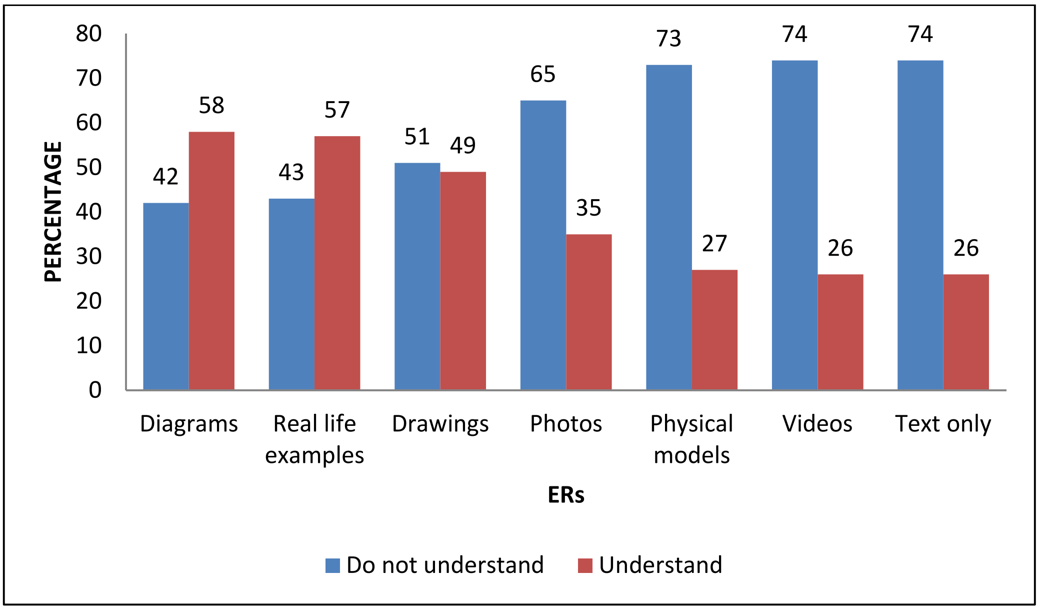

Figure 4.1: Learners' understanding of Life Sciences when presented in different ERs

In addition, the results revealed that learners also understand Life Sciences better when presented as more than one ER, where 32.7% better understand it when presented in three ERs and 22.9% better understand it when presented as two ERs. Only 20.2% understand Life Sciences better when presented as four ERs and 17.5% understand it when presented as one ER. One respondent indicated that he/she better understood Life Sciences when presented in all seven ERs (see Table 4.1).

Table 4.1: Learners understanding of Life Sciences presented in more than one mode of ER

Number of ERs presented	Learner frequency	Percentage
1	39	17.5
2	51	22.9
3	73	32.7
4	45	20.2
5	10	4.5
6	4	1.8
7	1	0.4
Total	**223**	**100**

Out of the 32.7% that understands Life Sciences in three modes, those who understand Life Sciences better when presented as text coupled with two other ERs were explored. The following results stood out amongst the rest, the majority (14%) preferred text coupled with diagrams and drawings followed by text coupled with diagrams and real life examples (5%). Furthermore, 18% understand Life Sciences phenomena better when presented as diagrams; drawings and real life examples without any use of text (see Table 4.2).

Table 4.2: Learners understanding of Life Sciences when presented as three different modes of ERs

Three ERs to present Life Sciences phenomena	Learner frequency	Percentage
Text, diagrams and drawings	10	14
Text, diagrams and real life examples	4	5
Text, diagrams and physical models	2	3
Text, diagrams and videos	2	3
Text, photos and real life examples	3	4
Text, drawings and photos	1	1
Text, drawings and real life examples	1	1
Diagrams, drawings and real life examples	13	18

4.3.2 Learners' use of ERs when studying Life Sciences

- *Learners use of single ERs*

External representations (ERs) offer a means of making phenomena visible that are either too small, too large, too fast, too slow or too abstract to see with the unaided eye. They illustrate invisible or abstract phenomena that cannot be observed or experienced directly. Therefore incorporating ERs in learning can increase the achievement of learners' learning outcomes (comprehension, understanding, making connections between ideas and concepts, all to make the meaning of Life Sciences clearer) and assist to perceive phenomena better. Results illustrated that a vast number of the learners used textbooks (92%) to study life sciences followed by exercise books (68%) and the internet (38%). The results further indicate that learners seldom use real life examples (20%), physical models (10%), video with animations (9%), and computer simulations (4%) when studying Life Sciences (refer to Figure 4.2).

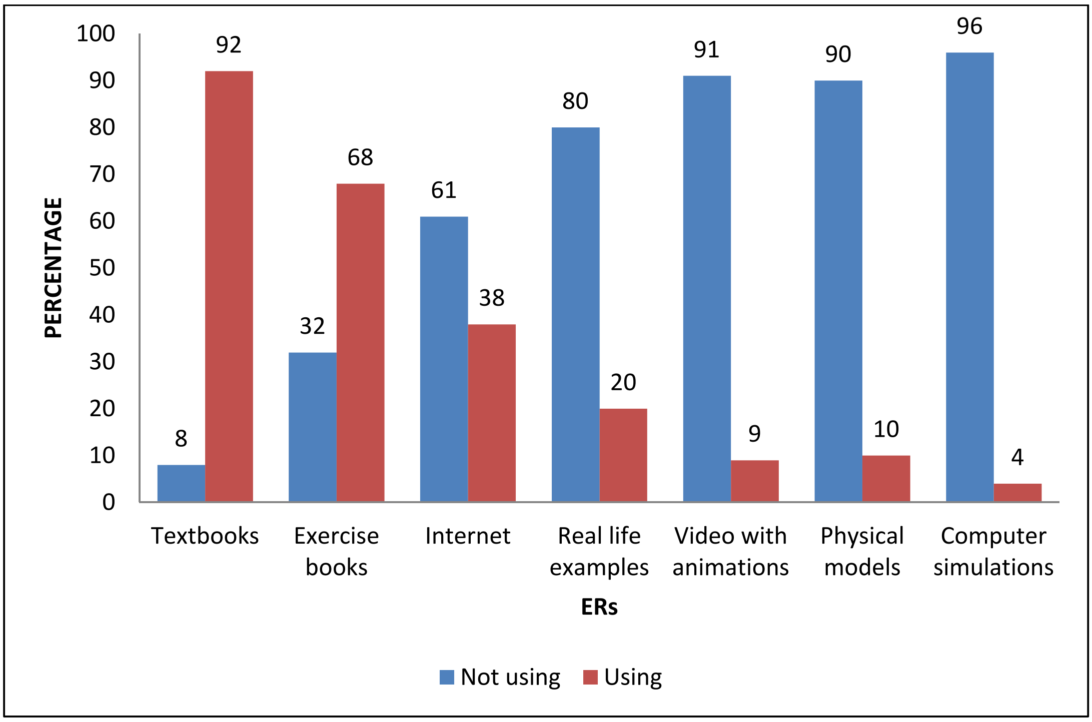

Figure 4.2: Learners' use of ERs when studying Life Sciences

- *Learners' use of coupled ERs*

When an individual can use more than one ER to understand phenomena it may help them understand phenomena even better. The results showed that (45%) of the learners use two ERs, while (28%) use three ERs when studying Life Sciences. Furthermore only 2%, use all six the ERs when studying Life Sciences while (15%) of the learners used only one ER when studying Life Sciences (refer to Table 4.3).

Table 4.3: Learners' use of more than one ER when studying Life Sciences

Number of ERs	Learner frequency	Percentage
1	34	15
2	100	45
3	62	28
4	20	9
5	3	1
6	4	2
Total	**223**	**100**

The high percentage of learners (45%), who make use of two ERs to study Life Sciences, were explored in order to examine which two ERs are respectively used when studying Life Sciences. Therefore, the results showed that 80% of the learners use textbooks and exercise books when studying Life Sciences, 13% use textbook and the internet, 5% use textbook and real life examples and only 1% use textbook and videos or textbook and computer simulations (refer to Table 4.4).

Table 4.4: Learners' use of two ERs when studying Life Sciences

Two ERs used to study Life Sciences	Learners frequency	Percentage
Textbook and exercise book	80	80
Textbook and internet	13	13
Textbook and real life examples	5	5
Textbook and videos	1	1
Textbook and computer simulations	1	1
Total	**100**	**100**

4.3.3 Learners' preference of ERs to study Life Sciences

According to McTigue and Flowers (2011) learners of today are technology driven and respond more successfully to text balanced with pictures than to text only data. The results elucidate that learners preferred textbooks (88%), exercise books (77%), drawings (48%) and diagrams (46%) to study Life Sciences. In addition videos (4%), computer simulations (5%), physical models (14%) and the internet (23%) are rarely preferred to study Life Sciences (refer to Figure 4.3).

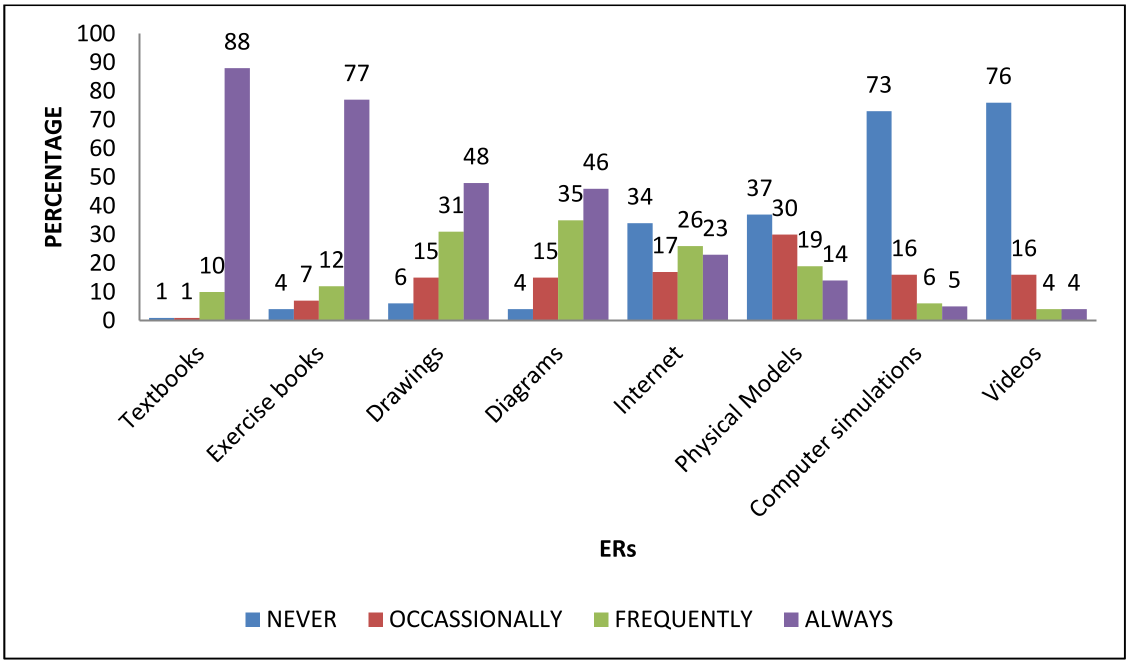

Figure 4.3: Learners' preference of ERs to study Life Sciences

4.3.4 Opinions of learners regarding teachers' use of ERs to teach Life Sciences

Learners of today are more acquainted with the new drastic changes in technology. Such acquaintance offers teachers a platform to use the educational technological devices as an advantage to create a positive learning atmosphere and enhance learning in a classroom as research showed that ERs have a superior advantage over text alone for teaching and learning (McTigue & Flowers, 2011). The learner's gave an impression that teachers use chalk boards (70%), exercise books (58%) and textbooks (58%) more frequently than other ERs to teach Life Sciences. They further indicated that the chances are high that the listed ERs ((videos with animations (92%), tablet personal computer (92%), computer simulations (87%), smart phones (84%), internet (75%), power point (63%) and white board (61%)) are never used in a classroom to teach Life Sciences. In addition physical models (38%) are occasionally used to teach Life Sciences (refer to Figure 4.4).

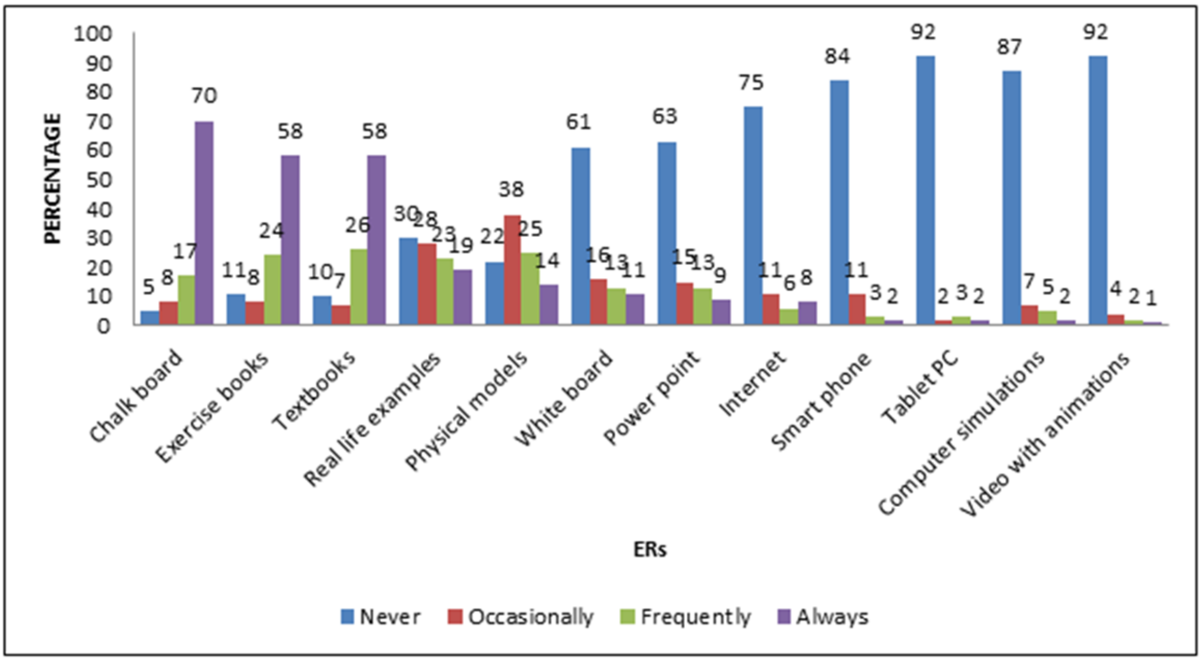

Figure 4.4: Opinions of learners regarding teachers' frequent use of ERs to teach Life Sciences

Teachers use ERs to enhance learners' visual literacy skills and to convey abstract concepts into concrete examples. The results elucidated that more than half of the learners (56%) described their teachers' use of external representations as resourceful while only 41% of the respondents describe their teachers' use of external representations as average. A few (3%) described it as unresourceful.

4.3.5 Learners' interpretation of physical models of a plant and an animal cell

There are factors that often affect learners' ability to interpret external representations. These factors include learners' general reasoning ability to interpret the external representations, to make sense of the external representation, and to understand the nature of the mode in which the desired phenomenon is represented by the external representation. Another factor is the learners' understanding, or lack of understanding, of the conceptual knowledge represented by the external representation and salient characteristics on the external representation which would obscure learners' focus if not understood. These factors are prerequisites for sound visualization and interpretation of external representations and should be properly addressed to enhance the visual literacy of learners (Schönborn & Anderson, 2006). The researcher therefore probed learners to interpret the perceived external an internal differences between physical models of an animal and a plant cell in order to examine if the learners could examine and note the similarities or differences, bring into or link in logical or natural association and demonstrate a connection between an animal and a plant cell presented as a model. The results showed that almost two thirds (62%) could observe the difference in cell wall/cell membrane, 45% observed differences in vacuole sizes, 37% in shape, 34% in chloroplasts and 23% noticed the difference between the two types of cells. Only 7% referred to the colour difference (see Figure 4.5).

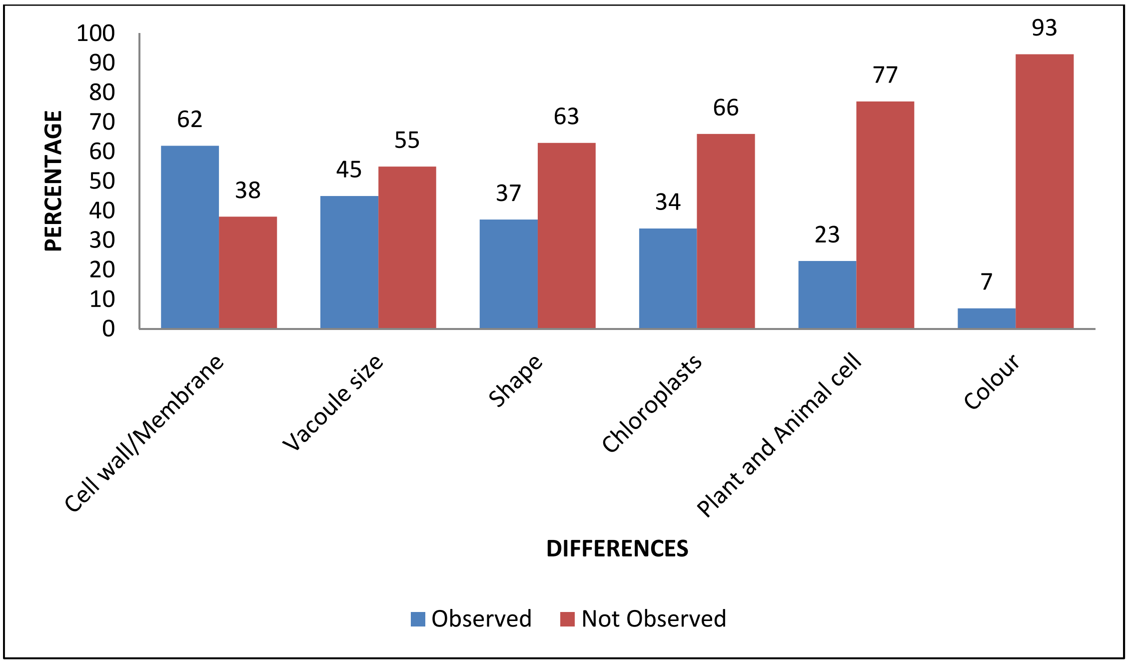

Figure 4.5: Observed differences learners used to interpret physical models of a plant and animal cell

4.3.6 Interpretation of sketches of a plant and an animal cell

The ability to link two-dimensional diagrams to three-dimensional reality, understand scale and magnification and relate diagrams in exam papers to what is shown in their textbooks are some of the skills required in visual literacy. Learners were given two sketches: one of an animal cell and one of a plant cell, in order to see whether they could differentiate between the two. The results showed that 83% could indicate which sketch was a plant cell while 82% could indicate which sketch was an animal cell (see Figure 4.6).

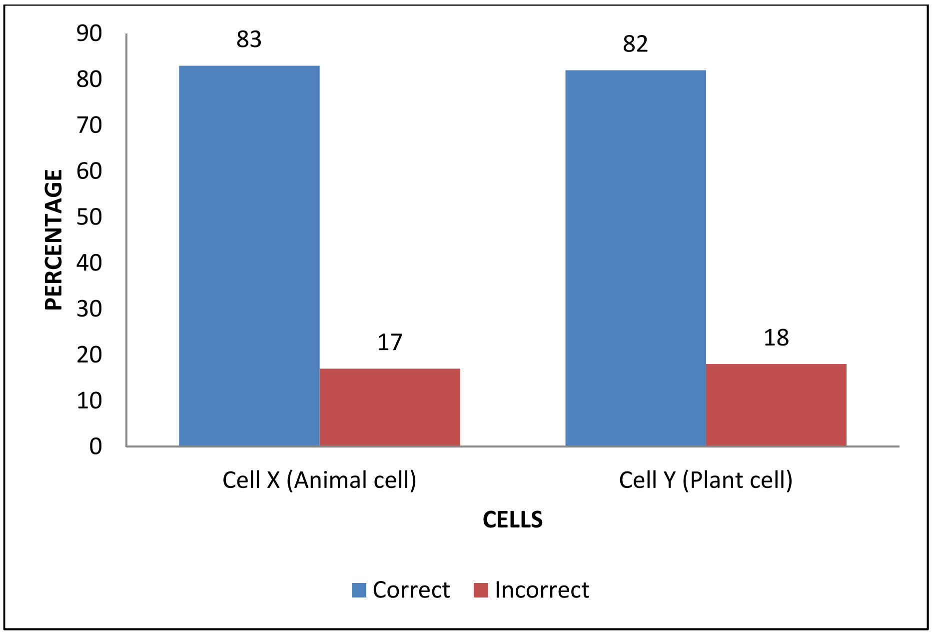

Figure 4.6: Learners' ability to distinguish between the sketches of an animal cell and a plant cell

Learners argued that the main reasons how and why they could differentiate between the two sketches (an animal and plant cell) were the shape of the sketches (72%), the vacuole size within the sketches (66%), presence and/ or absence of chloroplast in the sketches (78%) and a double outline which is perceived as double membrane or cell wall (39%) (refer to Figure 4.7).

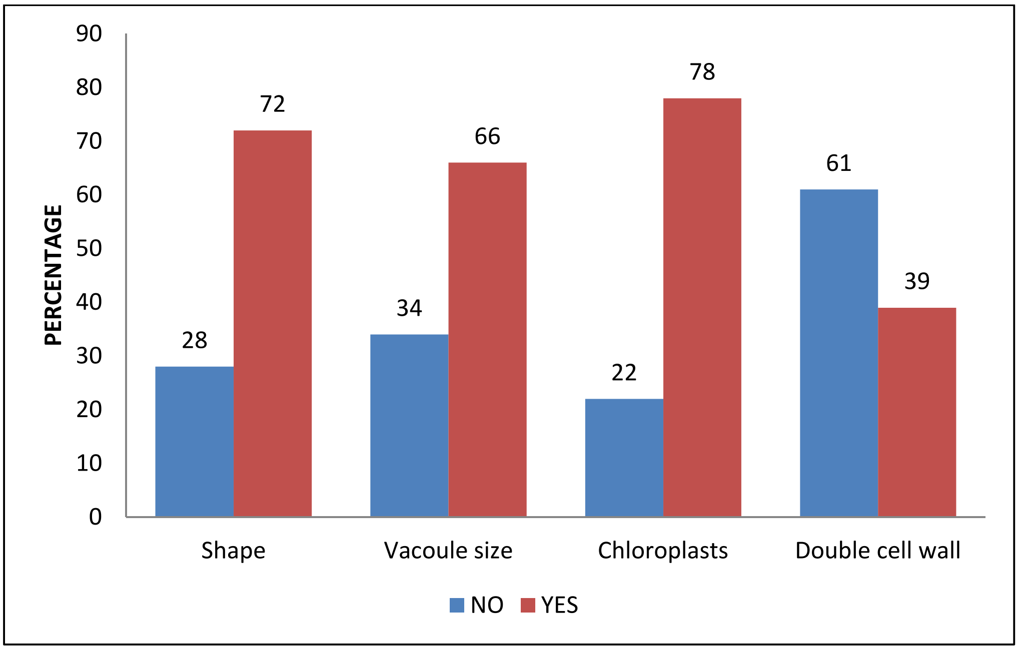

Figure 4.7: Learners ability on how they could differentiate between the two sketches of cells

4.3.7 Learners' preferences on external representation of an animal cell

External representations can be presented in different modes that are often used to unfold certain phenomena. Learners were probed on which ER would best enhance their knowledge of an animal cell in terms of a photo of a physical model, a two-dimensional drawing and an electron microscope photo. The results show that the majority of the learners (68%) preferred a 2D drawing followed by physical models (22%) and an electron microscope photo (10%) to enhance their knowledge of an animal cell (see Figure 4.8).

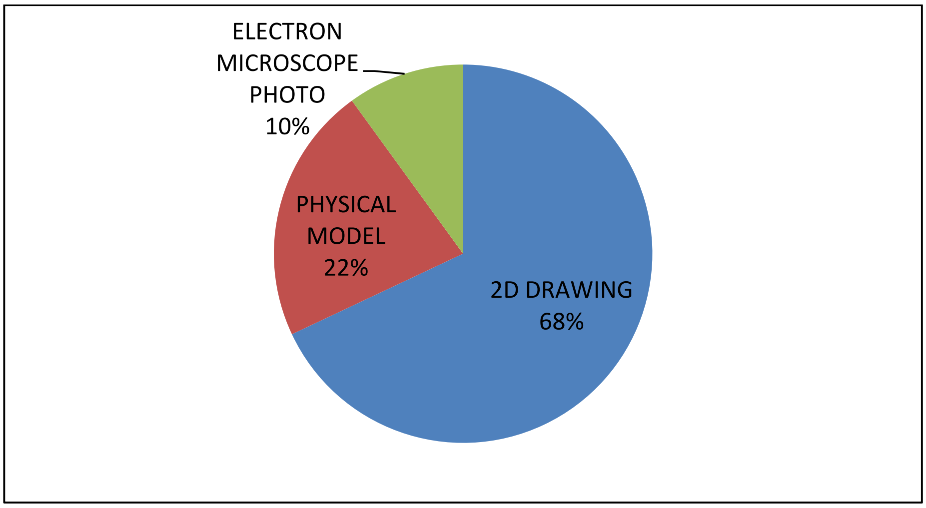

Figure 4.8: Learners' preference on ER that will best enhance their knowledge of an animal cell

Furthermore the learners argued that the main reason for their preferences was that the ERs were clearly visible and simple (36.4%). The following two learners are highlighted as an example:

"It is clear and not as complicated as the other two. You can see everything more clearly than the other two" (Learner 47, School F)

"Because of the drawing is easy and clear to see it" (Learner 48, School F)

The other reasons that emerged were that the ERs are easy to understand and remember (13%), they are familiar (10.9%), they appear realistic (8.2%), informative (6.5%) and colourful (4.3%) (refer to Table 4.5).

Table 4.5: Reasons emerged from learners' preference on best ER to enhance animal cell knowledge

Learners' reasons	Learners frequency	Percentage
Non sense reason	38	20.7
Informative	12	6.5
Easy to understand and remember	24	13.0
Clearly visible and simple	67	36.4
Realistic	15	8.2
Colourful	8	4.3
Familiar with	20	10.9
Total	**184**	**100**

4.3.8 Learners' preferences on external representation of an animal cell to understand the structure of a cell

Metros and Woolsey (2006) highlighted that learners' need multimodal fluency with skills to decode and encode visual descriptions that represent scientific phenomena; therefore, learners have to be able to select and effectively use a set of cognitive skills for perceiving, processing and expressing external representations in response to scientific knowledge in Life Sciences. Learners were probed as to which ER (physical model, 2D drawing, mind map and a table) would enhance their understanding of cells the best. The results showed that learners chose physical models (26%) and a table (21%) as their first preference as opposed to 2D drawings (19%) and mind maps (10%) to enhance their knowledge on cells. Furthermore, mind maps (32%) and physical models (20%) yielded high percentages of being selected as the last option followed by a table (13%) and a 2D drawing (10%) (see Figure 4.9).

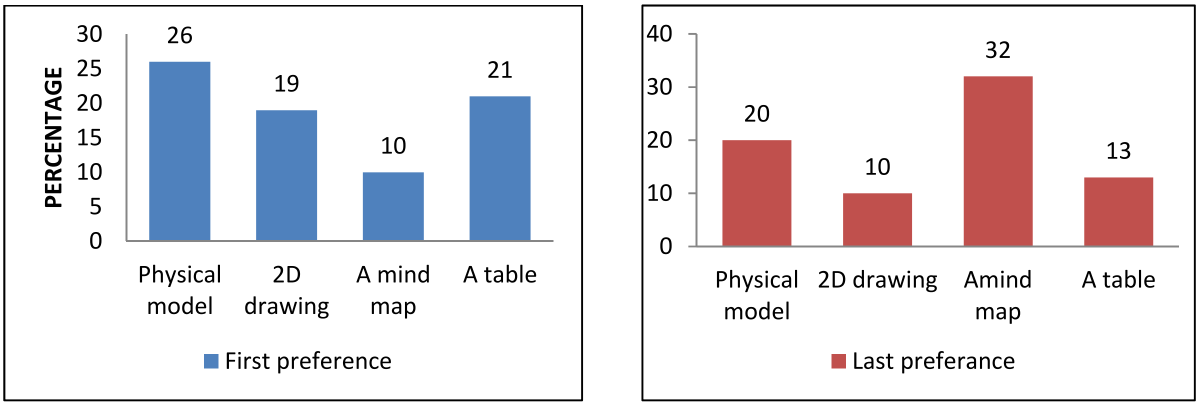

Figure 4.9: First and last preference on external representation of an animal cell

The results further stipulated the reasons why the learners chose different modes of representations as their first priority to understand an animal cell. Fifty-four percent of the learners argued that the modes were visually understandable and informative, followed by easy to read, understand and recall (23%), familiar (8%) prefer text over diagrams (6%) and colourful and realistic (4%) (refer to Table 4.6). For example:

"Figure D has realistic, visual and a human eye can see it clearly". (Learner 100, School B)

"Figure E is a drawing and a drawing gives more information, it is easy to explain and draws attention". (Learner 106, School E)

"Figure D is realistic and I can imagine how a cell looks like". (Learner 32, School F)

Table 4.6: Reasons learners motivated on their first preference of ER that will enhance their knowledge of a cell

Learners' reasons	Learner frequency	Percentage
No reason	8	5
Visually understandable	42	27
Easy to read, understand and recall	36	23
Familiar with	12	8
Prefer text over diagrams	9	6
Colourful and realistic	6	4
Informative	42	27
Total	**155**	**100**

Reasons for the last priority were: complicated (43.8%), no diagrams just text (18.5%), difficult to read, understand and remember (17.1%), less information and not interesting (8.2%), 3D shape (1.4%) and not familiar with (2.1%) (see Table 4.7). The following are examples of learners' comments:

Figure G: "I can understand the labelled diagram better because it shows the names of the component inside a cell" (Learner 155, School A)

"It is the way we have been taught and it is the way it is in the textbook" (Learner 213, School C)

Figure H: "Doesn't have much information and it is a bit hard to understand" (Learner 144, School B)

Figure I: "…is complicated to understand and it is confusing" (Learner 53, School D)

"Has only text and no diagrams on it so you cannot explain organelles by only text" (Learner 48, School D)

Figure J: "…is hard to understand because it does not show the components" (Learner 155, School A)

Table 4.7: Reasons learners motivated on their last preference of ER that will enhance their knowledge of a cell

Learners' reasons	Learner frequency	Percentage
No reason	13	8.9
Complicated	64	43.8
3D shape	2	1.4
Not familiar with	3	2.1
Difficult to read, understand and remember	25	17.1
Less information and not interesting	12	8.2
No diagrams just text	27	18.5
Total	**146**	**100**

4.3.9 Learners' expressions when requested to draw and label mitochondria organelle

The ability to translate text into a drawing is one of the skills required in visual literacy. Learners were probed to draw a mitochondrion. In this regard the results show that more than half of the learners (64%) drew a two-dimensional drawing while only 3% attempted to draw a three-dimensional representation and almost half (33%) of the learners did not draw anything. Nonetheless only 8% of the drawings were labelled correctly 11% were incorrectly labelled and 49% had no labels (refer to Figure 10).

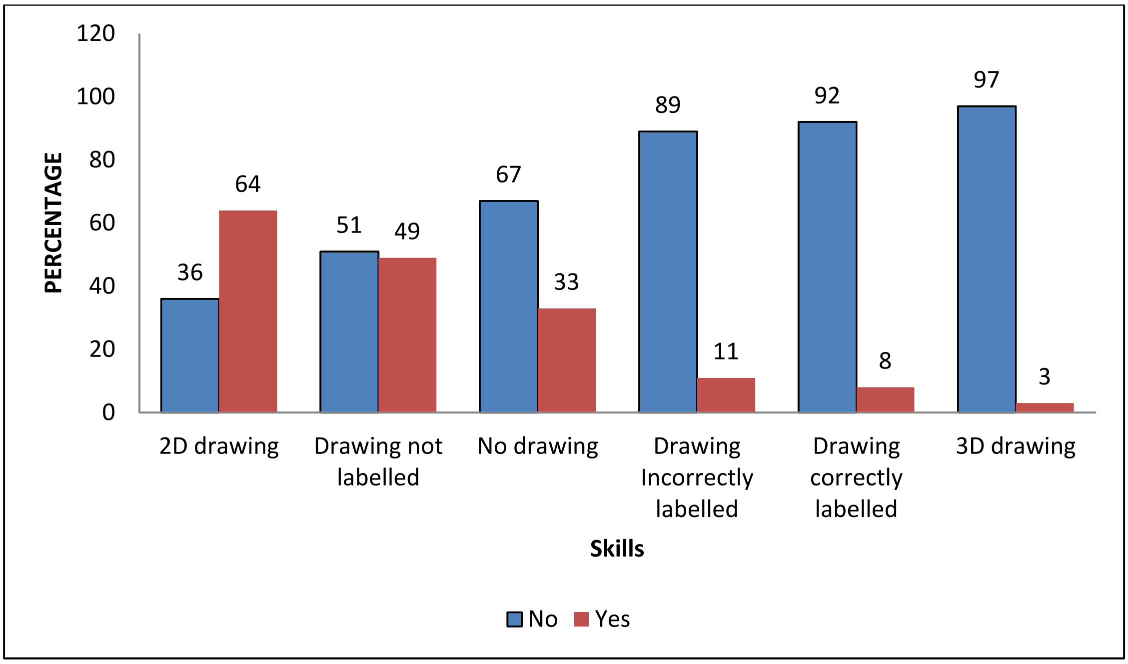

Figure 4.10: Learners' responses on drawing mitochondria

4.3.9.1 Examples of learners' responses when requested to draw a mitochondrion

Communicating visually is one of the core aspects in visual literacy. The learners were probed to draw a sketch of a mitochondrion. The following are examples of the learners' drawings:

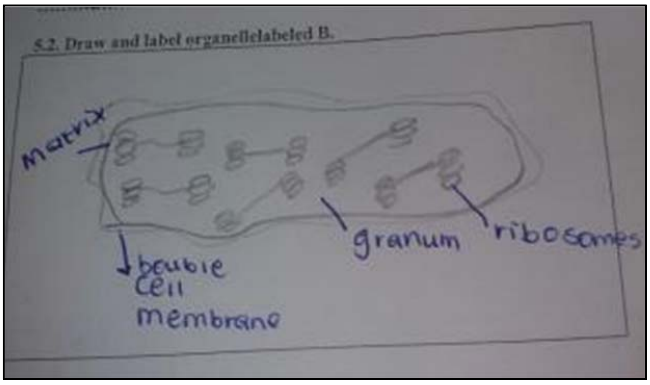

Figure 4.11A: Learner 22 (School F)

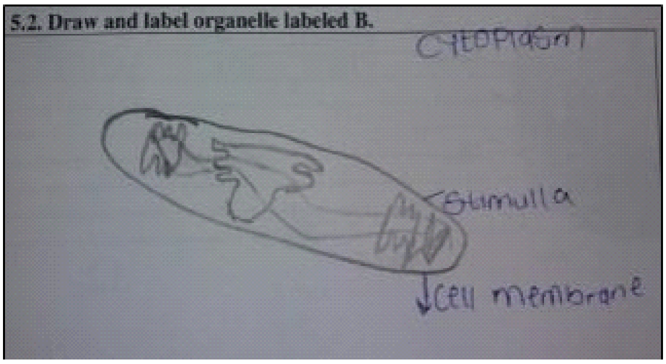

Figure 4.11B: Learner 1 (School F)

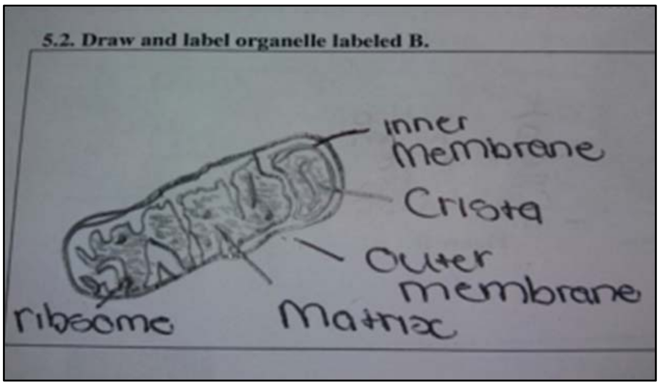

Figure 4.11C: Leaner 104 (School C)

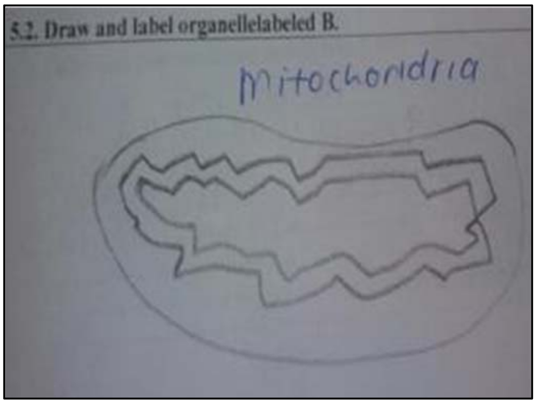

Figure 4.11D: Learner 85 (School E)

4.3.10 Diagnostic analysis of the Life Sciences visual literacy test

Diagnostic analysis is an analysis performed to provide deeper insight level of the performance of individuals, i.e. how learners' think and use skills while engaged in interpreting. It uses a system of error analysis as the corner stone for the process which can reveal patterns that exists in an interpreters work.

The results revealed that learners scored higher in the questions that required low level cognitive effort (see Appendix A) where they were required to apply and recall knowledge in the Life Sciences visual literacy test (refer to Table 4.8).

Table 4.8: Highly scored questions in the Life Sciences visual literacy test

Question number	Skills Required	Percentage	
		Correct	Incorrect
1	Identify/perceive colours	48.4	51.6
3i	Complete Imagine Recall/ retrieve	83.0	17.0
3ii		82.1	17.9

Additionally, in questions that ordered higher cognitive effort (see Appendix A), learners performed poorly. These questions required learners to visualise using their visuospatial ability to be able to synthesize a requested phenomenon (refer to Table 4.9).

Table 4.9: Most difficult questions in the Life Sciences visual literacy test

Question number	Skills Required	Percentage	
		Correct	Incorrect
5.1	Outline and Recall/Retrieve	26.9	73.1
6.1a	Arrange/order/organise/classify Recall/retrieve Analyse Relate	23.2	76.8
6.1b		25.8	74.2
6.1c		13.8	86.2
6.1d		27.6	72.4
6.2a	Arrange/order/organize/classify/ Recall/retrieve/Manipulate/ mental rotation; recognize orientation; recognition	48.5	51.5
6.2b		28.4	71.6
6.2c		20.1	79.9
6.2d		49.4	50.6

4.4 RESULTS OF THE SPATIAL ABILITY TEST

4.4.1 Diagnostic analysis of the spatial ability test

There are four common types of spatial abilities which include spatial or visuospatial perception, spatial visualization, mental rotation and mental folding.

In the spatial ability test (see Appendix C), the results portrayed that questions that required more mental rotation, comparison, pattern detection, discrimination, and analysis skills were questions where learners scored above a percentage of eighty (see Table 4.10).

Table 4.10: Highly scored questions in the spatial ability test

Question number	Skills Required	Percentage	
		Correct	Incorrect
1	Mental rotation, compare, pattern detection, discriminate, analyse and find	96.1	3.9
2		80.3	19.7
4		89.8	10.2
6		89.8	10.2
8		85.4	14.6
9		90.7	9.3
10		89.9	10.1
12		83.2	16.8
13		94.9	5.1
14		80.7	19.3
15		85.2	14.8
19		86.9	13.1
23		87.0	13.0

4.4.2 Most difficult questions in the spatial ability test

The questions that involved complex mental folding, visualization and perception or required learners to perform certain skills cognitively were questions where learners performed poorly (see Table 4.11).

Table 4.11: Questions in the spatial ability test in which the respondents performed poorly

Question number	Skills Required	Percentage	
		Correct	Incorrect
26	Mental rotation, compare, pattern detection, discriminate, analyse, find	33.3	66.7
29		34.2	65.8
33	Mental rotation, analyse, complete (cognitively), imagine, relate, infer, predict, arrange	34.5	65.5
34		21.0	79.0
35		31.3	68.7
36	Mental rotation, analyse, complete (cognitively), imagine, relate,	28.0	72.0
38	infer, predict, arrange, depth perception	29.8	70.2
40	Analyse, predict, complete, mental rotation	29.3	70.7
41		15.4	84.6
42		19.9	80.1
43	Analyse, complete, predict	32.1	67.9
44		28.0	72.0
45		25.8	74.2

4.5 COMPARISON BETWEEN GROUP PERFORMANCES OF RESPONDENTS ON THE LIFE SCIENCES VISUAL LITERACY TEST AND THE SPATIAL ABILITY TEST

In the analyses the mean scores of the Life Sciences visual literacy and the spatial ability test were measured respectively. The relationship between the two corpuses may descriptively have an impact on visual literacy of the learners. A summary of results obtained are illustrated below. The summary consists of the mean and standard deviation scores of the learners' performances in the Life Sciences visual literacy test and spatial ability test. Standard deviation is a measure of the dispersion or range of score, calculated as the square root of the variance (Maree, 2007). A low standard deviation indicates that the scores are clustered together while a high standard deviation indicates that the scores are widely dispersed. The Life Sciences visual literacy test (LSVLT) and spatial ability test (SAT) had a standard deviation of 3.498 and 8.907 respectively, with the latter being larger than the former, indicating that the scores for the SAT are more widely spread than those of the LSVLT scores (refer to Table 4.12). In the SPSS output 'Total_SAT' refers to the actual SAT score that was out of 45 and 'Total_LSVLT' refers to the actual LSVLT score that was out of 24. Thus, the mean percentage for SAT equals 20.63/45*100 = 45.8% and the mean percentage for LSVLT equals 7.70/24*100 = 32.08%.

Table 4.12: Descriptive statistics between total LSVLT and total SAT

Total scores	N	Minimum	Maximum	Mean	Std. Deviation
Total_SAT	207	2	37	20.63	8.907
Total_LSVLT	225	0	16	7.70	3.498

From Table 4.12 it should be noted that all 225 respondents completed the Life Sciences visual literacy test, however, only 207 completed the spatial ability test and this is why we have the values of 207 and 225 under the 'N'-column of the SPSS output for Total_SAT and Total_LSVLT, respectively. Thus, for the Total_SAT we have 18 missing values.

Next, a paired samples t-test is run to find out whether the difference in between the LSVLT and SAT scores are significantly different. The paired samples t-test is used to compare means that are from the same individual. The ‘t’ in SPSS output in the analysis refers to the value of the t-test while ‘Sig. (2-tailed)’ is the p-value. The null hypothesis (H_0) is the probability model that will play the role of chance and it was tested at a confidence level of 95%. It should be noted that the p-values are not compared to 0.05 but rather to 0.05/5 = 0.01 alpha levels due to the Bonferroni adjustment which is discussed in Section 3.6 in Chapter 3. Several hypotheses were considered.

Hypothesis 1:

Null hypothesis (H_0):
The mean score of the Life Sciences visual literacy test is not statistically significantly different to the mean score of the spatial ability test.

Alternative hypothesis (H_a):
The mean score of the Life Sciences visual literacy test is statistically significantly different to the mean scores of the spatial ability test.

Recall that the mean percentage for SAT equalled approximately 46% and the mean percentage for LSVLT equalled approximately 32%. The null hypothesis is rejected since the p-value equals 0.000 (< 0.01), therefore the difference of approximately 14% is significantly different (refer to Table 4.13). It should be noted that a p-value can’t technically equal 0 and, in Table 4.13, the value of 0.000 actually represents the fact that the p-value < 0.0001.

Table 4.13: Paired samples t-test between mean LSVLT and mean SAT scores

Pair	Mean	Std. deviation	Std. Error Mean	Lower limit of the 95% confidence interval	Upper limit of the 95% confidence interval	t	df	Sig. (2-tailed)
LSVLT percentage and SAT percentage	-13.242	21.831	1.517	-16.234	-10.251	-8.727	206	0.000

It should be noted that in Table 4.13 the percentages were considered where 'LSVLT_percentage' and 'SAT_percentage' refer to the percentages attained in the two tests, respectively. However, whether the actual scores or percentages are entered into SPSS, it doesn't make a difference to the final result. For example, when running the paired samples t-test on 'Total_SAT' and 'Total_LSVLT' the p-value still equals 0.000 and the null hypothesis is still rejected.

4.5.1 Visual literacy between genders in the Life Sciences visual literacy test and spatial ability test

First we consider the Life Sciences visual literacy test, followed by a discussion on the spatial ability test. Life Sciences is an intricate subject that is based on scientific study of living things from molecular level to their interactions their environment and with one another (CAPS, 2013). As mentioned above, gender may play a role on how learners apply their visual literacy skills in this subject. Therefore, males' and females' performances in Life Science visual literacy were pursued and results showed that males scored an average of 31.47% whilst females scored slightly higher with an average of 33.50% (refer to Table 4.14).

Table 4.14: Descriptive statistics for gender in Life Sciences visual literacy test

Score	Gender	N	Minimum	Maximum	Mean	Std. deviation
LSVLT_ percentage	Male	121	0	67	31.47	13.703
	Female	99	4	67	33.50	15.510

Hypothesis 2:

Null hypothesis (H_0):
The mean score of males is not statistically significantly different to the mean score of females in the Life Sciences visual literacy test.

Alternative hypothesis (H_a):
The mean score of males is statistically significantly different to the mean score of females in the Life Sciences visual literacy test.

The resulting p-value of Levene's test (p-value = 0.088) is greater than the significance level of 0.01, indicating that the variance is not significantly different, therefore the obtained differences in the sample are likely have to occurred from random sampling from a population with equal variances. The t-test has a p-value of 0.305 (> 0.01) thus the null hypothesis is not rejected. Therefore, the mean score of males is not statistically significantly different to the mean score of females in the Life Sciences visual literacy test (see Table 4.15).

Table 4.15: Levene's test for equality of variances and the t-test for equality of means between genders for the LSVLT

	Levene's Test for Equality of Variances		**t-test for Equality of Means**						
Equality of variances	**F**	**Sig.**	**T**	**Df**	**Sig. (2-tailed)**	**Mean Diff**	**Std. Error Diff**	**95% Confidence Interval of the difference**	
								Lower	**Upper**
Equal variances assumed	2.930	0.088	-1.029	218	0.305	-2.028	1.971	-5.912	1.857
Equal variances not assumed			-1.106	197.3	0.311	-2.028	1.995	-5.963	1.907

Next, we consider the spatial ability test. Spatial ability is the over-arching concept that largely refers to skills representing, transforming, generating and recalling of symbolic, non-linguistic information. According to research, males perform better on tests of spatial perception and mental rotation, however they perform equally well on spatial visualisation tests (Linn & Peterson, 1985). The results illustrate that both males and females perform at an average of 46% (see Table 4.16).

Table 4.16: Descriptive statistics for gender in the spatial ability test

Score	Gender	N	Minimum	Maximum	Mean	Std. deviation
SAT_ percentage	Male	111	4	82	45.89	19.950
	Female	94	7	76	46.03	19.800

Hypothesis 3:

Null hypothesis (H_0):

The mean score of males is not significantly different to the mean score of females in the spatial ability test.

Alternative hypothesis (H_a):

The mean score of males is significantly different to the mean score of females in the spatial ability test.

The resulting p-value of Levene's test (p-value = 0.794) is greater than the significance level of 0.01, indicating that the variance is not significantly different. The t-test had a p-value of 0.959 (> 0.01). Therefore, the null hypothesis is not rejected and the mean score of males is not significantly different to the mean score of the females in the spatial ability test (refer to Table 4.17).

Table 4.17: Levene's test for equality of variances and the t-test for equality of means between males and females for the spatial ability test

	Levene's Test for Equality of Variances		t-test for Equality of Means						
Equality of variances	**F**	**Sig.**	**T**	**Df**	**Sig. (2-tailed)**	**Mean Diff**	**Std. Error Diff**	**95% Confidence Interval of the difference**	
								Lower	**Upper**
Equal variances assumed	0.069	0.794	-0.051	203	0.959	-0.142	2.787	-5.637	5.352
Equal variances not assumed			-0.051	197.9	0.959	-0.142	2.785	-5.635	5.350

4.5.2 Visual literacy between the school locations in the Life Sciences visual literacy test and spatial ability test

The location of the school determines to a large extent the level of student achievement (Perry & McConney, 2010). Orji (2013) mentioned that school location referred to urban-rural setting where urban schools are those in the municipalities or schools found in towns and rural schools are those located in the villages, whereas townships are situated in the semi urban areas. According to research done by Osokoya and Akuche (2012) schools' locations has a significant effect on students' cognitive attainment and performance in practical skills.

The results revealed that the urban schools performed best with a mean of 36.98%, followed by the rural schools with a mean of 30.79% and then township schools with a mean of 26.79% (refer to Table 4.18).

Table 4.18: Descriptive statistics of schools' locations in the Life Sciences visual literacy test

Score	Location	N	Minimum	Maximum	Mean	Std. deviation
LSVLT_ percentage	Urban	88	8	67	36.98	14.514
	Township	65	0	63	26.79	12.650
	Rural	72	4	63	30.90	14.531

Hypothesis 4:

Null hypothesis (H_0):
The mean score of the urban, township and rural school locations in the Life Sciences visual literacy test is not statistically significantly different to each other.

Alternative hypothesis (H_a):
The mean score of the urban, township and rural school locations in the Life Sciences visual literacy test is statistically significantly different to each other.

The ANOVA test is used to test for differences between groups when we have three or more groups. Since, for location, we have rural, township and urban, an ANOVA was run and the results are presented in Table 4.19.

Table 4.19: ANOVA for differences of schools' locations in the Life Sciences visual literacy test

ANOVA	Sum of Squares	df	Mean square	F	Sig.
Between Groups	4027.525	2	2013.762	10.263	0.000
Within Groups	43560.130	222	196.217		
Total	**47587.654**	**224**			

The null hypothesis is rejected since the p-value (= 0.000) is less than 0.01, thus there is a statistically significant difference between the mean scores for the different locations in the Life Sciences visual literacy test (refer to Table 4.19). Post-hoc Fisher's least significant difference tests were run to find where the differences are between the pairs. It should be noted that not all the SPSS output is presented here. Only the pairs and the corresponding p-values are given for conciseness.

Table 4.20: Post-hoc Fisher's least significant difference (LSD) tests for differences of schools' locations in the Life Sciences visual literacy test

Pair	p-value	Significant difference
Rural-township	0.088	No
Rural-urban	0.007	Yes
Township-urban	0.000	Yes

The results show that the difference between rural (30.90%) and township (26.79%) is not statistically significant. However, the differences between rural (30.90%) and urban (36.98%) and the differences between township (26.79%) and urban (36.98%) are statistically significant for the Life Sciences visual literacy test. Next the spatial ability test is considered.

Table 4.21: Descriptive statistics of schools' locations in the spatial ability test

Score	Location	N	Minimum	Maximum	Mean	Std. deviation
SAT_ percentage	Urban	80	4	82	42.22	21.629
	Township	60	7	82	43.19	19.840
	Rural	67	7	78	52.57	15.577

Hypothesis 5:

Null hypothesis (H_0):

The mean score of the urban, township and rural school location in the spatial ability test is not statistically significantly different to each other.

Alternative hypothesis (H_a):

The mean score of the urban, township and rural school locations in the spatial ability test is statistically significantly different to each other.

Table 4.22: ANOVA for differences of schools' locations in the spatial ability test

ANOVA	Sum of Squares	df	Mean square	F	Sig.
Between Groups	4504.982	2	2252.491	6.031	0.003
Within Groups	76196.730	204	373.513		
Total	**80701.712**	**206**			

The null hypothesis is rejected since the p-value equals 0.003 (< 0.01). Therefore, there is a statistically significant difference in the mean scores of the urban, township and rural schools in the spatial ability test (refer to Table 4.22). To further investigate where the differences are, some post-hoc tests in the form of t-tests were run. Again, not all the SPSS output is presented here. Only the pairs and the corresponding p-values are given for conciseness.

Table 4.23: Post-hoc Fisher's least significant difference (LSD) tests for differences of schools' locations in the spatial ability test

Pair	p-value	Significant difference
Rural-township	0.007	Yes
Rural- urban	0.001	Yes
Township- urban	0.771	No

The results show that the difference between township (43.19%) and urban (42.22%) is not statistically significant. However, the differences between rural (52.57%) and urban

(42.22%) and between rural (52.57%) and township (43.19%) are statistically significant.

4.6 STATISTICAL CORRELATIONS

4.6.1 Introduction

Correlation is a measure of the strength of the linear relationship between two quantitative variables (Field, 2014). A correlation coefficient (r) gives an indication of both the strength and direction of the linear relationship between two variables. The variables of interest here include, for example, the score of the Life Sciences visual literacy test, the score of the spatial ability test, the gender of the learners and the location of the schools.

Pearson correlation coefficient

The correlation between two continuous variables (e.g. LSVLT score, SAT score) was measured using the Pearson correlation coefficient. If the correlation is positive, the respondents performed well in both tests (or performed poorly in both tests) and if the correlation is negative they performed well in one test and poorly in the other one.

Spearman correlation coefficient

The correlation between an ordinal variable (e.g. location) and a continuous variable (e.g. LSVLT score, SAT score) was measured using a Spearman's correlation, where, if the correlation is positive, it means that respondents who selected high values in the ordinal scale also scored high in the test and those who selected low values in the ordinal scale also scored low in the test. If the correlation is negative, it means that respondents who selected high values in the ordinal scale scored low in the test and those who selected low variables in the ordinal scale scored high in the test. This correlation is also used for the correlation between a Likert-type question and a continuous variable.

Point-biserial correlation coefficient

The correlation between a continuous variable (e.g. LSVLT score, SAT score) and a dichotomous variable (e.g. gender) was measured using Point-biserial correlation. Since the coding for the gender variable was coded as 1 = Male and 2 = Female, the correlation would be interpreted as follows: If the correlation is positive, it means that respondents who scored high values in the test are female and vice versa. Respondents who scored low values in the test also selected mostly male. If the correlation is negative, it means that respondents who scored high values in the test also selected mostly male and vice versa. Respondents who scored low values in the test also selected mostly female.

Correlations for this study

First, we consider the correlation between the LSVLT and SAT scores. Since these are continuous correlations, a Pearson correlation coefficient was computed. The correlation between LSVLT and SAT equals to 0.226 with a significance level of 0.001 (refer to Table 4.24). This positive correlation is statistically significant, since p-value = 0.001 (< 0.01).

Table 4.24: Correlation between the total score in the Life Sciences visual literacy and spatial ability test

Variables correlated	Statistic	Value
LSVLT_ percentage and SAT_ percentage	Pearson Correlation Sig. (2-tailed) N	0.226 0.001 207

4.6.2 Correlation between the mean (Life Sciences visual literacy test) and gender variable

The correlation between gender and average performance in the Life Sciences was analysed using Point-biserial correlation. The correlation between Life Sciences visual literacy test and gender variable equals 0.070 with a significance level of 0.305 (refer to Table 4.25). Even though this is a weak positive correlation, the correlation is not statistically significant, since p-value = 0.305 (> 0.01).

Table 4.25: Correlation between the mean (LSVLT) and gender variable

Variables correlated	Statistic	Value
Gender and LSVLT_ percentage	Correlation Sig. (2-tailed) N	0.070 0.305 220

4.6.3 Correlation between the mean (spatial ability test) and gender variable

The correlation between spatial ability test and gender is equals to 0.004 with a significance level of 0.959 (see Table 4.26) which denotes a weak positive relationship however, the correlation is not statistically significant because the p-value is equal to 0.959 (> 0.01).

Table 4.26: Correlation between the mean (SAT) and gender variable

Variables correlated	Statistic	Value
Gender and SAT_ percentage	Correlation Sig. (2-tailed) N	0.004 0.959 205

4.6.4 Correlation between the mean (Life Sciences visual literacy test) and location variable

The correlation between Life Sciences visual literacy test and location of the schools is equal to 0.181 with a significance level of 0.006 (see Table 4.27) which denotes a weak positive relationship. This correlation is significant, since p-value = 0.006 (< 0.01).

Table 4.27: Correlation between the mean (LSVLT) and schools' locations

Variables correlated	Statistic	Value
Location and LSVLT_ percentage	Correlation Sig. (2-tailed) N	0.181 0.006 225

4.6.5 Correlation between the mean (spatial ability test) and location variable

The correlation between spatial ability test and location of the schools equals to -0.185 (which denotes a weak negative relationship) with a significance level of 0.008 (see Table 4.28). This correlation is statistically significant because the p-value is equal to 0.008 (< 0.01). This confirms what was found in Tables 4.21 and 4.23, i.e. that learners from rural schools performed statistically much higher than learners from urban and township schools.

Table 4.28: Correlation between SAT and schools' locations

Variables correlated	Statistic	Value
Location and SAT_ percentage	Correlation Coefficient Sig. (2-tailed) N	-0.185 0.008 207

4.6.6 Correlation between opinions of learners regarding teachers' frequent use of ERs to teach Life Sciences and the total score in the Life Sciences visual literacy test

The teachers' use of different ERs in a classroom may create a positive learning atmosphere where learners may get a chance of interacting with a variety of text that will grant them a solid background on content. A Spearman correlation between the frequent use of ERs by teachers and the total score in the Life Sciences visual literacy was calculated. A Spearman correlation was used, since the LSVLT score is continuous and the frequent use of ERs are all Likert-type variables coded as follows:

1 = Never

2 = Occasionally

3 = Frequently

4 = Always

Table 4.29: Spearman correlation coefficients between the frequent use of ERs to teach Life Sciences and total score in the Life Sciences visual literacy test

Variables correlated	Statistic	Value
Frequency of LTSMs use: Chalkboard (V33) and LSVLT_percentage	Correlation Coefficient Sig. (2-tailed) N	0.005 0.944 216
Frequency of LTSMs use: Internet (V34) and LSVLT_percentage	Correlation Coefficient Sig. (2-tailed) N	-0.018 0.799 204
Frequency of LTSMs use: Textbooks (V35) and LSVLT_percentage	Correlation Coefficient Sig. (2-tailed) N	-0.067 0.333 211
Frequency of LTSMs use: Video with animations (V36) and LSVLT_percentage	Correlation Coefficient Sig. (2-tailed) N	0.179 0.010[a] 216
Frequency of LTSMs use: Computer simulations (V37) and LSVLT_percentage	Correlation Coefficient Sig. (2-tailed) N	0.152 0.030 202
Frequency of LTSMs use: Physical models (V38) and LSVLT_percentage	Correlation Coefficient Sig. (2-tailed) N	-0.097 0.163 206
Frequency of LTSMs use: Exercise books (V39) and LSVLT_percentage	Correlation Coefficient Sig. (2-tailed) N	-0.115 0.098 209
Frequency of LTSMs use: Real life examples(V40) and LSVLT_percentage	Correlation Coefficient Sig. (2-tailed) N	0.046 0.515 201
Frequency of LTSMs use: Power point presentation (V41) and LSVLT_percentage	Correlation Coefficient Sig. (2-tailed) N	0.094 0.192 196
Frequency of LTSMs use: Smart phone (V42) and LSVLT_percentage	Correlation Coefficient Sig. (2-tailed) N	-0.067 0.336 206
Frequency of LTSMs use: Tablet PC (V43) and LSVLT_percentage	Correlation Coefficient Sig. (2-tailed) N	0.147 0.035 207
Frequency of LTSMs use: Whiteboard (V43) and LSVLT_percentage	Correlation Coefficient Sig. (2-tailed) N	0.091 0.189 208

[a] This p-value equals 0.0097 when taken up to 4 decimal spaces which is less than 0.01.

The only p-value that is less than 0.01 is the p-value associated with the use of video with animations. This correlation equals 0.179, thus, the more frequently the teacher uses video with animations in class, the better learners perform in the Life Sciences visual literacy test.

4.6.7 Correlation between learners' preference of ERs to study Life Science and total score in the spatial ability test

Again, a Spearman correlation coefficient was calculated and the results are given in Table 4.30.

Table 4.30: Spearman correlation coefficients between the frequent use of ERs to study Life Sciences and the total score in the spatial ability test

Variables correlated	Statistic	Value
Frequency of LTSMs use: Chalkboard (V33) and SAT_percentage	Correlation Coefficient Sig. (2-tailed) N	0.050 0.479 200
Frequency of LTSMs use: Internet (V34) and SAT_percentage	Correlation Coefficient Sig. (2-tailed) N	0.005 0.945 188
Frequency of LTSMs use: Textbooks (V35) and SAT_percentage	Correlation Coefficient Sig. (2-tailed) N	-0.101 0.161 196
Frequency of LTSMs use: Video with animations (V36) and SAT_percentage	Correlation Coefficient Sig. (2-tailed) N	-0.054 0.459 192
Frequency of LTSMs use: Computer simulations (V37) and SAT_percentage	Correlation Coefficient Sig. (2-tailed) N	-0.039 0.592 187
Frequency of LTSMs use: Physical models (V38) and SAT_percentage	Correlation Coefficient Sig. (2-tailed) N	-0.001 0.991 190
Frequency of LTSMs use: Exercise books (V39) and SAT_percentage	Correlation Coefficient Sig. (2-tailed) N	-0.109 0.131 193
Frequency of LTSMs use: Real life examples (V40) and SAT_percentage	Correlation Coefficient Sig. (2-tailed) N	-0.023 0.758 185
Frequency of LTSMs use: Power point presentation (V41) and SAT_percentage	Correlation Coefficient Sig. (2-tailed) N	-0.087 0.246 180
Frequency of LTSMs use: Smart phone (V42) and SAT_percentage	Correlation Coefficient Sig. (2-tailed) N	-0.104 0.152 191
Frequency of LTSMs use: Tablet PC (V43) and SAT_percentage	Correlation Coefficient Sig. (2-tailed) N	-0.014 0.846 191
Frequency of LTSMs use: Whiteboard (V43) and SAT_percentage	Correlation Coefficient Sig. (2-tailed) N	-0.200 0.005 192

The only p-value that is less than 0.01 is the p-value associated with the use of the whiteboard. This correlation equals -0.200, thus, the more frequently the teacher uses the whiteboard, the worse learners perform in the spatial ability test.

CHAPTER 5: SUMMARY, RECOMMENDATIONS AND CONCLUSIONS

“Too often the skill of closely reading what we experience visually is devalued in school over traditional print-based text”

- Unknown

5.1 INTRODUCTION

In the previous chapter the results of the empirical study were presented and the findings of the study were discussed in detail. Chapter 5 provides an overview of the study, together with the conclusions drawn and the resulting recommendations. The limitations encountered in conducting the study are described and the possibilities for future research are mentioned. In addition, the chapter will also attempt to link the spatial ability skills with the visual literacy skills in Life Sciences curricula as spatial development is inseparably related to science education because science includes an ability to use the senses to observe and make observations about the environment in the life, physical, and earth sciences. Spatial relationships in shapes, sizes, and location of objects provide information to help learners discriminate between objects in the environment. These same skills are needed in the visual arts, social studies (mapping) and technology. Furthermore, quantitative results and the literature reviewed are linked and the findings are discussed with a view of responding to the following research questions.

The primary research question that will address the visual literacy of Grade 10 Life Sciences learners is stated below:

What is the visual literacy of Grade 10 Life Sciences learners in cytology?

To probe if there is any relationship between the visual literacy of the learners and their gender the following secondary research question was posed.

- What is the difference between the visual literacy of males and females in cytology?

In order to examine the influence of school location on the visual literacy of the learners the following secondary research question was posed.

- What is the correlation between schools' locations and the learners' level of visual literacy?

In this chapter the primary research question will be discussed first followed by the two secondary research questions.

5.2 DISCUSSION OF THE FINDINGS IN TERMS OF THE RESEARCH QUESTIONS

The study sought to explore the visual literacy of Grade 10 Life Sciences learners in cytology. It further explored the spatial ability and visual literacy skills learners needed to be able to learn with ERs. The study explored gender representation in sampling as both males and females were involved to determine the relationship between gender and the level of visual literacy in cytology. It further explored if there is any correlation between the schools' locations and the learners' level of visual literacy.

Data was collected through questionnaires administered to learners. The collected data was analysed by the utility of a statistical programme called SPSS version 23. The study findings were summarized based on the objectives which guided the data collection and the theoretical framework. The theoretical framework suitable for this study was the cognitive theory of multimedia learning. The suitability is enhanced by how learning is active when information is presented in both pictures and words, enabling learners to integrate acquired knowledge with existing knowledge; it is the prior knowledge of the learner that determines how much information can be held simultaneously in working memory. The findings of the study are presented as follows.

5.2.1 The visual literacy of Grade 10 Life Sciences learners in cytology

- ***Learning with the use of ERs***

The results revealed that most learners indicated that they understood Life Sciences better when presented in three modes, where they understood it better if it's text coupled with diagrams, drawing or real life examples. This is also evident as the results also showed that learners preferred 2D drawings to best enhance their knowledge of an animal cell. This may explain why learners prefer to use exercise books and textbooks to study Life Sciences as it may contain most of the desired modes (text, 2D drawings and diagrams).

According to Cook (2006) cognitive load theory provides a theoretical foundation for designing instructional materials to best enhance learning. The basic premise of this theory is that learning will be hindered if the instructional materials overwhelm learners' cognitive resources. According to this theory, the hindrance placed on working memory can be reduced by either increasing its capacity or reducing its cognitive load. Working memory has two components, a visuospatial sketchpad and a phonological loop, that initially process visual and verbal information independently. Therefore, combining text messages with other ERs such as pictures and sound, can increase capacity of working memory and enhance learning (Chandler & Sweller, 1992). This finding is not in line with the theory of cognitive load because teachers are not always using dual mode to teach Life Sciences. They to some extent limit the capacity of working memory of the learners by using ERs that give too much information in one mode. Furthermore, how learners interact and interpret scientific visualizations to actively construct meaning is very important in undergraduate science education because if learners cannot accurately decode ERs they will struggle with approximately 40% of the content in assessment tasks. Therefore, incorporating both pictures and text in learning can increase learners' learning outcomes (McTigue & Flowers, 2011). In addition, the correlation between learners' preference of ERs to study Life Science (internet and physical models) and the total score in the Life Sciences visual literacy test indicated a negative correlation however significant between internet and physical models.

- **The use of ERs to enhance visual literacy skills of learners**

The findings showed that teachers always used chalkboards, textbooks and exercise books to teach Life Sciences more than any other ERs. The ERs learners use to study and ERs they prefer to use to study Life Sciences resonate with their opinions on the teachers' choice of ERs to teach Life Sciences. Therefore, teachers mostly use chalkboard, exercise books and textbooks and the learners found these resources very useful. One can say that the choice a teacher makes on ERs suitable to teach a certain phenomenon has an influence on the learners' understanding and preference of ERs used to study.

This finding is (to some extent) at odds with that of Mnguni (2014) where he states that experts (teachers, authors, and researchers) assume that what they perceive as good teaching and learning aid in Life Sciences will necessarily be good for promoting visual literacy and understanding of concepts amongst learners. The assumptions mentioned above are resonated by McTigue and Flowers (2011), namely, that students' opinions on accessible diagrams and publisher decisions on grade-level diagrams are not well aligned. Hence the learners consider salient features (colour, shape, lines and or texture) as important factors in a diagram or drawing that it is intended to represent.

- **Interpretation of ERs by learners**

Learners were asked to examine the differences and similarities between a plant and an animal cell. They were asked to only mention the differences they could observe between the two cell types. The differences mentioned were based on the main characteristics of the cells. Salient features like colour and shape were infrequently observed.

These findings are consistent with previous research by Schönborn and Anderson (2006) who state that there are factors that often affect learners' ability to interpret ERs. These factors include learners' general reasoning ability to interpret the ERs, making sense of the ER, the nature of the mode in which the desired phenomenon is represented by the ER, the learners' understanding (or lack of) of the conceptual knowledge represented by the ER and salient characteristics on the ER which could obscure learners' focus. These factors are prerequisites for sound visualization and interpretation of ERs and should be properly addressed to enhance visual literacy of our learners. Therefore, learners were able to use visuospatial skills (depth perception / recognition of depth cues) and visual literacy skills (focus) to "make concrete observations". The salient features on the ERs did not obscure the learners' focus. They were able to interpret the ERs without making the salient features the main focus.

Research demonstrates that learners use different characteristics like colour, shape and complexity to make sense of the ER (Mnguni, Schönborn & Anderson, 2016). The more complex the ER is the more they do not understand it. The difficulty to understand it may arise from the lack of learners' prior knowledge of all the concepts that are represented by the ER, the nature of the ER, how well or poorly its features represent the phenomena it is designed to represent and the total reasoning capacity that the learner has available for interpreting the ER (Schönborn & Anderson, 2009). The lack of these factors may be due to the ER teachers use to teach Life Sciences or the ERs textbooks used to present a certain phenomenon, or lack of visuospatial skills to work with the ER. This is evident as the learners provided reasons that they preferred 2D diagrams rather than any other ERs. Their reasons included that the ERs are simple, not complicated and that they are used to it (they have seen it more frequently). Therefore, if the learners have never seen the ER before, it tends to overwhelm them and makes them unable to interpret the ER correctly.

On the contrary, in this study learners chose physical models as their first preference to enhance their understanding of cells and a table and mind map as their last preference.

This implied that if learners were frequently exposed to ERs it would improve their visuospatial skills to interpret and reason with the physical models. These skills may be improved by following some of the guidelines suggested by Schönborn and Anderson (2009) that teachers should make the conceptual knowledge depicted by ERs explicit to learners by following the same approach used with other lessons without ERs, explaining and clarifying to learners what particular conceptual knowledge the ER was and what it was not representing. In addition teachers should ensure understanding of the knowledge of the visual language and conventions used by ERs through explicitly teaching the learners with different ERs so that they could gain necessary visual vocabulary and ER processing skills.

- **Externalisation skills of learners**

When learners were asked to draw a mitochondrion, they drew an oval structure with mostly incorrectly labelled chloroplast labels. Only a few attempted to draw 3D drawings. The incorrectly labelled structures may result in confusion between a mitochondrion and a chloroplast or difficulties with applying skills learned in one situation to a new situation.

According to Mnguni (2014) visualisation is a process that consists of three main stages namely; internalisation, conceptualisation, and externalisation. In this model internalisation refers to the process in which the sense organs work with the brain to absorb information, conceptualisation is a process of interpreting what has been absorbed and the construction of mental pictorial and verbal models in short term memory. Externalisation is communication of the pictorial and verbal models. The level of complexity is from internalisation to externalisation (see Appendix A).

According to Schönborn and Anderson (2009) visualization skills can be strengthened by allowing learners to generate their own diagrams as this is a powerful tool for improving scientific visual literacy. This is called expression, where one applies knowledge in new situations, or translates mental models into visual models (Mayer, 2003). The diagrams may be concept maps or flow charts which will enable them to structure, organize and compare concepts graphically. The planning, organizing and comparing of skills unconsciously strengthens their processing skills of other abstract ERs and stimulates their metacognitive thinking skills.

- **Conceptualisation skills of learners**

Learners scored highly in questions that ordered lower visuospatial skills like arrange, order, compare in the Life Sciences visual literacy test and the spatial ability test but scored lower in the questions that ordered high cognitive skills like mental rotation, analyse, complete (cognitively), imagine, relate, infer, predict, arrange.

According to Mnguni, Schönborn and Anderson (2016) learners who have an average level of visual literacy have a strong chance of developing and using visualisation skills below average level. Therefore, the more skills learners possess the higher they will move on the visual literacy scale and they will be able to think, learn and communicate visually. This shows that learners are not explicitly taught visual literacy skills.

5.2.2 The relationship between gender and visual literacy

When attempting to address the question whether gender has an influence on the level of visual literacy of learners it was found, in this study, that although females slightly outperformed males (with a percentage or two) in the LSVLT score and SAT score, respectively, this difference is not statistically significant. This may indicate that the learners possess the same level of visual literacy and possess an equal amount of conceptual reasoning despite their gender. This is in contrast to many research papers since many science education researchers have reported that gender influences students' understanding and their attitude towards science (Piraksa et al., 2014). Those research papers resonate well with a study conducted by the Organisation for Economic Cooperation and Development of gender equity in schools, where the results revealed that girls performed worse than boys in mathematics and science education (Hsi & Hoadley, 1997). Acar's, Buber's and Tola's (2015) findings revealed that females outperformed males in a physics conceptual knowledge test. However, no significant difference between males and females was found in respect of scientific reasoning.

To investigate the role that spatial thinking plays in learning, problem solving, and gender differences in high school geometry, spatial thought was examined along with its counterpart verbal-logical thought. The results of Piraksa et al. (2014) reveal that whereas males and females differed in spatial visualization and in their performance in high school geometry, they did not differ significantly in logical reasoning ability or in their use of geometric problem-solving strategies. Gender comparisons showed that males outperformed female students in mental rotation in a study executed by Piraksa et al. (2014). Findings of this study are (to some extent) at odds with those of Piraksa et al. (2014) and Hsi and Hoadley (1997).

5.2.3 Correlation between schools' locations and level of visual literacy of the learners

The location of a school does have an influence on the visual literacy of the learners. In the LSVLT the highest performing to the lowest performing were urban areas, followed by rural areas and then township areas. Urban areas performed the best with a statistically significant difference compared to the other areas and rural and township areas performed poorly but did not have a statistically significant difference compared to each other.

In the SAT a different pattern was found where rural areas performed the best, followed by township and then urban areas. Rural areas performed the best with a statistically significant difference to the other areas and township and urban performed worse than rural however, but did have a not statistically significant difference compared to each other.

The findings of this study regarding the LSVLT align well with those of previous research. According to Osokoya and Akuche (2012) a school's location has a significant effect on students' cognitive attainment and performance in practical skills. When learners attend schools located in a resourced to a well-resourced environment, they tend to perform better than those who attend from un-resourced or under resourced environments. In this study, the learners who are classified to be in high socio-economic environments performed better than learners whom the author classified as being from low and middle socio-economic environments in the LSVLT. This may be due to the exposure of a variety of teaching and learning resources, like Wi-Fi, to learners in urban areas.

The learners who are classified as being in a low socio-economic environment performed better than learners whom the author has classified as being of high and middle socio-economic environments in the SAT. This may be that learners in schools located in low socio-economic environments possess general better spatial ability skills than learners from schools in high and medium socio-economic environments because they rely more on textbooks to learn. Therefore; they are able to successfully apply those skills to respond to the SAT.

This finding is not in line with those of Morgan, Farkas, Hillemeier and Maczuga (2009) where they state that children from low socio-economic environments develop academic skills slower than learners from higher socio-economic environments. Their findings state that low socio-economic environments in childhood are related to poor cognitive development, language and memory, because the school systems in low socio-economic environments are often under resourced, negatively affecting students' academic progress and outcomes (Aikens & Barbarin, 2008).

In addition, even though learners from environments classified as rural outperformed learners from an environment classified as township, the score difference is not statistically significant. However, the difference in scores between urban and township or rural is statistically significant, which may indicate that learners from schools that are located in environments that have high socio-economic status possess basic to moderate VL skills compared to learners from schools located in low and middle socio economic environments who only possess adequate spatial ability skills.

5.3 SUMMARY

Learners need extensive exposure to ERs when they are being taught Life Sciences. They need to be educated to interpret and reason with ERs used to teach them. In that case teachers need to incorporate different ERs that would stimulate different senses in their lessons, ERs that will also enhance visual literacy skills. To improve the visual literacy skills of learners, teachers should explicitly address the key factors of the ERs, that is, what the ER is representing, and help the learners unfold meaning from it.

Despite the extensive need to incorporate ERs into Life Sciences curricula, gender on its own has little impact on the level of visual literacy of learners in cytology as both male and females performed more or less equally in the tests. However, school location does play a role in the level of visual literacy of the learners. Schools located in high and medium socio-economic environments did not perform as well as the ones located in low socio-economic environments (for the spatial ability test). This may be due to the manner in which the author has classified the schools according to their locations.

The learners are exposed to few ERs when they are taught Life Sciences. This result in a few visual literacy skills being developed to be able to understand phenomena represented by the ER. In that regard the findings outlined that learners performed better in the questions that required low visuospatial skills than in the questions that required high visuospatial skills. Therefore, the fewer visuospatial skills the learners possess the more learning difficulties they will experience when working with different ERs.

5.4 IMPLICATIONS OF THE STUDY

This study suggests evidence for a call to integrate different strategies that will enhance visual literacy in the Life Sciences curricula. Therefore, teachers should explicitly address and develop visual literacy skills through designed instructional programmes that would promote diversity in the cognitive images formed through the use of formalised ERs.

Formal training of teachers should be introduced at tertiary level on how to use different ERs to teach Life Sciences phenomena. For teachers who are already in the field, the Department of Basic Education should develop workshops where teachers are trained on how to implement effective teaching that will develop visual literacy of the learners and how to use ERs that will enable effective visual thinking, learning and communication by learners. Also teachers have to be trained to design different ERs that will stimulate different senses in formal teacher training programmes.

The study appears to support the argument that learners still encounter learning difficulties when learning with ERs. They fail to correctly visualise and interpret ERs in the manner in which the ER and the lesson were intended to. The teaching tools which teachers use are not effectively developing visual literacy skills and visuospatial skills.

5.5 SIGNIFICANCE OF THE STUDY

In addition to the provision of some directions for future research, the study findings have made contributions to the literature on visual literacy in Life Sciences teaching and learning with ERs, since research in this area is relatively new and the related literature is still limited.

The learners are still at an early stage in high school where choosing the subjects for their career paths is very important. Therefore, the study findings should contribute to the understanding of the development of visual literacy skills in Life Sciences curricula and the modes of ERs learners prefer and understand when learning. This will ensure that they are able to understand phenomena better and successfully respond to assessment tasks.

The study also contributed in indicating that learners in Grade 10 Life Sciences were on low to average levels of visual literacy. Therefore, this indicates that explicit teaching of visual literacy is no longer optional but a necessity.

5.6 LIMITATIONS OF THE STUDY

There were problems that arose from the data collection process. Some of the questions in the questionnaire were left unanswered, especially in the spatial ability test. This may be due to time frame as the questionnaires were administered after school. Furthermore, most of the learners left the spatial ability test questions blank as they complained that they lack understanding or skills to solve the problems.

During administration of the questionnaires, most learners requested to consult their textbooks and their teachers' notes as they said they did not remember the content clearly.

There were two features of the research design which may have affected the quality of the findings. The first was the decision to make use of questionnaires, and not incorporate a group discussion with the learners after they have responded to the questionnaires. Although there were sound reasons for this decision (see Section 3.1.1), the absence of the discussions limited the researcher from obtaining feedback from the learners' experience on the questionnaires. Secondly, the findings of this study cannot be generalised to a broader population in South African Life Sciences classrooms in high schools. The purpose of this study was not to generalise but to get a deeper understanding of a specific topic however this may be extended to other environments or similar locations if put in context. In addition, although some of the schools were located in high socio-economic locations they possessed the characteristics of a medium to low socio-economic status.

5.7 RECOMMENDATIONS

The study recommends three aspects based on the study findings. These recommendations are based on Life Sciences curricula, improving learners' visual literacy skills. Schönborn and Anderson (2006) suggested that to improve the visual literacy skills of learners in Life Sciences curricula, the use of ERs should be reinforced by providing the ERs to both teachers and learners and helping the teachers with necessary workshops to equip them with skills needed to explicitly teach learners using ERs.

Recommendations for Life Sciences curricula in high schools

The learners had complaints about the level of difficulty of the spatial ability test. The researcher suggests that such tests should be incorporated in the Life Sciences curricula where visual literacy can be thought of as part of the science subject. Visuospatial ability skills are independent from visual literacy and Life Sciences. The findings showed that learners possessed insufficient spatial ability skills to be able to successfully respond to assessment tasks incorporated with ERs.

Recommendations for improving visual literacy skills of learners

The study shows that teachers decisions on the ERs used to teach in Life Sciences have an impact on the learners understanding of phenomenon. Therefore, teachers should use ERs that would require learners to use visualisation skills they had already acquired to understand the ER. The results also revealed that the teachers always use chalkboards, textbooks and exercise books to teach Life Sciences. The researcher suggests that the Department of Education should provide workshops on how to use ERs in Life Sciences classrooms to transform abstract concepts into more concrete ones. Furthermore it is recommended that at the tertiary institutions in the Faculty of

Education, visual literacy should be part of the methodology modules curricula.

Recommendations for further research

This study recommends the following for further research:

- Similar research should be replicated in other provinces to determine the level of visual literacy of the learners in Life Sciences.
- A study should be conducted on different ERs that could be used in Life Sciences to enhance better understanding of Life Sciences phenomena and at the same time improve visualisation skills of learners.
- A study should be conducted to investigate the relationship between visual literacy, spatial abilities and Life Sciences content.
- A study should also be conducted to explore the level of visual literacy of primary school learners.
- A study should be conducted on the fact that schools in low socio-economic environments outperformed schools from high socio-economic environments in general tests.

5.8 CONCLUDING REMARKS

A quantitative approach using a survey study was conducted. The theoretical framework of this study was developed from literature. This study was guided by the concept of visual literacy and the theory of multi-media learning.

The data of this study was collected through administration of a questionnaire. There were 225 Grade 10 Life Sciences learners as respondents. The study explored the visual literacy of Grade 10 Life sciences learners in cytology and the spatial ability skills learners needed to be visually literate.

The findings of this study indicated that Grade 10 Life Sciences learners lacked average visual literacy skills. The teachers always use the traditional chalkboard, textbook and exercise books to teach which inhibited the development of visual literacy skills of learners. The learners' preference of ERs to best enhance their knowledge of cells is not aligned with the ERs teachers use to teach Life Sciences. The limited ERs teachers expose to learners, somehow limits their visualisation skills. The learners portrayed confusion between a mitochondrion and a chloroplast that appeared similar in structure. This may suggest that the conceptual knowledge depicted by the ER used to present a mitochondrion or chloroplast was to some extent not made explicit to learners. The learners struggle with more difficult questions which may suggest that learners are limited to low level visualisation skills in visual literacy due to limited use of ERs by their teachers. The teachers use simple ERs to present phenomena in Life Sciences.

The findings also indicated that learners could not simultaneously use visuospatial skills and visual literacy skills when requested to draw a mitochondrion. They rather drew structures incorrectly labelled. This might show that the learners were unable to use the visuospatial skills and visual literacy skills simultaneously required to draw. For instance, skills like recalling and mental rotation at the same time. The less visuospatial skills the learners possessed the more learning difficulties they had when learning using ERs in Life Sciences.

When learners are given ERs that they are unfamiliar with or that are not used by their teachers or reflected in their textbooks, they find it difficult to interpret them or relate the ERs with each other. It discourages the learners to work with the ER and misleads them to focus on certain parts of the ERs rather than the ERs holistically. These learning difficulties may result in limited skills to work with ERs.

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APPENDIX A: TABLE OF COGNITIVE COMPETENCE

Visualization	**INTERNALIZATION VISUAL MODE**		**CONCEPTUALIZATION OF VISUAL MODES**		**EXTERNALIZATION OF VISUAL MODES**	
Level	1. OBSERVE *See or notice different visualization modes*	2. PERCEIVE *Interpret what is seen*	3. VISUALIZE *Act or power of forming visual modes not present to the eye*	4. VISUOSPATIAL ABILITY *Denoting the ability to comprehend and conceptualize visual representations and spatial relationships*	5. SYNTHESIZE *Expressing mental visual modes as external visual modes*	6. EVALUATE *Make judgments based on mental visual modes or external visual modes*.
Visualization skills	See different images or objects, notice difference, movement and so forth.	Ground perception Depth perception Pattern detection Use image Interpret phenomena	Imagine Draw objects cognitively	Complete images cognitively Mental rotation Analyze and Interpret images	Arrange and re-arrange Sketch or draw objects from a written text Propose alternative representation of phenomena diagrammatically	Predict Discriminate Relate Infer
Blooms Cognitive tasks	defines, describes, identifies, knows, labels, lists, matches, names, outlines, recalls, recognizes, reproduces, selects, states	comprehends, converts, diagrams, defends, distinguishes, estimates, explains, extends, generalizes, gives an example, infers, interprets, paraphrases, predicts, rewrites, summarizes, translates	applies, changes, computes, constructs, demonstrates, discovers, manipulates, modifies, operates, predicts, prepares, produces, relates, shows, uses	analyzes, breaks down, compares, contrasts, diagrams, deconstructs, differentiates, discriminates, distinguishes, identifies, illustrates, infers, outlines, relates, selects, separates, solves	categorizes, combines, compiles, composes, creates, devises, designs, explains, generates, modifies, organizes, plans, rearranges, reconstructs, relates, reorganizes, revises, rewrites, summarizes, tells, writes	appraises, compares, concludes, contrasts, criticizes, critiques, defends, describes, discriminates, evaluates, explains, justifies, relates, summarizes, supports
Assessment task related	Test / examination	Assignments	Practical tasks		Research projects and or investigations	
	Knowledge, comprehension		Application		Analysis, synthesis and evaluation	
Cognitive level effort	LOW LEVEL COGNITIVE EFFORT		HIGH LEVEL COGNITIVE EFFORT			
NEED FOR PRIOR KNOWLEDGE INCREASES TOWARDS THE RIGHT						

APPENDIX B: LIFE SCIENCES VISUAL LITERACY TEST

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

VISUAL LITERACY QUESTIONNAIRE

For office use only	
School number	
Respondent number	

Instructions

- *Do not write your name or the name of your school on any page*
- *Answer all the questions.*
- *Write neatly and legibly.*
- *Do not write on the shaded areas*

SECTION A (BIOGRAPHICAL DATA)

Answer the following questions by writing OR crossing (X) in the correct box. **FOR OFFICE USE**

1. What is your age in years? [ ] **V1**

2. What is your gender? **V2**

Male	1
Female	2

3. Area of school where you are attending **V3**

Urban area	1
Township area	2
Rural area	3

4. **In the following list, mark all the subjects that you are currently doing.**

Accounting	1	**V4**	
Business Economics	2	**V5**	
Economics	3	**V6**	
Geography	4	**V7**	
History	5	**V8**	
Life Orientation	6	**V9**	
Life Sciences	7	**V10**	
Mathematics	8	**V11**	
Physical Sciences	9	**V12**	
Mathematical Literacy	10	**V13**	
Computer Application Technology	11	**V14**	
Any other (Specify)		**V15**	

5. **Do you understand Life Sciences phenomena better when presented as (You may choose MORE than ONE option)**

Text only	1	**V16**	
Diagrams	2	**V17**	
Drawings	3	**V18**	
Photos	4	**V19**	
Physical models	5	**V20**	
Real life examples	6	**V21**	
Videos	7	**V22**	

6. **Which of the following do you use when studying Life Sciences? (You may choose MORE than ONE option)**

Internet	1	**V23**	
Textbooks	2	**V24**	
Video (with Animations)	3	**V25**	
Computer simulations	4	**V26**	
Physical models	5	**V27**	
Real life examples	6	**V28**	
Exercise books	7	**V29**	

7. **What is the most important reason you chose to do Life Sciences as a subject? (You may choose only ONE REASON).**

Content	1
Curiosity (exploring and discovering)	2
Easy	3
Hands-on activities (e.g. Dissection)	4
Intrinsic interest	5
Needed for further education	6
Parents' recommendation	7
Teachers' recommendation	8

V30	

8. What is your home language?

Afrikaans	1
English	2
Ndebele	3
Sepedi	4
Swati	5
South Sotho	6
Tsonga	7
Tswana	8
Venda	9
Xhosa	10
Zulu	11

V31	

9. **How often does your teacher explain Life Sciences concepts in your mother tongue?**

Never	1
Sometimes	2
Always	3

V32	

10. **To what extent does <u>your teacher</u> use the following teaching and learning support material when teaching Life Sciences?(Answer each question)**

	Never	Occasionally	Frequently	Always		
Chalk board					**V33**	
Internet					**V34**	
Textbooks					**V35**	
Video with animations					**V36**	
Computer simulations					**V37**	
Physical models					**V38**	
Exercise books					**V39**	
Real life examples					**V40**	
PowerPoint presentation					**V41**	
Smart phone					**V42**	
Tablet PC					**V43**	
White board					**V44**	

11. How would you describe the teachers' use of visual examples in Life sciences?

Resourceful	1	**V45**	
Average	2		
Un-resourceful	3		

12. Are you currently taking any courses focusing on art or photography at school?

Yes	1	**V46**	
No	2		

13. To what extent do <u>you</u> use the following learning support material when you are studying Life Sciences?

	Never	Occasionally	Frequently	Always
Computer simulations				
Diagrams				
Drawings				
Internet				
Exercise books				
Physical Models				
Textbooks				
Video with animations				

V47	
V48	
V49	
V50	
V51	
V52	
V53	
V54	

SECTION B (LIFE SCIENCES)

1. **How many colors (including white and black background) can you see in Figure A?**

V55	

FIGURE A

…………………………………………………………………….

2. What are the most obvious external and internal differences you can observe between the two sketches?

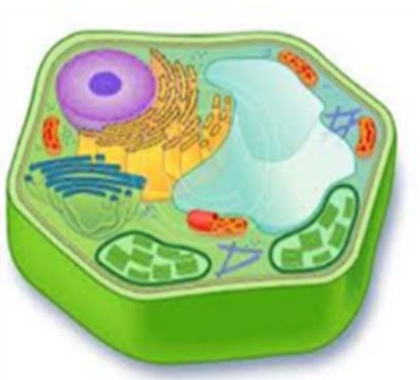

FIGURE B **FIGURE C**

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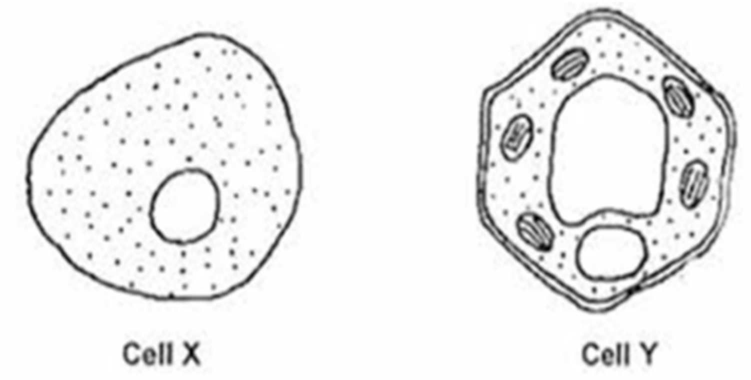
V56	
V57	
V58	
V59	
V60	

3.1. According to the sketches below, which cell is a plant cell and which one is an animal cell? Tick in the appropriate box.



	Animal cell	Plant cell
Cell X	1	2
Cell Y	1	2

V60	
V61	
V62	
V63	

3.2 Why and how could you decide which one was an animal cell and the other a plant cell?

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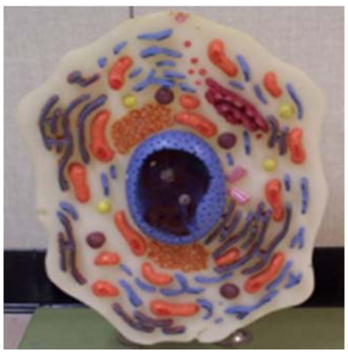
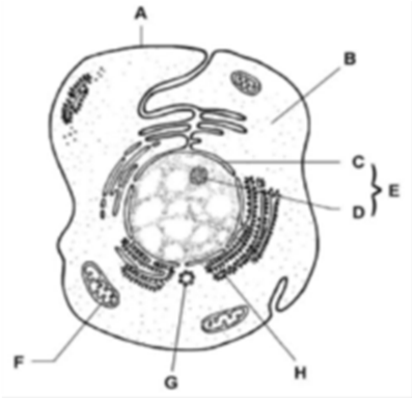
V64	
V65	
V66	
V67	

4.1 Which of the following figures do you think will best enhance your knowledge of an animal cell?





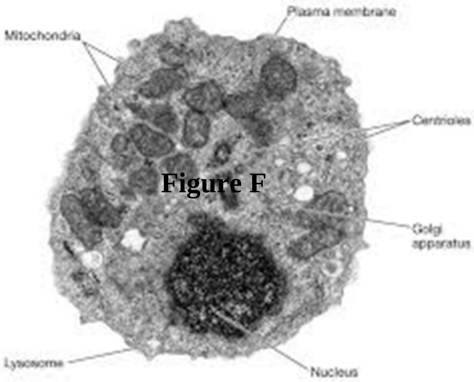


Figure F

V68	

…………………………………………………………………………………………………

4.2 Explain your answer as indicated in 4.1.

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…………………………………………………………………………………………………
…………………………………………………………………………………………………
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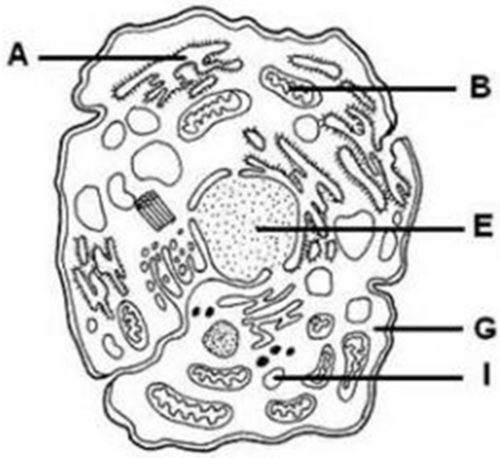
V69	
V70	
V71	

5. Study the diagram below and answer the questions that follow.



An animal cell

5.1. Which label (letter) represents the part of the cell where most energy is generated?

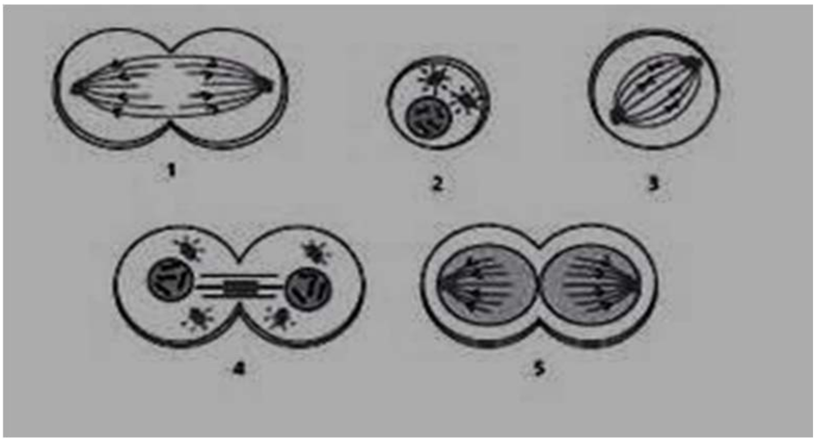
V72	

……………………………………………………………………………………………

5.2. Draw and label organelle labeled B.

V73	
V74	
V75	
V76	
V77	

6. **The diagram below shows five cells in various phases of mitosis in an animal cell. Note the cells are not arranged in order. Use the diagram to answer the questions that follow.**



6.1 Which images depict the following phases of mitosis? Write down only the correct number in the appropriate spaces.

Prophase		**V78**	
Metaphase		**V79**	
Anaphase		**V80**	
Telophase		**V81**	

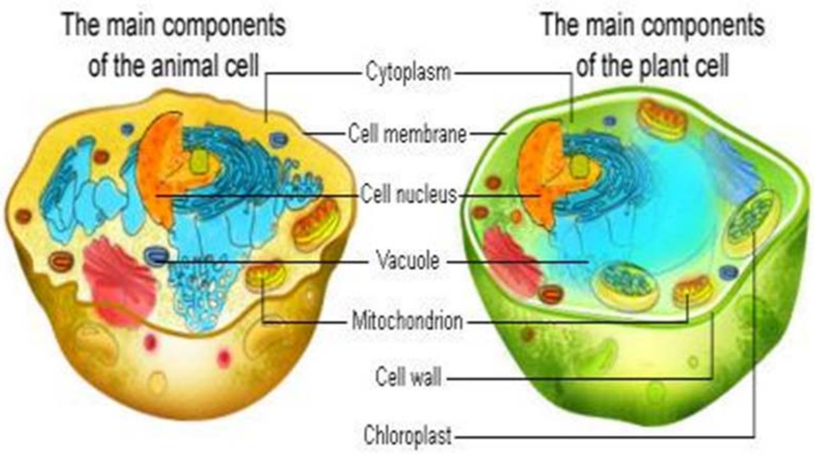
6.2 Which models depict the following phases of mitosis in an animal cell listed on the table? Write down the correct number in the appropriate space.

1 2 3 4 5

Prophase		**V82**	
Metaphase		**V83**	

Anaphase			**V84**	
Telophase			**V85**	

7.1 The following four figures present plant and animal cell structures in different ways. Please rank the figures below (using 1, 2, 3 and 4) in your order of preference to understand the structure of a cell. Number 1 will be the figure you prefer the most.



V86	
V87	
V88	
V89	

Figure G

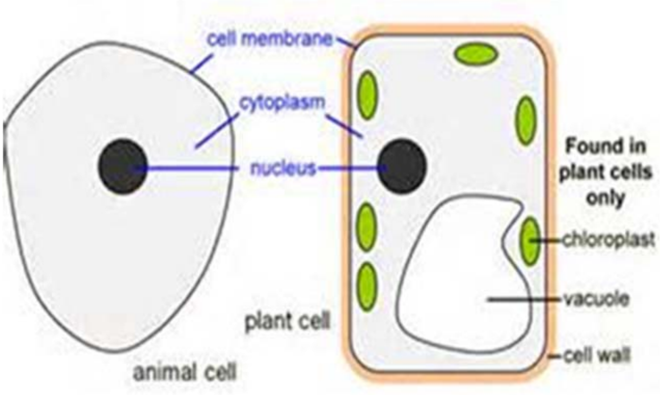


Figure H

Figure G	
Figure H	
Figure I	
Figure J	

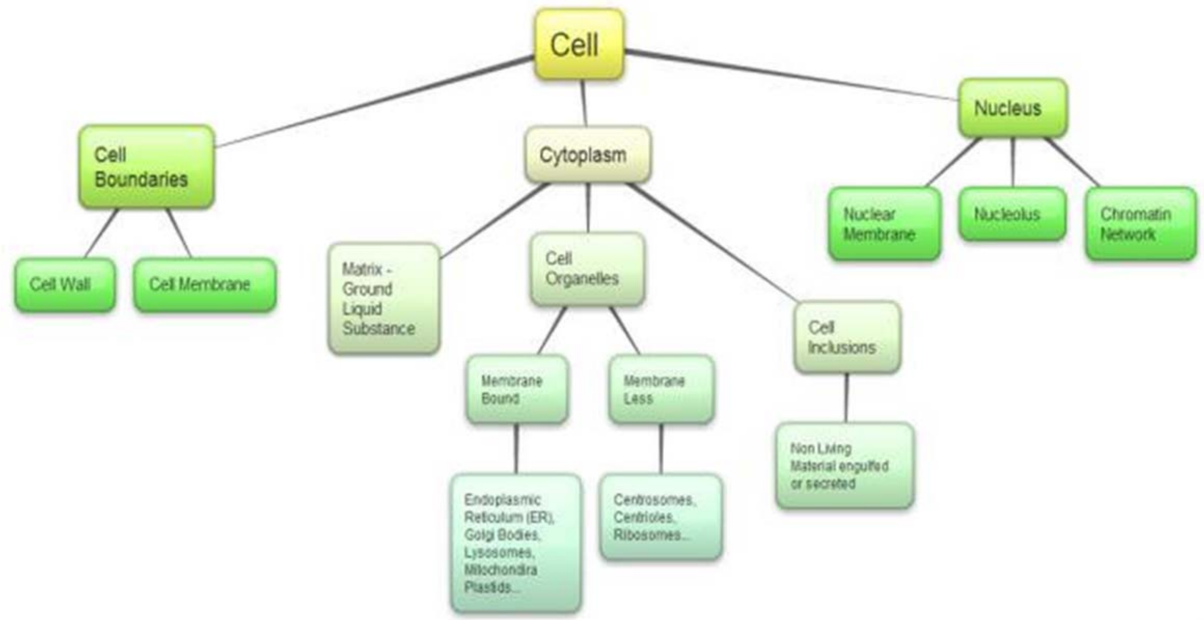


Figure I

Cell part	Plant, Animal or Both	Function
Cell membrane	Both	Controls what enters and leaves the cell
Cytoplasm	Plant	Protects the inner organelles
Nucleus	Both	Cytosol and cell organelles outside the nucleus
Ribosomes	Both	Makes proteins

Figure J

V90	
V91	
V92	
V93	

7.2. Motivate why you would choose one of the above figures as your <u>first choice</u> to explain and illustrate cell structure best. You may give MORE THAN ONE reason

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7.3. Motivate why number 4 was listed as your last choice to explain and illustrate cell structure. You may give MORE THAN ONE reason

V94	
V95	
V96	
V97	

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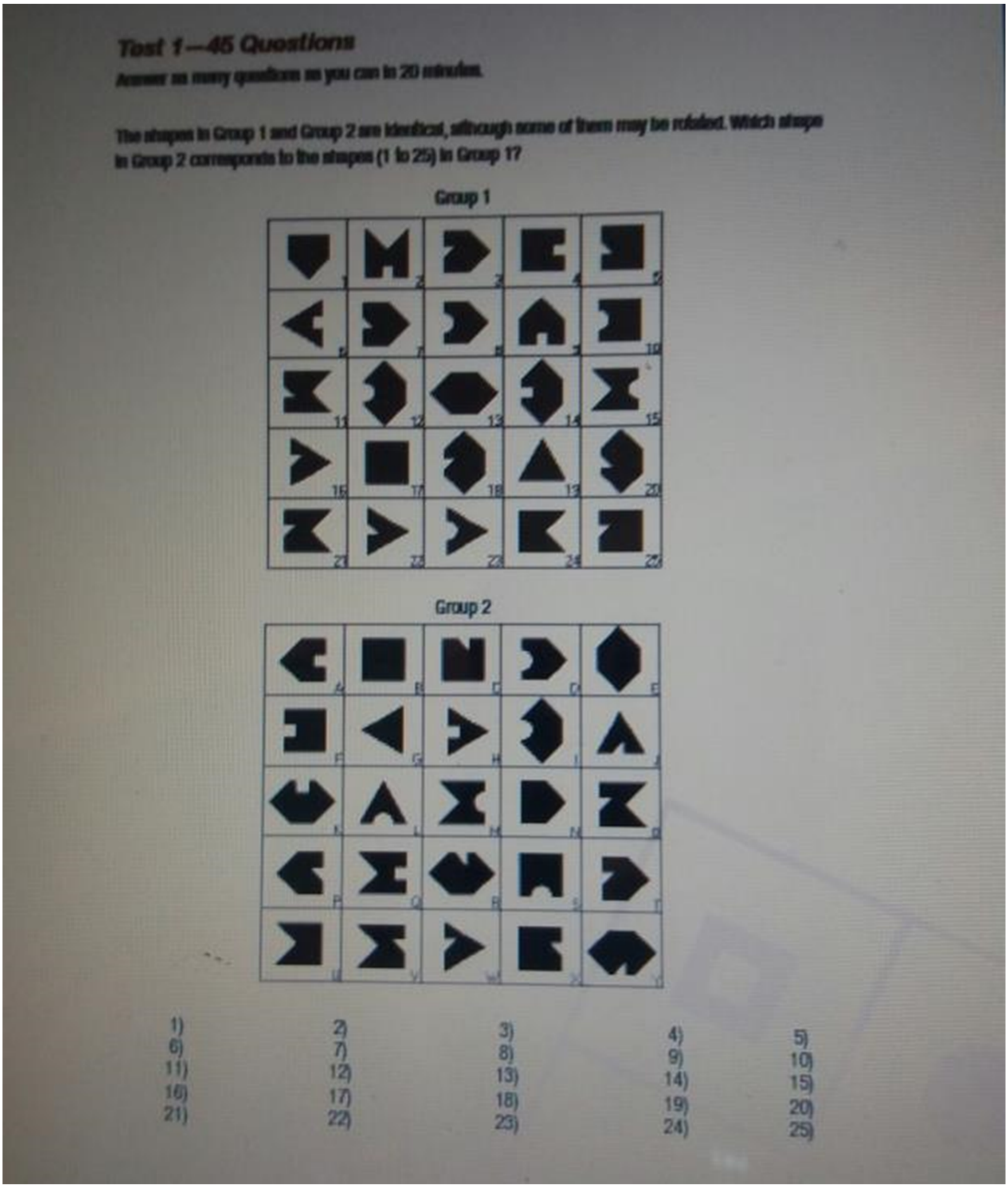
APPENDIX C: SPATIAL ABILITY TEST



Test 1—45 Questions

Answer as many questions as you can in 20 minutes.

The shapes in Group 1 and Group 2 are identical, although some of them may be rotated. Which shape in Group 2 corresponds to the shapes (1 to 25) in Group 1?

Group 1

Group 2

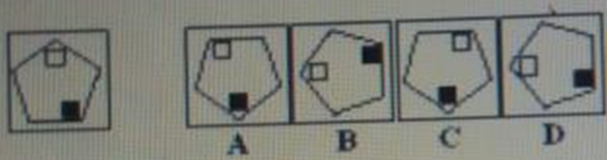
1)	2)	3)	4)	5)
6)	7)	8)	9)	10)
11)	12)	13)	14)	15)
16)	17)	18)	19)	20)
21)	22)	23)	24)	25)

In the figures shown below, one of the shapes (A-D) is identical to the first figure but has been rotated.

26) Which figure is identical to the first?

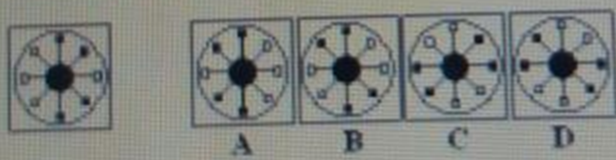
A B C D

27) Which figure is identical to the first?



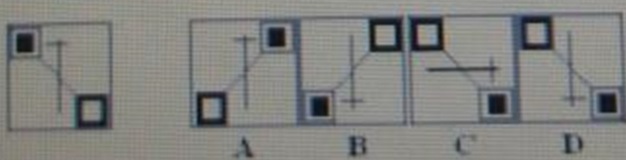
A B C D

28) Which figure is identical to the first?



A B C D

29) Which figure is identical to the first?

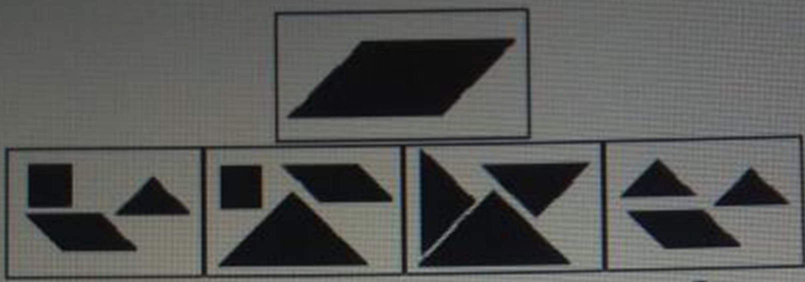


A B C D

30) Which figure is identical to the first?

A B C D

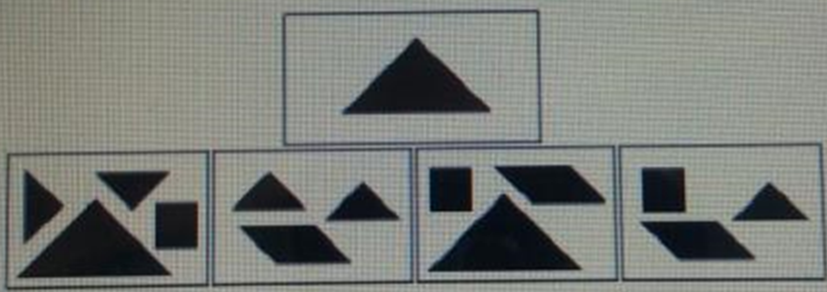
31) Which group of shapes can be assembled to make the shape shown?



A B C D

A B C D

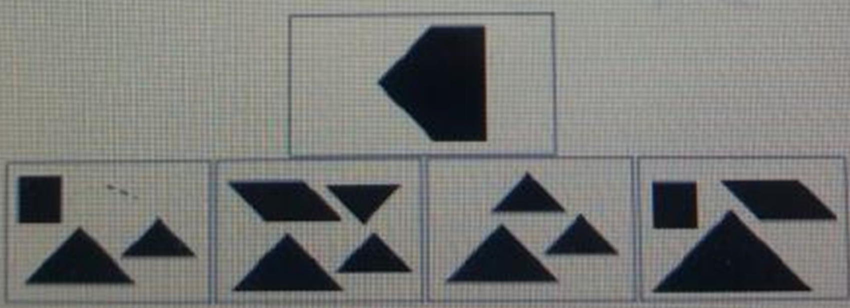
32) Which group of shapes can be assembled to make the shape shown?



A B C D

A B C D

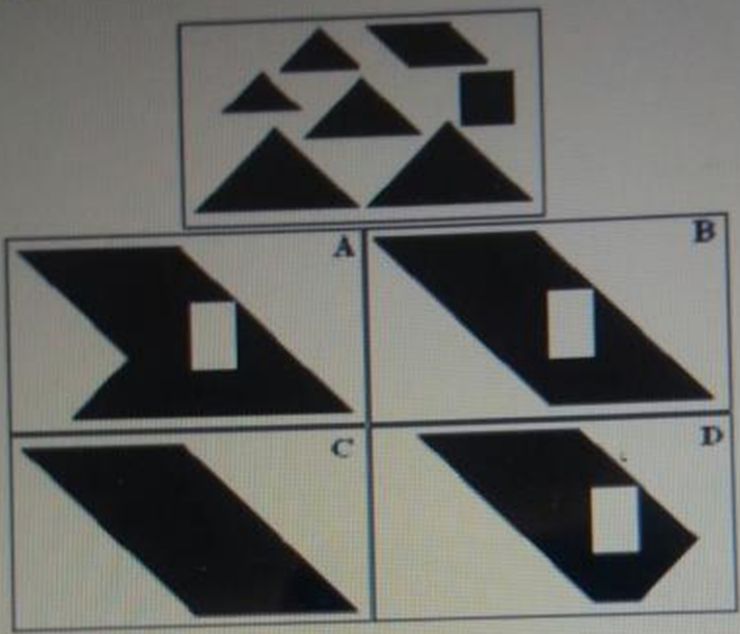
33) Which group of shapes can be assembled to make the shape shown?



A B C D

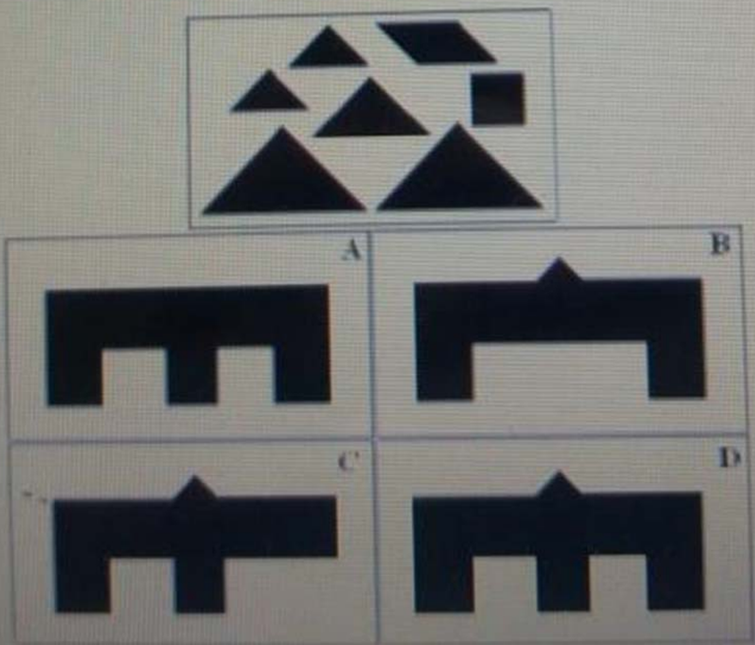
A B C D

34) Which shape can be assembled using all of the individual shapes shown?



A B C D

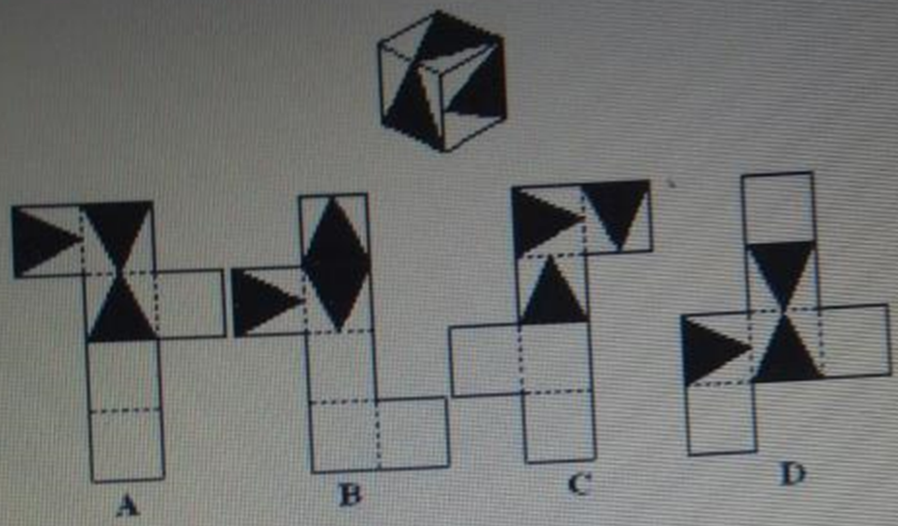
35) Which shape can be assembled using all of the individual shapes shown?



A B C D

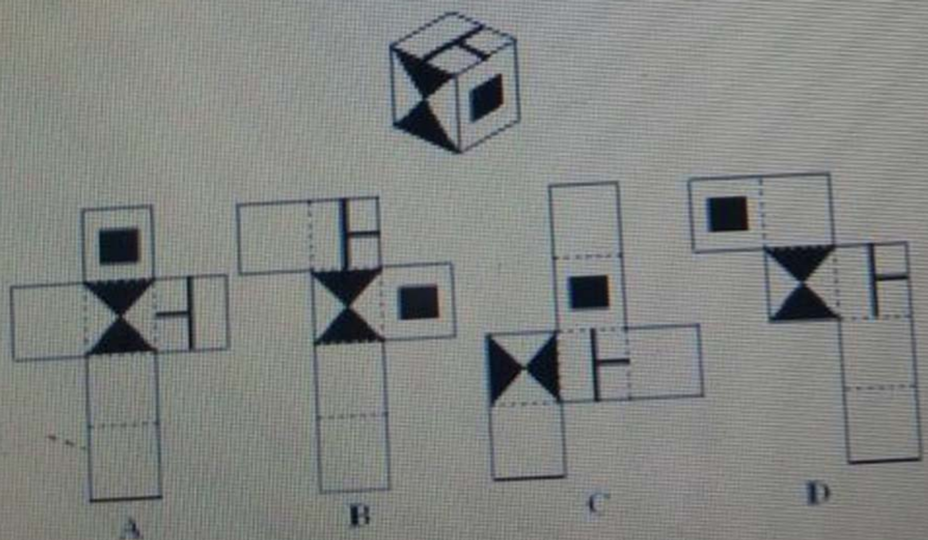
Which pattern can be folded to make the cube shown?

36)

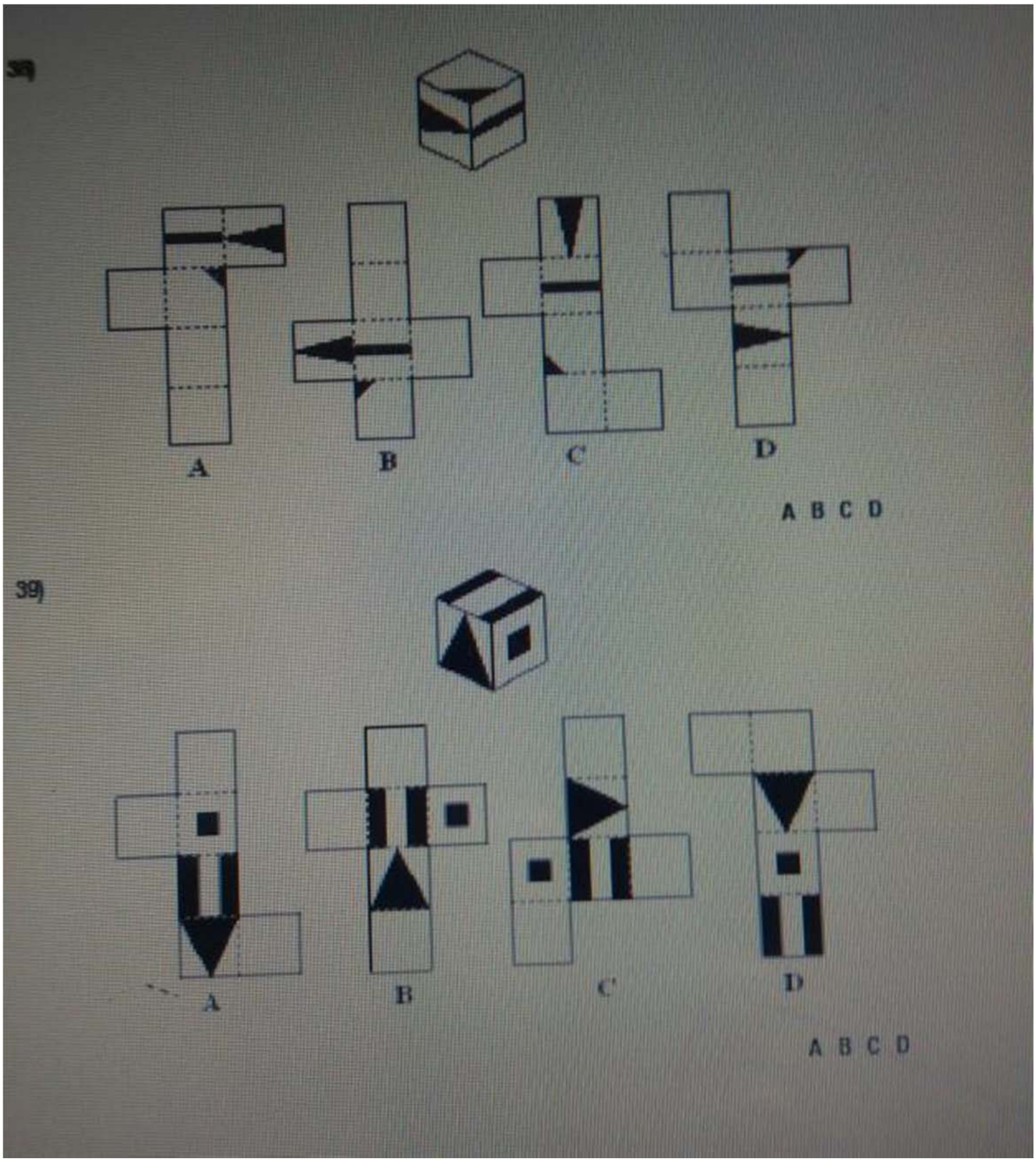


A B C D

37)



A B C D


38)

A B C D

A B C D

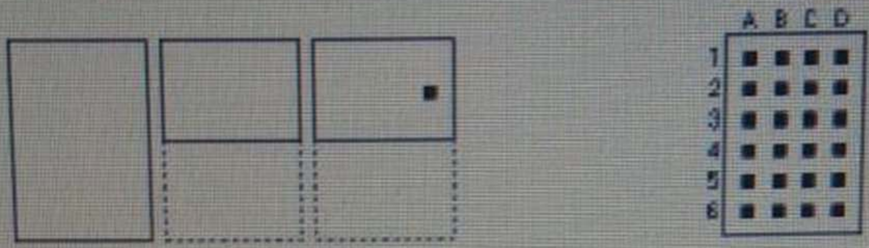
39)

A B C D

A B C D

The drawings show a sheet of paper which has been folded. The dashed lines indicate the whole sheet, each drawing represents a single fold. The black square shows where a hole was punched. Where do the holes appear when the sheet is unfolded?

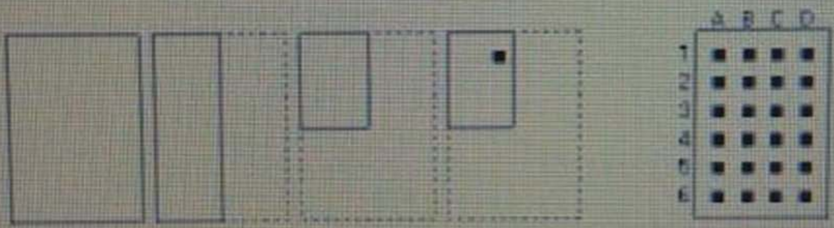
40)



A	B	C	D
2C,5C	2D,5D	3D,3D	2C,2D

A B C D

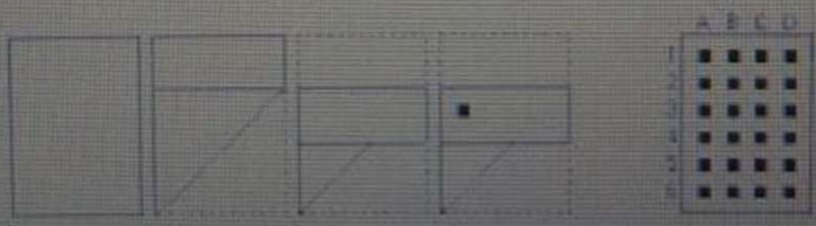
41)



A	B	C	D
1B,1C,5B,5C	2B,2C,5B,5C	1B,2C,6B,6C	1B,1C,6B,6C

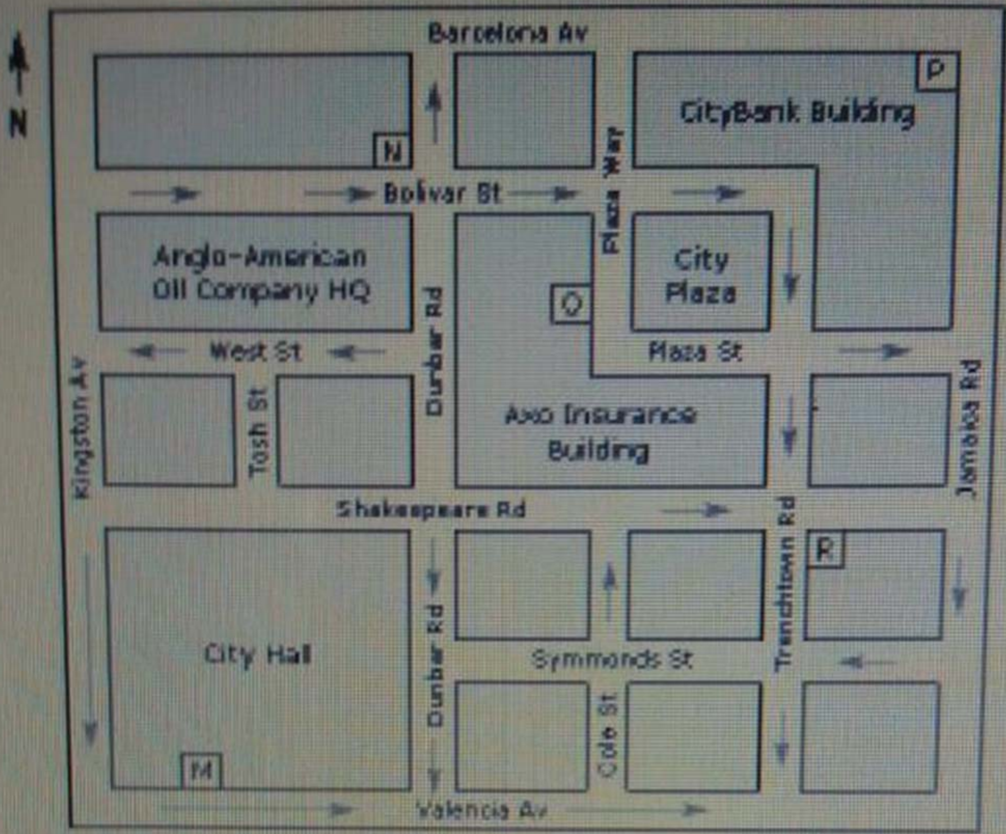
A B C D

42)



A	B	C	D
3A,2A,6D	3A,5A,6D	3A,5A,3D	3A,2A

A B C D



43) Officer Perez is in Tosh St with City Hall to her right. What direction is she facing?

A	B	C	D
North	South	East	West

44) She turns and walks to the junction with West St. She then turns right and walks to the next junction before turning left. Where is location 'O' in relation to her position?

A	B	C	D
North	South	East	West

45) Officer Martinez starts from location 'M' and proceeds as follows: left onto Valencia Av - heading East, second left - heading North, second right - heading East, second left - heading North. He proceeds North for two blocks. What is his location?

A	B	C	D
N	O	R	P

End of Spatial Reasoning – Test 1

APPENDIX D: LETTER TO THE DEPARTMENT OF BASIC EDUCATION

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

1 August 2016

Gauteng Department of Basic Education
Sol Plaatje House
222 Struben Street
Pretoria
0001

Subject: Request to conduct research in schools

Dear Sir/Madam

I am currently enrolled for a Master's degree in Education at the University of Pretoria, Groenkloof campus. The research that I wish to conduct for my dissertation is entitled "Exploring the visual literacy of Grade 10 life sciences learners in cytology".

This project will be conducted under the supervision of Professor J.J.R. de Villiers, Professor W.J. Fraser and Dr. M.A. Graham who are based at the University of Pretoria, South Africa. I therefore seek permission to approach several schools in the Tshwane South district to conduct this research project (see application attached).

Enclosed is a copy of my dissertation proposal, which includes copies of the instrument measures and consent forms to be used in the research. The information from this study will be used for academic purposes only. In my research report, and in any other academic communication, pseudonyms will be used and no other identifying information will be given. Collected data will be in my or my supervisor's possession and will be locked up for safety and confidentiality purposes. After completion of the study, the material will be stored at the University of Pretoria, according to policy requirements.

On completion of the study, I undertake to provide the Department of Education with a bound copy of the full research report. All data collected with public findings will be made available in an open repository for public and scientific use. Thank you for your time and consideration.

Yours sincerely,

____

Tshegofatso Taukobong
076 542 5020 (cell); 012 652 1151 (fax); t.tshego@yahoo.com (e-mail)

APPENDIX E: LETTER TO THE PRINCIPAL

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

1 August 2016

Principal
Tshwane South District
Subject: Permission to conduct a research project in your school
Dear Principal

I ask for permission to collect data at your school. I am an MEd (General) student at the University of Pretoria, Groenkloof Campus. The project is entitled "***Exploring the visual literacy of Grade 10 Life Sciences learners in cytology***".

The purpose of the study is to discover the level of visual literacy of Grade 10 Life Sciences learners in cytology. Those learners who are willing to take part will be required to respond to a life sciences visual literacy questionnaire (see attached) that asks various questions about their understanding of visual literacy and their ability to apply it. This will take place after school hours.

Furthermore, the learners will be requested to read the instruments, complete the documents and send or give them back to me. It should take learners about 60 minutes to complete.

Through the learners' participation I hope to understand the following:

- Grade 10 learners' level of visual literacy.
- Visual literacy skills Grade 10 learners need to think, learn and communicate visually in the life sciences curricula.

Through this study, I hope to identify and develop strategies for visual literacy to improve learners' performance in life sciences performances in our schools. The results of this study will be used to write a dissertation and will be published in scientific journals or presented at conferences, as well as on the internet. All data collected with public findings will be available in an open repository for public and scientific use.

The following terms will govern learners' participation:

1. The study will involve an anonymous survey, that is, names will not appear in the research.
2. Pseudonyms will be used in all written records and reports.
3. School names will be treated as strictly confidential.
4. Responses will be treated confidentially and will only be accessed by the participating learner (the participant), the researcher (Ms. Tshegofatso Taukobong) and the supervisors.
5. Participation is voluntary; learners have the right to withdraw at any time of the study, for any reason, without prejudice. The information collected at that time will be discarded.
6. The summary of the findings will be made available to all of the participants.
7. There will be no direct benefits to the learners or the school. However, possible benefits to life sciences education are the improvement of learners' visual literacy skills and knowledge in cytology.

Should you have any questions or concerns about the study, please contact me at the given contact details. The Faculty of Education at the University of Pretoria has approved this study.

……

CONSENT

If you agree to participate in the study under the above stated terms, please fill in the details below and return to me.

Principals Signature: ___________________ Witness' Signature: _____________________

Date: ______________ Date: ______________

Ms Tshegofatso Taukobong
Faculty of Education
University of Pretoria
Groenkloof Campus
Pretoria
Tel: 076 542 5020
Email address: t.tshego@yahoo.com.

Yours truly,
Tshegofatso Taukobong

……………………………… ……………………………..
Signature Date

APPENDIX F: LETTER TO THE PARENTS/GUARDIAN

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

1 August 2016

Dear Parent/Guardian

Subject: Permission for your child to take part in a research study

I ask permission for your child to take part in my research study. I am an MEd (General) student at the University of Pretoria. In order to complete my study, I need to collect data.

The study is titled "***Exploring the visual literacy of Grade 10 Life Sciences learners in cytology***". The purpose of this study is to determine the level of visual literacy of Grade 10 life sciences learners in cytology.

If you allow your child to take part, I shall ask him/her to respond to a life sciences visual literacy questionnaire (see attached). This questionnaire asks various questions about learners' understanding of visual literacy, as well as their ability to apply it.

Your child's participation in this study is voluntary. She/he may decline to participate or to withdraw from participation at any time. Withdrawal or refusal to take part will not affect your child 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 outside school hours with prior approval of the school, and it will take your child at least an hour to complete.

Through the learners' participation, I hope to understand the following:

- Grade 10 learners' level of visual literacy.
- Visual literacy skills Grade 10 learners need to think, learn and communicate visually in Life Sciences curricula.

The following will be analysed:

- Grade 10 Life Sciences knowledge on cytology. This knowledge will be learned during term one in a strand named life at molecular, cellular and tissue level, under the topic "cells: the basic unit of life".
- General spatial ability/skills.

I hope that the results of this study will be useful in identifying and developing strategies and visual literacy to improve learners' life sciences performance in our schools. The results of this study will be used to write a dissertation that may be published in scientific journals or presented at conferences, as well as on the internet. All data collected with public finding will be made available in an open repository for public and scientific use.

Learner participation will be governed by the following terms:

1. The study will involve an anonymous survey, that is, names will not appear in the research.
2. Pseudonyms will be used in all written records and reports.
3. School names will be treated as strictly confidential.
4. Responses will be treated confidentially and will only be accessed by the participating learner (the participant), the researcher (Ms. Tshegofatso Taukobong) and the supervisors.
5. Participation is voluntary; learners have the right to withdraw at any time of the study, for any reason, without prejudice. The information collected will then be discarded.
6. The summary of the findings will be made available to all of the participants.
7. There will be no direct benefits to the school or learners, however, possible benefits to life sciences education are to improve learners' visual literacy skills and knowledge in cytology.

If you have any questions or concerns about your child completing the questionnaire, please contact me at the given contact details. The Faculty of Education at the University of Pretoria has approved this study. We are also seeking permission from the Provincial Department of Education, the school, as well as the parents/guardians. Only after all parties involved have given permission will we continue with the study.

CONSENT

If you agree that your child may take part in the study under stated terms, please fill in the details below and return separately, NOT with the Life Sciences visual literacy questionnaire.

Parent/Guardian Signature: ______________

Date: ______________

Witness' Signature: _____________________

Date: ______________

Yours sincerely,

Ms. Tshegofatso Taukobong
Faculty of Education
University of Pretoria
Groenkloof Campus
Pretoria
Tel: 076 542 5020
Email address: t.tshego@yahoo.com

……………………………… ……………………………..
Signature Date

APPENDIX G: LETTER TO THE LEARNERS

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

1 August 2016

Dear learner,

I would like to invite you to take part in a research project entitled "***Exploring the visual literacy of Grade 10 Life Sciences learner in cytology***". I am doing this study to find ways to develop the visual literacy of learners in the life sciences curricula. This will help you, and many other learners of your age, in different schools. Attached to this letter is a life sciences visual literacy questionnaire that asks questions about your understanding of VISUAL LITERACY, as well as your ability to use it.

I am asking you to look over the instruments, complete them and give them back to me if you choose to take part in my study. It should take you about an hour to complete the questionnaire, and this will be conducted after school hours with prior approval of the school.

The results of this project will be submitted as a report for my MEd project, which I am doing at the University of Pretoria. Through your participation, I hope to understand the following:

- Grade 10 learners' level of visual literacy.
- Visual literacy skills Grade 10 learners need to think, learn and communicate visually in the life sciences curricula.

I will be analysing the following:

- Grade 10 Life Sciences knowledge on cytology. This knowledge will be learnt during term one in a strand named life at molecular, cellular and tissue level, under the topic "cells: the basic unit of life".
- General spatial ability skills.

The results of this study will be used to write a dissertation and will be published in scientific journals and presented in conferences, as well as on the internet. All data collected with public finding will be made available in an open repository for public and scientific use.

Should you decide to take part, the following terms will apply:

1. You should not write your name on the questionnaire.
2. Pseudonyms (unreal names and codes) will be used in all reports.
3. Participation in this research is voluntary; you have the right to withdraw of the study for any reason, without any prejudice. If you do so, no one will blame or criticize you, and the information collected will be discarded.
4. Your responses will be treated as strictly confidential and will only be accessed by you (the participant), the researcher (Ms. Tshegofatso Taukobong) and her supervisors.
5. Nothing that you write for this study will be revealed to other persons in a manner that will reveal your identity.
6. The summary of the findings will be available to all participants.
7. There will be no direct benefits to you or your school, however, possible benefits to life sciences education are the improvement of learners' visual literacy skills and knowledge of cytology.

If you have any questions or concerns about completing the questionnaire or about being in this study, you may contact me at the given contact details. The Faculty of Education at the University of Pretoria has approved this study. We are also seeking permission from the Provincial Department of Education, the school, and your parent/guardian. Only after all parties involved, including you, have given permission will we continue with the study.

CONSENT

If you agree to take part in the study under stated terms, please fill in the details below and return separately, NOT with Life Sciences visual literacy questionnaire.

Learners Signature: ___________________

Date: ______________

Witness' Signature: ______________________

Date: ______________

Yours sincerely,
Ms. Tshegofatso Taukobong
Faculty of Education
University of Pretoria
Groenkloof Campus
Pretoria
Tel: 076 542 5020
Email address: t.tshego@yahoo.com

……………………………… ……………………………..
Signature Date

APPENDIX H: GDE APPROVAL LETTER

For administrative use:
Reference no. D2016 / 263 A
Enquiries: Diane Buntting 011 843 6503

GAUTENG PROVINCE
EDUCATION
REPUBLIC OF SOUTH AFRICA

GDE AMENDED RESEARCH APPROVAL LETTER

Date:	10 September 2015
Validity of Research Approval:	8 February 2016 to 30 September
Previous GDE Research Approval letter reference number	D2015 / 362 dated 10 December 2014
Name of Researcher:	Taukobong T.M.
Address of Researcher:	2675 Umhlume Street Extension 15; Olievenhoutbosch; 0175
Telephone / Fax Number/s:	012 652 1151; 076 542 5020; 012 652 1161
Email address:	t.tshego@yahoo.com
Research Topic:	Exploring the visual literacy of Grade 10 Life Science learners in Cytology
Number and type of schools:	SIX Secondary Schools
District/s/HO	Tshwane North; Tshwane South and Tshwane West.

Re: Approval in Respect of Request to Conduct Research

This letter serves to indicate that approval is hereby granted to the above-mentioned researcher to proceed with research in respect of the study indicated above. The onus rests with the researcher to negotiate appropriate and relevant time schedules with the school/s and/or offices involved. A separate copy of this letter must be presented to the Principal, SGB and the relevant District/Head Office Senior Manager confirming that permission has been granted for the research to be conducted. However participation is VOLUNTARY.

The following conditions apply to GDE research. The researcher has agreed to and may proceed with the above study subject to the conditions listed below being met. Approval may be withdrawn should any of the conditions listed below be flouted:

CONDITIONS FOR CONDUCTING RESEARCH IN GDE

1. *The District/Head Office Senior Manager/s concerned, the Principal/s and the chairperson/s of the School Governing Body (SGB.) must be presented with a copy of this letter.*

2015/09/11

1

Making education a societal priority

Office of the Director: Knowledge Management and Research
9th Floor, 111 Commissioner Street, Johannesburg, 2001