The significance of visual literacy in improving science literacy

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Abstract

Science knowledge is valued as a platform to equip learners with problem-solving skills, and conceptual knowledge of science. The skills to solve problems are crucial to adapting and thriving in the ever-changing world. Over the years, technological advances have contributed to a significant increase of images in the print and electronic media and our everyday life. As such it is not surprising that there are also more images used in science textbooks than before. Since visual literacy is customarily the domain of the arts, science learners are not explicitly taught how to interpret the images that are prevalent in the science textbooks. Hence the main question of this research is how could developing visual literacy skills develop science literacy? In order to answer the main question, I explored the following sub-questions: What is visual literacy?; What is science literacy?; What types of visual representations are used in the Grade 8 Natural Sciences textbooks and how frequently are the different types used for different sub-topics?; In what ways do the visual representations work to explain science concepts?

This is a conceptual study in the interpretivist paradigm. A purposive sample of 5 textbooks with the focus on the topic of “Visible light” was used. An analysis based on Barthes’s (1997) and Rose’s (2001) methods for visual analysis was used to analyse three categories of images, namely iconic images, schematic diagrams and graphs and charts. It was found that iconic diagrams are used to present everyday knowledge whereas the schematic diagrams are used to represent abstract science knowledge, and the graphs and charts are used to communicate numerical data. The results showed that all the books start by presenting everyday knowledge using iconic diagrams followed by the schematic diagrams and graphs and charts showing abstract knowledge. This progression helps learners to understand new science concepts as they build on their prior knowledge.

In conclusion, I suggest that learning how to decode images will help learners to better grasp the science content. This study contributes to highlighting the need to include visual literacy in educator training programmes in science disciplines. There is also a need to research the visual literacy skills of both teachers and learners in order to determine the best visual literacy framework to be incorporated into the formal curriculum.

Declaration

I, Mmatsela Veron Kobe declare that this research report is my own unaided work. It is submitted foe the degree of Master of Curriculum Studies at the University of Witwatersrand, Johannesburg. It has not been submitted before any degree or examination or any other university.

Signed

Mmatsela Veron Kobe

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- My siblings, who did not get to see me during the school holidays as I put in more time into the paper.

My sincere and humble gratitude to the God of Mount Zion who guided me through this journey, His grace enabled me to get this far.

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List of definitions

1. **Affordances:** representational constraints and possibilities, types of representations fostered and hindered by a given medium both materially and socially
2. **Connotation:** the imposition of second meaning on the photographic message proper
3. **Connoted message:** the manner in which the society to a certain extent communicates what it thinks of the photographic message
4. **Denotation:** the manner of describing a visual image without adding feelings, morals or culture. Pure description of the visual image
5. **Denoted message**: the analogon itself
6. **Mode**: socioculturally shaped resource for meaning making
7. **Multimodality**: phenomenon of communication which defines the combination of different semiotic resources, or modes, in texts and communicative events, such as still and moving image, speech, writing, layout, gesture; and or proxemics.
8. **Multimodal texts**: print-based and digital texts that utilize more than one mode or semiotic resource to represent meaning potentials
9. **Multiliteracies**: a term that emphasises how negotiating the multiple linguistic and cultural differences in society is central to the pragmatics of the working, civic and private lives
10. **Multiple intelligences**: the Theory by Howard Gardner which holds that a person possesses more than one form of intelligence which cannot be measured by the test score but a person’s performance, ideas and products according to their culture or environment.
11. **Synaesthesia**: the process of shifting between modes and representing the same thing from one mode to another
12. **Science literacy**: consists of the knowledge and understanding of scientific concepts, and processes required for personal decision making, participation in civic and cultural affairs and economic productivity.
13. **Visual literacy**: the ability to interpret, negotiate and make meaning from information presented in the form of an image and the ability to convey context-specific and universal meaning using visual images.

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Chapter 1

An introduction to the problem

Introduction

Due to an increase in the use of advanced technology, the use of images has also increased in our everyday life. Social and print media uses still and moving images in abundance. Additionally, the use of smartphones has made it easier for people to access images. The widespread use of social media has made it easy for everyone with a smartphone to communicate using images. Most people who own these technological gadgets can edit and manipulate images by doing what is known as "Photoshop". Schools like other social institutions have seen an increase in the prevalence of images in textbooks and wall charts (Kress, 2006). The dominance of images in our everyday life and in learning materials renders teaching visual literacy a necessity (Felten, 2008) because education needs to respond to technological, political and economic changes and equip learners with necessary skills for civic participation (Mnguni, 2014). Thus, one of the most needed skills required of the learners is visual literacy.

Amongst the most needed skills in the current knowledge-based society, is the science literacy. A knowledge society depends on the creation, sharing and application of knowledge in their production (Muller, 2000). This society is characterized well educated citizens who are innovative and as a result build their country's economy through businesses. It is undeniable that "science literacy is regarded as a noble goal; achieving it is highly desirable" (Liu, 2009, p. 304) hence it has high status in our society today. Science education is crucial because the nature of science gives learners access to a body of knowledge, inquiry and problem-solving methods, ways of thinking about the world and how science knowledge interact with the society and technology (Ramnarain and Padayachee, 2015). It is about understanding phenomena in our environment and how we interact with the environment. Science education is known for developing problem-solving skills amongst learners necessary for the ever-changing world. Science gives learners to a vast of careers that are in demand, e.g. engineering. It is for this reason that science is a desirable and valuable goal in the world.

A good science curriculum is crucial in achieving the noble goal. A curriculum is a great tool that guides implementation of the intended aims and goals of science education. Textbooks are often used to translate the aims of science education stipulated in the curriculum into classroom practice (Khine and Liu, 2017). Hence the quality of the textbook has a great impact on teaching (Ramnarain and Padayachee, 2015) and learning of science. For this reason, this study will focus on analysing the textbook as a crucial tool to improving science literacy.

According to Mnguni (2014) science knowledge can be too abstract as phenomena can be explained at the microscopic (too small to be seen with a naked eye) and macroscopic levels (too big to be seen with an unaided eye). Mnguni (2014) highlights that the use of images in science has to do with the complexity of the science concepts. Mnguni (2014, p. 1) argues that

> students, especially entrant students (in university), often report misconceptions and learning difficulties associated with various concepts especially those that exist at a microscopic level, such as DNA, the gene and meiosis as well as those that exist in relatively large time scales such as evolution.

Since the concepts are too abstract they are often represented visually. It is very important for learners and teachers to acquire necessary skills to interpret the science visual representations. From the brief discussion above, it is clear that visual literacy and science literacy are some of the most important skills needed in the current times. The need to study this area is further articulated in the background to study, rationale of the study and the significance of this study as discussed in this chapter. A clear aim of the study and the research questions to achieve this aim will also be addressed in this chapter.

1.2 Background to the study

I am a grade 8 Natural Sciences teacher who is passionate about science. From my teaching experience, I notice that Science textbooks have visual images such as diagrams, illustrations and graphs alongside written text to explain content. This is in keeping with trends in representing information as identified by Kress (1988) who notes that the education field no longer relies on writing as a dominant way of communicating but has shifted towards using images more than before. Like all texts, visual texts need to be read and interpreted to be fully comprehended. Visual texts are still images or pictures. The need of visual literacy is not only limited to the classroom but is in demand in our current society (Kress, 2006). Despite, scientific concepts being represented visually on wall charts and textbooks as in the classrooms and illustrated, I have always overlooked it and did not see the need to question or analyse its significance until recently.

In my classes, I have noticed that Science learners experience challenges when dealing with visual imagery. Learners in my class learners have at times experienced difficulties interpreting visual representations, and working with graphic information, and some struggled with deducing answers from diagrams in assessment tasks. Labelling the diagrams was never a problem for them; however they were mostly unable to answer questions about the processes, concepts and reasoning represented in diagrams. In the biological sciences structures, functions and processes are mostly interrelated. For example, a cell wall (part of the cell structure) in a plant cell is an outer strong layer that protects and supports the cell (function) and acts as a filtering mechanism because it allows certain substances, including proteins to pass through it while keeping other substances outside when regulating diffusion (process). The inability of learners to deduce such valuable information from visual images, can impact negatively on learning.

Another challenge is that learners rely mostly on the teachers to interpret visual representations for them. This may hinder their ability to engage with visual representation independently. These challenges coupled with lack of understanding of visual images and their functions are equally troubling. Regardless of the use of graphic communication, it is rare for science teachers to talk about the importance and methods for interpreting visual imagery in science classes. Graphic communication involves communicating information or knowledge using graphic elements such as symbols, images such as photographs or paintings and colour. Despite the fact that Kress acknowledges that “analysing visuals is, or should be, an important part of the ‘critical’ disciplines” (2006, p. 14), learners are still not taught how to analyse visual representations.

Most teachers tend to overlook the skill of interpreting images when teaching because they lack the knowledge of its importance. For example, I studied Natural Science in my primary and senior secondary school and majored in Life Sciences from 1st to 3rd year in my undergraduate degree. Despite my exposure in this subject, it was only in my 4th year while studying a B.Ed. undergraduate degree that I came across the concept of visual literacy in the science classroom. The interesting fact is that I am only studying visual literacy in depth now in my Masters degree. However, my Life Sciences lecturer always made it her goal to instil in us the habit of drawing structures, labelling parts and relating this to their functions and the processes involved when teaching. She was adamant that by doing so our learners will do better, which I believe is a prediction worthy of exploration in future. It is imperative to take into consideration the challenges I come across that involve images in the Natural Science textbooks. I believe that it is important to consider ways of improving learners' visual literacy as an attempt to understanding of scientific phenomena.

1.3 Problem statement

It is well known that South African learners perform poorly in Mathematics and Science. The 2015 Trends in International Mathematics and Science Study (TIMSS) revealed that the country's average score in Grade 9 science was 358 out of 700 (Michael et al., 2016). "TIMSS is an international assessment of mathematics and science at fourth and eighth grades that has been conducted every four years since 1995" (Michael et al., 2016:1). Only 39 countries participated in the 2015 science assessment for grade eight (which is grade 9 in South Africa) science. TIMSS uses five 'international benchmarks' to rank learners. The highest scale is called '*Advanced*' with above 625 points, followed by '*High*' with 550 to 625 points. The third benchmark is 'Intermediate' with 475 to 550 points followed by *'Low*' with 400 to 475. The last one is '*Not Achieved*' with less than 400 and South Africa falls within this Benchmark. The Human Sciences Research Council (HSRC) in South Africa introduced one more benchmark called Potentials (325 to 400 points). As a result, the Not Achieved benchmark is for less than 325 points as opposed to 400 used internationally. The lowering of the 'not achieved level' in South Africa was aimed at helping the learners within this points score to improve their science knowledge so they can achieve a higher benchmark.

South Africa's low performance in science is attributed to unqualified teachers teaching the subject. Some teachers are noted to have insufficient content knowledge compared to teachers in other African countries (Spaull, 2013). Learners are also required to apply mathematical skills in science education, which makes learning science more complex (Swanepoel, 2010). Additionally, the communication in science subject can also contribute to the low achievement. Reading and writing in the language used to teach science also poses a serious challenge on learners. This is due to the fact that most learners are not first-language English speakers. It has been discovered that most inexperienced teachers and teachers with insufficient content knowledge are likely to rely on the textbooks instead of creating their own learning materials (Swanepoel, 2010). It is important to note that every learner has the right to have a textbook for each subject which calls for the need to have quality textbooks.

We need to analyse the content of science textbooks (Khine & Liu, 2017) as textbooks provide content and how it has to be taught. Textbooks contain content prescribed by and aligned to the national curriculum. Additionally the textbooks seek to; a) fulfil specific aims of the subject, b) teach relevant skills and c) pace content according to time allocated for the subject. Additionally the textbooks provide learners and teachers with formal and informal activities within each topic. The activities are meant to develop the necessary skills and facilitate the acquisition of science knowledge. Therefore, most science teachers largely rely on using textbooks as they seem to be a translation of the abstract curriculum into a feasible and concrete action plan (Khine and Liu, 2017).

It is my contention that textbooks are important tools that both teachers' and learners use in the classroom to learn and teach science knowledge. Since textbooks make use of a range of images to communicate their content, there is a need to better understand the types of images that are used, so that we can determine ways to develop learners' literacies. The focus in this study will be on how images work in science textbooks work to convey science knowledge. Lack of the necessary skills to engage with images in the science textbooks can contribute to poor performance in Natural Sciences in Grade 7-9, Life Sciences and Physical Sciences in grade 10-12.

1.4 Aim of the study

In this analytical research study I will explore the use of images to communicate science concepts in the Grade 8 Natural Science textbooks in order to establish how developing visual literacy might develop science literacy. The study will begin with an exploration of the key concepts which are visual literacy and science literacy. I will then survey the visual representations found in the Grade 8 Natural Science textbooks, showing how the visual representations work to explain the topic "Visible light." Through this study I will make an argument for why the development of visual literacy skills can improve our science literacy.

1.5 Research questions

The main research question that this study seeks to address is how could developing visual literacy skills develop science literacy?

In order to address this main research question, the following sub-questions will be pursued:

1. What is visual literacy?
2. What is science literacy?
3. What types of visual representations are used in the Grade 8 Natural Sciences textbooks and how frequently are the different types used for different sub-topics?
4. In what ways do the visual representations work to explain science concepts?

1.6 Rationale

Visual literacy is important in the science classroom because of the predominance of imagery in the textbooks in which scientific phenomena and concepts are represented visually. Therefore, science requires learners to develop skills of using visual communication. Furthermore, the skill of visually representing data gathered from experiments is valued in the Natural Sciences. For example, learners are required to represent data from a practical investigation using a graph; it can be a histogram, bar or line graph and others. Not only is drawing valued, but the ability to interpret graphs is crucial. Learners are expected to interpret visual images in order to get information from them. I suggest that the ability to interpret images aid learners to better comprehend science content. Despite the prevalence of visual representations, developing visual literacy is neglected in the science classroom, and in the training of science teachers. This research project is a conceptual research project that aims to establish a relationship between developing visual literacy and science literacy in order to advocate for the inclusion of visual literacy as part of the science curriculum. I will show that through developing their visual literacy, learners will be better equipped to understand scientific concepts represented visually. Visual literacy will allow learners to work independently and also value the images in the science textbooks.

1.7 Significance of the study

This study advocates for teaching visual literacy in Natural Sciences classes. Teachers will be enlightened about how visual images are used to explain science phenomena and concepts. This advocacy is aimed at prompting teachers to pay more attention to visual images and to come up with methods to incorporate the development of visual analysis skills in their teaching. Furthermore, the teacher trainers can be informed by this study and see the need to embed visual literacy in teacher training curriculum.

1.8 Organisation of the research report

I deviated from the usual structure of an educational research report as theory informs my analysis.

Chapter 1 outlines the research problem and background, the aim and rationale of the study. The research questions which guide the study are also formulated in the first chapter.

Chapter 2 focuses on the research paradigm, design and approach. Secondly it discusses the methods of data collection and analysis of the data. Included in this chapter is a description of the analysis tools that are utilised in the study.

Chapter 3 provides answers to the first and second research questions, which are ‘what is visual literacy?’ and ‘what is science literacy?’ respectively.

Chapter 4 answers the third research question; 'what types of visual representations are used in the Grade 7 Natural Sciences textbooks? The chapter discusses the theory of multimodality and how multimodal texts/ science textbooks work.

Chapter 5 analyses the types of images used in the topic visible light and how they represent science knowledge and dimensions of science literacy. This chapter answers the following question**; '**in what ways do the visual representations work to explain science concepts?'

Chapter 6 makes clear the implications of the research findings, recommendations and concluding remarks. The reference list is at the end of the paper.

It is important to note that there is no literature review chapter as the literature is embedded throughout the study and report. In keeping with interpretivist, conceptual research practices will be discussed in the method chapter (page 9), I consult relevant literature, and discuss various other studies in each chapter in relation to the themes of the chapter.

Conclusion

In this chapter I have established that the South African learners perform poorly in international science assessments compared to other countries. This challenge warrants that we seek ways of improving science education by first determining where the problem lies. One of the challenges identified in the background of the study is that learners struggle to understand science concepts represented by visual representations used in the science textbooks. This challenge sheds a light on the need for visual literacy skills to be explored. As a result the main research question seeks to understand how improving visual literacy of science learners can help learners to improve their science knowledge. Four sub-questions were formulated to assist in answering the main question. In addition, the significance and the rationale of the study were discussed. In chapter 2, I discuss how data was collected and analysed to answer the research questions presented in chapter 1.

Chapter 2

Research methodology

2.1 Introduction

Research is a systematic and controlled process used to discover what is thought of as truth, which is influenced by how we come to know reality. (Cohen et al., 2011). This chapter outlines the research design that has been used in the study. I will discuss the research paradigm that underpins the research design, and which in turn impacts on the research design and approach, specific research methods of data collection, analysis and interpretation. This is a qualitative, conceptual research, in the interpretivist paradigm. These terms will be discussed in detail under the relevant topics in this chapter.

2.2 Interpretivist paradigm

Research paradigms are the “philosophical assumptions the researcher brings to the study” (Creswell, 2013, p. 13). Our view of social reality influences what we believe, and what we come to know which in turn influences our methods of research. I believe that there are multiple social realities that exist depending on our knowledge and experiences. The uniqueness of our experiences renders these realities subjective. This view is influenced by the interpretivist paradigm which is based on hermeneutics and phenomenology. Hermeneutics holds that for one to understand the whole one needs to understand the parts (Maree, 2016). Phenomenology advocates that studying social phenomena requires one to consider that people interpret events subjectively. Interpretivists assume that “human actions continuously recreate social life” (Cohen et al, 2011, p. 46) and in turn the human behaviour is affected by the knowledge of the social life.

As a researcher, my method of investigation is a subjective interpretation of images in the science textbooks. This means that as the researcher I am not detached from the research however I actively engage with the data. Since there are multiple realities depending on our knowledge and social practices in which we engage in, I am using the science context to interpret the images I am working with. This means that my own science literacy skills and science literacy influence how I interpret the data. Within this interpretivist paradigm the qualitative method was adopted to answer the research questions.

2.3 Research design and approach

“Research approaches are plans and the procedures for research that span the steps from broad assumptions to detailed methods of data collection, analysis, and interpretation” (Creswell et al., 2013). The selection of a research approach is also based on the nature of the research problem or issue being addressed, the researchers’ personal experiences, and the audiences for the study (Creswell et al., 2013). The two main approaches are the qualitative and the quantitative methods.

Quantitative method is often utilised by positivists who believe that reliable objective methods and instruments must be used to uncover truth (Muijs, 2011). Scholars preferring the quantitative method believe that the researcher must be objective and detached from the study as to eliminate bias or their subjectivity while maximising objectivity (Muijs, 2011). Currently, there has been a move from positivism to post-positivism which believes that there is indeed objective reality out there however human beings influence reality with their subjectivity. As such quantitative lies in the positivist and post-positivist paradigms (Cohen et al., 2011).

The nature of research questions determine which approach is more suitable. The qualitative method is used to answer questions that need numerical answer, numerical change, testing a hypothesis, or cause and effect amongst variables (Muijs, 2011). This method enables the researcher to obtain measurable and objective data to answer research questions. The data if analysed using statistics which are mathematical procedures (Cresswell, 2012) and the results can be used to make generalisations. The procedures used to collect and analyse data must be reliable to prevent the bias and subjectivity of the researcher from influencing the results.

On the other hand, qualitative research helps one to explore unknown variables by focusing on the central phenomena (Cresswell, 2012). Central phenomena is the “key concept, idea or process being studied in qualitative research” (Cresswell, 2012, p.

16). Qualitative research requires the researcher to learn from participants or the data they are working with. It allows the research to analyse texts to describe phenomena central to the study. The researcher's subjective interpretation of the meaning of the data is central in qualitative research, hence it is based on the interpretive paradigm (Cohen et al., 2011).

As mentioned earlier, this study is guided by the interpretivist school of thought and qualitative design. Since I am working with texts qualitative research permits the extraction of meaning from data such as "meanings people embed into texts and objects" (Creswell, 2017, p. 53). Firstly the study used conceptual analysis to explore the visual literacy and science literacy. Secondly, content analysis of the science textbooks was conducted.

This research study although it is qualitative, it borrows from the quantitative as well. The quantitative method allowed the collection of data to show the frequency and type of images in each books in the topic 'Visible light' as well as the frequency and types of images used in each sub-topic. I have chosen the topic because it has many images with coherent themes in all the grade 8 textbooks. The aim of employing this method in the first part of the research was to show the type of images dominant in the textbooks. Additionally, the data was used to determine which type of image is dominant in each topic so that that type of image can be analysed in terms of how it teaches the main science concepts in the topic.

2.4 Research sample

A purposive sampling of five Grade 8 Natural Sciences textbooks which are Spot on, Platinum, Siyavula, step-by-Step and Oxford Successful was adopted. Furthermore only the topic 'Visible light' was analysed making the sample purposive since the topic was chosen intentionally to explore the relationship between visual literacy and science literacy. Since textbooks are the data the study worked with, a suitable data collection method was needed.

2.5 Data collection methods

Methods are tools that researchers use to collect data about social reality from individuals, groups, artefacts and texts in any medium (Creswell et al. 2013). The following methods were used in the two stages of data collection;

Stage 1: Conceptual analysis/ literature analysis

Conceptual analysis was used to answer the following questions.

- What is visual literacy?
- What is science literacy?

A concept is "the relationship between a word (or symbol) and an idea or conception" (Cohen et al., 2011, p. 11). We use concepts to create meanings and makes sense of our reality. Concept analysis is a philosophical method concerned with analysing the meaning of concepts by looking at their different uses and applications (Wilson, 1963). One of the ways to define concepts is by looking at the social context in which they are used. Thus conceptual analysis was conducted to give meaning to the concepts visual literacy and science literacy using the science textbook as the context. The analysis was then followed by the content analysis of the science textbooks.

Stage 2: Textual/content analysis

Content analysis was used to answer the following question

- What types of visual representations are used in the Grade 8 Natural Sciences textbook?
- In what ways do the visual representations work to explain science concepts?

According to Cohen et al. (2007, p. 40), "content analysis involves coding, categorizing (creating meaningful categories into which the units of analysis –words, phrases, sentences etc. – can be placed), comparing (categories and making links between them), and concluding– drawing theoretical conclusions from the text". This study will employ the eleven stages of conducting content analysis as described by Cohen.
Here is a table summarising how stage 2 is done as adapted from Cohen et al (2007).

Steps	Analysis of visual text
1. Research questions to be addressed	• What types of visual representations are used in the Grade 8 Natural Sciences classroom how frequently are the different types used for different sub-topics? • In what ways do the visual representations work to explain science concepts?
2. Sample population	Grade 8 Natural Sciences Textbooks
3. Sample	4 textbooks & 1 workbook from 9 textbooks. Purposeful
4. Context of the generation of the document	The textbooks are CAPS compliant and approved by the Department of Basic Education at a national level.
5. Units of analysis	Visual images and written text within the topic “Visible light”
6. Codes to be used in the analysis	Rose’s (2001) visual methodologies questions
7. Categories for analysis	Number/frequency of images Types of visual images Denotative and connotative messages
8. Coding and categorizing of the data	Khine & Liu’s (2017) categories of diagrams Barthes’s connoted and denoted messages in the photographic image

The five books to be analysed are;

No.	Tittle
1.	Spot on
2.	Platinum
3.	Oxford Successful
4.	Step-by-step
5.	Siyavula Workbook

Number/frequency of images per book and per topic

Book no.	Iconic images	Schematic diagrams	Charts and graphs
1			
2			
3			

4			
5			

The data for this study is located in the interaction of the following; eight sub-topics within the main topic 'Visible light', ten perspectives and four levels of science literacy, three types of images and 4 textbooks and 1 workbook. Figure 2.1 shows the complexity of the data I am working with.

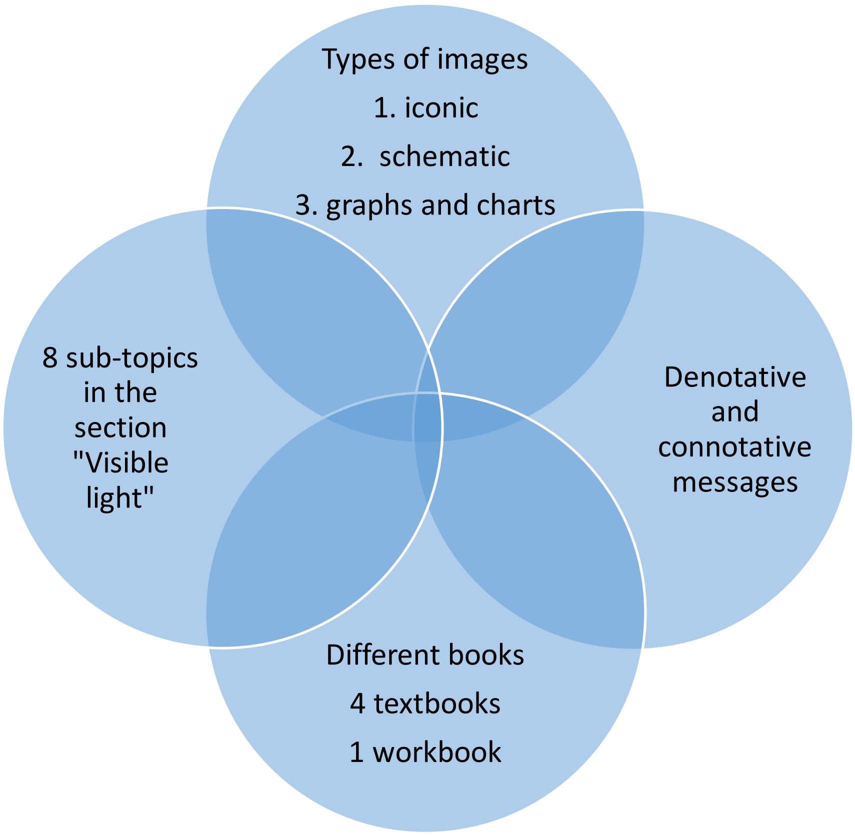


Figure 2.1: Components of data in this study

Rose (2001) formulated questions to assist researchers in analysing various images. The list of questions was very long hence I decided to take questions that were applicable to this study. The questions are also categorised according to Barthes' connotative and denotative levels of the photographic image. The denotative level describing the image itself, whereas the connotative level has to do with the knowledge associated with the image based on the social setting in which it is found or the social conditions of the readers. The instrument thus draws from the analysis of images by Barthes (1997) and Rose (2001).

2.6 Instrument for analysing visual images

<u>Production of the image</u>

1. When was the image published?__________________
2. Author? _______________________________________
3. Where was it published? _________________________

Denotative level	**The image itself** 1. What type of image is shown? 2. Is it one of a series? 3. What is being shown? Describe all components. 4. What science concepts are being displayed? 5. What does the caption of the image say? 6. How does the caption influence our understanding?	**Answers**
Connotative level	**Audience** 1. What does the audience need to understand in order to interpret the science concepts depicted? 2. Is more than one interpretation of the image possible? What are those possible interpretations? 3. How does the text foreground the image?	**Answers**

2.7 Ethics

This research does not have participants as I work with visual texts in the textbooks as my data. I am analysing content of textbooks which are readily available because they are used by learners. The nature of this research does no harm to people, in fact the education community will gain more knowledge from the study.

2.8 Conclusion

In this chapter, I have explained how the study uses qualitative approach to answer the research question and sub-questions. The method includes the conceptual and content analysis respectively. Four textbooks and one workbook used in the South African school are the data this study works with and the instrument of analysis developed is used to make sense of the data. It is important to remember that the analysis of the data includes five books, ten science literacy perspectives, three types of images and eight sub-topics in the books forming various layers of the data which overlap and influence one another. The layers intersect as science literacy skills and perspectives which are evident in the three types of images used throughout the eight sub-topics. However these science literacy skills and perspectives can only be deciphered when the learners are able to understand how visual images communicate (visual literacy).

Chapter 3

Understanding literacy

3.1 Introduction

In chapter 2, I outlined the methodology of the research. The first part of this study is a conceptual analysis of key concepts. As a result, chapter 3 engages with relevant literature in order to define the concepts ‘science literacy’ and ‘visual literacy’. The aim is to answer the first two research questions which are ‘what is visual literacy?’ and ‘what is science literacy?’ The chapter begins with the definition of visual literacy, the overview of visual literacy in the science classroom and the use of semiosis to read images. These are followed by the definition of scientific literacy at a simplistic view and at a complex view to enrich our understanding. As I discuss these concepts, I refer to studies in visual literacy in the science field that were conducted in South Africa. The studies help in identifying what has been done in the field of science and visual literacy to avoid duplication of knowledge. Gaps in the field, which support the need for my study, are also identified.

3.2 Visual Literacy defined

Literacy is the ability to read and write. Felten (2008, p. 60) defines visual literacy as “the ability to understand, produce, and use culturally significant images, objects, and visible actions”. It includes the ability to interpret, negotiate and make meaning from information presented in the form of an image and the ability to convey context-specific and universal meaning using visual images. This definition excludes the visible actions (gestures, body language) and objects (models) used in the science classroom. This definition is useful for me because the focus of my study is on the science images in the science textbooks. According to Fernández and Ruiz-Gallardo (2017, p. 161), visually literate learners can “find, interpret, evaluate, use, and create images and visual media effectively”. Not only are learners supposed to decode images, they have to be able to create images and use them effectively to communicate. Communication in science includes the drawing of diagrams, concept maps, charts and graphs amongst others to represent science concepts.

Dondis (1973) compared learning to communicate visually with images to learning written and verbal language. He argues that just as one needs to master alphabets, words, grammar and syntax in order to use them in endless ways to communicate, one needs to comprehend the meaning conveyed by the basic elements of an image such as shape, color, texture and scale amongst others to be able to understand images. Not only do we need to understand the individual elements we also have to elements as combined into forms and arranged in relation to each other. By so doing, we are able to interpret the meaning conveyed by the whole image as believed by hermeneutics which influences the interpretivist view. For us to understand the whole we need to study and analyse the parts. The interpretivist view allows us to see scientific texts as socially constructed. For us to comprehend their meanings we need to be familiar with the conventions and rules that govern them.

Figure 3.1 on the next page, from Oxford successful Textbook by Baxter et al. (2013, p. 153) shows an insect labelled 'object' observed under a convex lens. When one looks into the convex lens, the magnified virtual (not real) image of the object is observed. This process which might be familiar to learners is described using a diagram. In real life, learners will be looking down into the convex lens (also known as hand lens), and see the enlarged image. They do not observe any bending of light rays that makes this observation possible.

The light rays bend when they passes one medium such as air into another medium such as glass (convex lens). This process called refraction is not visible to the naked eyes of learners. As such the diagram is crucial in making explicit and available the process that happens in a split second in real life. Images preserve this process which happens too fast when observed with an unaided eye. The diagram is an abstract representation of an experience (using hand lens to observe small organisms or objects). It uses conventions to illustrate how refraction occurs.

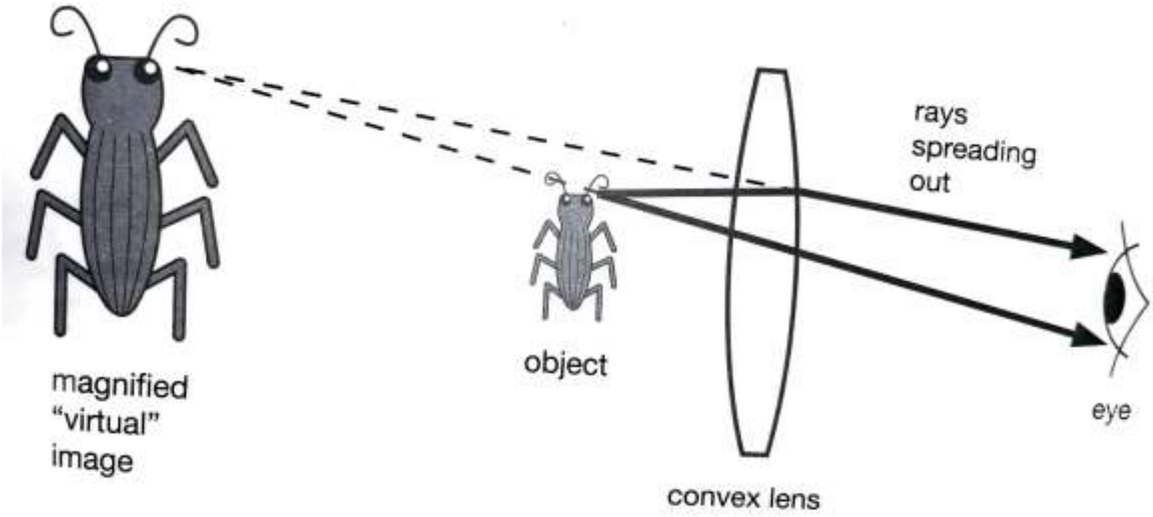


Figure 3.1: "A magnifying glass bends light rays to enlarge objects" from Baxter et al. (2013, p. 153).

The meaning conveyed by the image above is not obvious to someone who has never observed any object under the convex lens. Firstly the uses of the elements is intentional to produce certain meaning. The following elements are observed: shape, lines (dashed and solid), size of both the object and image, arrows on solid lines and labels. Without the convex lens, the light rays (solid lined) were going to focus on the object and we would see the original-sized object. However, due to the presence of the convex lens, the rays are focused on a different focal point hence the dotted lines. This extension of the solid lines by the dashed lines, is reflected back to the eyes and we observe an enlarged image. The image above illustrate the point that one needs to engage with all the elements of the image to understand how they create an overall meaning which is how a “magnifying glass bends light rays to enlarge objects” (Baxter et al., 2013, p. 153).

A visually literate learner has a grasp of what Kress and van Leeuwen (2006) termed the visual ‘grammar’ in their book “Reading Images”’. The visual ‘grammar’ describes the way in which depicted elements – people, places and things – combine in visual ‘statements’ to make meaning. In short, visual grammar refers to how visual elements are used and arranged together to create meaning as illustrated using figure 3.1 above. Analysis of visual images is crucial as the “visual language is not transparent and universally understood, it is culturally specific” (Kress, 2006, p. 4). In this case, the above is not transparent, one needs to understand the basic elements in order to decode the message. The image is not decorative, instead it conveys science phenomena learned in the Natural Sciences textbook and the classroom. Visual literacy is the ability to read, interpret and create images specific to a certain context, such as the science textbook.

3.3 Visual Literacy in the Science classroom

Studies conducted on visual literacy in science in the South African context are pertinent to my study since I am working with textbooks used in South African schools. However, although various studies on visual literacy in the South African educational setting have been conducted, most studies have focused on analysing history textbooks (Bertram& Wassermann, 2015), English teaching (Mbelani, 2008), nature of science in the science textbooks (Ramnarain & Padayachee , 2015) and visual literacy in the field of higher education (Mnguni, 2016; Newfield, 2011). There is a gap in terms of analysing visual literacy in science education at a high school level, especially in the senior phase (grade 7-9). One of the studies useful for my research was conducted by Taukobong (2017) in Gauteng schools. The study explored the level of visual literacy of 225 Grade 10 Life Sciences learners across six secondary schools in Pretoria. The study explored 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 test and a spatial ability test were used to collect data. The results showed that most Grade 10 Life Sciences learners lack average visual literacy skills. Learners found it difficult to represent science concepts (e.g. mitochondria of a cell) using diagrams. They also found it challenging to decode information from provided diagrams. Visual literacy is not explicitly taught in Natural Sciences in the lower grades and in FET phase (grade 10-12). Unfortunately written text is still overly emphasized at the expense of teaching learners skills to engage with visual images, hence learners have low visual literacy in grade 10.

Taukobong (2017) results showed that gender does not play a role on the learners' performance in visual literacy skills as both genders performed equally in both tests. This might be due to the fact that learners in the same environment are exposed to the same teaching and learning resource. They are taught by the same teachers which will have an impact on their visual literacy skill. However, the results showed that the location of the school (urban, rural or township) has an effect on the learners' performance in visual literacy skills. Learners in high socio-economic environments performed better than learners from low and middle socio-economic environments in the Life Science Visual Literacy Test. Most schools in urban areas are well-resourced and learners have access to a variety of teaching and learning materials and other technologies such as Wi-Fi, tablets and smartboards (Taukobong, 2017).

However, learners from rural areas performed better than those in township and urban schools in the Spatial Ability Test. Spatial ability encompasses "the ability to perceive spatial patterns, arrangements of elements and recognizing objects when seen from different angles and being able to manipulate visual objects by mentally rotating, turning, twisting or inverting one or more objects or parts" of a visual ensemble (Carrier & Clark, 1977, p. 61). The visual ensembles that need to be mentally manipulated in spatial ability tests can be two-dimensional and three-dimensional. Taukobong (2017) believes that learners in rural school rely heavily on using the textbook, hence they can apply spatial ability skills compared to the other schools. Taukobong's study is important in that Grade 7-9 Natural Sciences lays a foundation for learners to study Life Sciences in grade 10 to 12.

At the tertiary level, Mnguni's (2016) studies on visual literacy are of great value. Mnguni (2016) conducted a study at the University of University of Kwa-Zulu Natal and identified and classified Biochemistry students' conceptual and reasoning difficulties with interpreting external representations. A model was developed based on sources of the difficulties and factors influencing students' ability to interpret the external representations. In this study, he found out that visual literacy varies among Biochemistry students. Various visualisation skills are needed for students to effectively process the external representations in biochemistry, meaning lack of certain skills was likely to result in learners failing to comprehend the concepts. Mnguni asserts that "lack of visual literacy is one of the major factors leading to poor content understanding among students" (2016, p. 69). In this light, the educators needed to be aware of students' visualisation skills so that they can develop programs that will accommodate them and also develop needed skills.

Since science phenomena are presented visually in the form of images, inability of learners to derive meaning from images hinders their learning. Lack of visual literacy skills among students is attributed to little or no explicit teaching of visual literacy skills to students due to lack of a framework to guide educators. Mnguni argues that educators need to determine the levels of visual literacy skills of students and explicitly teach visual literacy and the skills for using visualization tools as essential components of Biochemistry curricula as a solution to improve performance in Biochemistry. Visualisation is a crucial process in studying science (Mnguni, 2014). Mnguni (2014) proposed the theoretical process of “visualization” and how it can be applied to understanding, teaching and studying of visual literacy in science education. Mnguni (2014) argues that the process of visualisation is achieved in three non-linear and overlapping processes which are; 1) internalisation of visual model, 2) conceptualisation of visual models and 3) externalisation of visual models.

In the internalisation of visual models stage, students make an effort to study the visual image. The cognitive effort spent on comprehension can be low, middle or high. In the low order students distinguish the various visual elements present in a visual image. For instance, when studying figure 3.1 on page 20 in this chapter, a learner will notice the difference in size of the object and the virtual image. In addition they will pay attention to the solid lines together with the dashed line and how they are used to explain the magnified image. Whereas the high level of effort requires the learners to use their prior knowledge (to be retrieved from long-term memory) in order to interpret the image. The learner can remember when they observed any object under a magnifying lens and try to relate this to the image they are looking at in figure 3.1. Once internalised, the visual images must be conceptualised in the Conceptualisation of Visual Models stage. Learners retrieve information from their memory to interpret the visual models. This stage overlaps with the internalisation of visual models stage. In the externalisation of visual models, learners express their mental visual images in the form of drawings or verbal descriptions.

The two studies discussed above gives a glimpse into the sad reality that a number of university and high school natural science students who participated in these studies lack visual literacy skills, seemingly because they are not taught these skills. This glimpse I believe is important considering there dearth of studies on visual in grade 7, 8 and 9 as I have mentioned earlier. The main problem to be noted is that teachers are not at fault, however the curriculum makes no provision for teaching learners skills necessary for interpreting images. As much as the curriculum requires teachers to teach learners to communicate visually, it does not always make provision for teaching these skills in the science classroom. As a result teachers tend to overlook the importance of images because they are not compelled to teach learners how to understand and eventually create these images.

3.4 A semiotic understanding of visual images/ reading images

Just as other texts which make use of codified conventions in order to communicate messages to the users of the language, visual images have their own codes that can only be deciphered if one has knowledge of their conventions. One way of approaching the deciphering of images is to understand the image as a "sign" in the semiotic sense. Semiotics as a "discipline is simply the analysis of signs or the study of the functioning of signs" (Cobley and Jansz, 1997, p. 4). A sign has two components which, in Saussure's school of semiotics, are called the "signifier" and the "signified". The signifier and the signified are distinguishable at an analytical level however in real practical life they are integrated (Rose, 2001). The signifier is the material aspect of the sign whereas the signified is the mental concept of the sign (Kress, 2010; Cobley and Jansz, 1997). The signifier is the word or image attached to a signified whereas the signified is the concept or object. For example, when hearing this concept "an animal that has four legs and looks after its young" one can think of a mammal. The word mammal is a signifier whereas the concept "mammal" is a signified.

There is no inherent relationship between the signifier and the signified (Cobley & Jansz, 1997). We sometimes use different signifiers for the same signified as a result of linguistic and cultural differences. The relation between the meaning (signifieds) and the signifier depends of the conventions used in a particular culture (Rose, 2001). Convention is when "the relation between signifier and signified is the result of the agreement among those who use them" (Guiraud, 1975, p. 24). Meanwhile codification "is the agreement among users of a sign as they recognise the relation between the signifier and the signified *(convention)* and respect its practice" (Guiraud, 1975, p. 25). The more people use a certain convention the more it becomes codified. The meanings (signifieds) of the signifiers can be problematized as they are ruled by conventions.

Similarly, in visual communication the elements such as colour, perspective and line are the 'signifiers', used to realize meanings which are the 'signifieds' (Kress & van Leeuwen, 2006). We attribute meaning to visual elements such as colours. For instance, red can symbolise danger, blood or love/passion. This is the signified that we attach to the colour red (signifier). The signified of the colour red, will depend on the context on which it is used. For instance, receiving a postcard with a drawing of a full red heart shape is unlikely to evoke fear because one is likely to associate it with love than danger. However, the image of a red heart that has a line that seems to divide it into two halves signifies heartbreak and will evoke sadness in normal circumstances. The association of red heart with a line breaking it into two a full heart shape have been codified and we know this codes hence we can decode their meaning.

Even though the relationship between the signifier and the signified is not inherent, visual images can be motivated conjunctions of signifiers and signifieds (Kress, 2006). The sign is based on a conventional relation which may be weaker or stronger (Guiraud, 1975). The relation can also be motivated or unmotivated (arbitrary). In a motivated relation, the image has properties that can make one to easily associate the signifier to the signified or the other way round. The motivated signs are the perfect representation of the signifier and signified .For instance, when looking at an image of a rainbow in the science classroom, one can easily associate it with rain or sunshine after a storm. However reading the word rainbow does not necessarily bring the mental image of the rainbow to the fore if you do not what the word means. In this way the relationship between the signified (mental image of rainbow) and the signifier (image of a rainbow) are motivated conjunctions whereas the relationship between the signifier (word-rainbow) and the signified (mental image of the rainbow) do not have an inherent relationship. Visual images can make it easier for us to have a clear mental image instead of relying on imagination, however this depends on the type of image shown.

Semiotic theory which deals with signs serves as a tool to understand visual codes. It provides a means to understand meanings in every image. By employing this theory in the study, I will be able to show that visual images are not to be taken for granted as they are codified and culture-specific, and just as learners need to learn written language literacy, they also need to learn visual literacy. The social semiotic theory by Kress and van Leeuwen (2006) takes into consideration the social context in which the signs are used and produced. In this case, the science textbook serves as a unique social context that uses codified images, and written text, to explain scientific phenomena. From the theory of social semiotics, one is able to understand that each visual representation engenders specific meanings in the particular context in which it is used. In order to clarify any misconceptions that learners may get from science visual representations, teachers need to teach learners to read the grammar of science images.

A detailed analysis of the relationship between visual image and written text is offered by Ronald Barthes's extension of the semiotic theory. The book titled '*Image, Music and Text*" by Ronald Barthes (1997) is helpful in understanding how written text which he calls the linguistic message and visual images (photograph and other illustrations) work. Barthes (1997, p. 25) acknowledged that the written text "constitutes a parasitic message designed to connote the image, to quicken it with one or more second-order signifieds". This implies that the written text is sometimes used to insert new meaning into the image by focusing on certain elements of the image while ignoring other elements. The written text is used to attribute a certain meaning or narrative to the photographic message.

Connotation is a "manner in which the society to a certain extent communicates what it thinks of it (image)" (Barthes, 1997, p. 17). According to Barthes, even the visual images such as photographs seem like a perfect analogon of reality, they are never neutral. Photographs are seen as the closest and perfect representation of reality and as such are believed to be true, because of the manner in which analog cameras worked with light. The camera is used for capturing what is in front of it and this image can thus be printed or saved on a digital device, hence the photograph is seen a perfect representation of reality.

However in the technologically advanced world we are aware of the manipulation or altering of the photograph through the process called 'photoshop' (Felten, 2008). Despite this awareness, there is still a lingering belief in the veracity of the photographic image, because of the relationship of the image to perceived reality. The 'channel of transmission' such as the textbook, newspaper or magazine affects meaning of visual images (Barthes, 1997). As such visual images convey dual messages- the denoted and connoted messages. The denoted message is the analogon of reality whereas the connoted message is the social, cultural, ideological or moral interpretations that we attribute to the visual images.

The connotations differ according to how the written text is presented in relation to the visual image. Barthes (1997) highlighted the following relations:

- When the written text is closer to the image it is seen as objective and less connotative.
- A caption does not have an obvious effect on connotation, it is seen as objective.
- The headline is seen as an emphasis or duplication of the image, instead of an insertion of meaning into the image, it is seen as objective
- The text in an article can be seen as separate from the image.

What is important in Barthes's extension of the semiotic theory is how the written text work with the images. The written text can be used to describe the image as it is or it can be used to insert meanings into the image. These relations are crucial as they form part of the visual literacy skills.

3.5 Science literacy defined

A simplistic view of science literacy is that science literacy refers to "the knowledge and understanding of scientific concepts and processes required for personal decision making, participation in civic and cultural affairs, and economic productivity" (Dani, 2009, p. 289). Like most concepts, the meaning and definition of science literacy has always been debated. One of the interesting definitions of science literacy is that of Bybee's (1997) who suggested four functional levels of science literacy respectively; a) nominal, b) functional, c) conceptual and procedural and d) multi-dimensional literacy. The four functional levels of science literacy indicate the level of competency in science literacy that one undergoes when learning science. These levels start from the lowest to the highest. I will use examples from the topic 'Visible light' in Grade 8 Natural Sciences Textbook to illustrate the levels.

I. At a low nominal level: learners can recognize scientific terms but do to have clear understanding of the meaning. For example, the topic 'Visible Light' uses the following key concepts; reflection, absorption, refraction, illumination and dispersion as the properties of light. Learners might struggle to differentiate between reflection and refraction even though they are aware that they are used in the topic ‘Visible Light’.

II. At a functional level: learners use scientific and technological vocabulary in a school test or exam. For example, learners can answer questions based on the key concepts in various forms like multiple choice, fill in the missing words and match column A and column B. They might take educated guesses because they have surface instead of deep understanding of these terms.

III. At the conceptual and procedural level: learners understand the relationship between concepts and can articulate their meanings. For example, learners can use the concepts listed in the nominal level to explain how a rainbow (spectrum of light) forms. One can explain that: the earth is **illuminated** by the light from the Sun after rain has stopped. The rays from the sun, enter the water droplets in the air which act as tiny prisms. As light enters the water droplets, it is **refracted (bent).** However instead of leaving the water droplet on the opposite side, the light ray is **reflected** inside the droplet. When it leaves the water droplet on the same side it entered but at a lower position, it is **refracted** again and **dispersed** into the different colours of the rainbow. Below is an image from Beckett (2017, p. 119) that explains the above process.

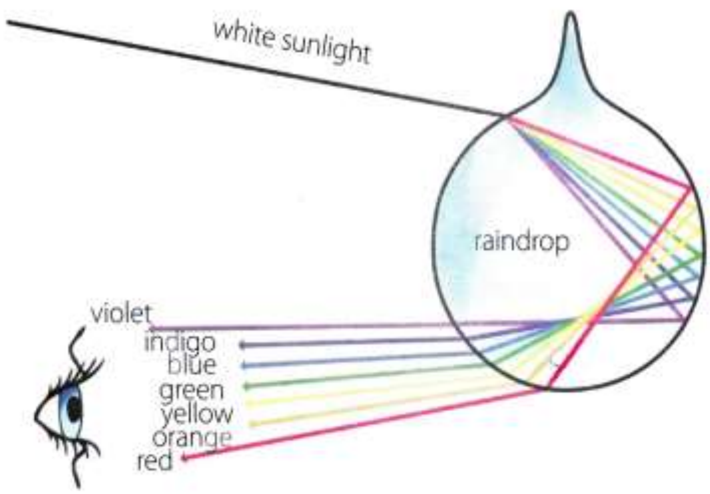


Figure 3.2 "Dispersion of light by a rain drop" from Vermaak et al. (2013, p. 136)

IV. At the multi-dimensional level: learners understand the relationship between science concepts and processes, they also understand the relationship between science and technology and the role of science in technology, their personal life and the society. The **properties of visible light** have led to the discovery of various things in the medical and technological field. Lasers are used as tools for welding and cutting metals. Due to what we know about visible light, the use of optic fibre is used by telecommunications companies such as Telkom to transmit data. In addition, how **'we see light'** is also crucial in the medical field. Optometrist are doctors that specialise in the function and care of eyesight. The topic 'Visible light' exposes learners to the field of optometry. Learners are taught about various disorders associated with eyesight such as colour-blindness, short-sightedness, long-sightedness and cataracts and their treatment from a science perspective. The use of convex (Figure 3.1 on page 20) and concave lenses are used to treat some of the disorders. In their personal life learners will be able to comprehend how wearing glasses corrects these disorders. This knowledge equip learners with the understanding of societal health problems.

These levels of science literacy are captured in the specific aims of Natural Sciences in grade 8 as stipulated in the Grade 7-9 Natural Sciences CAPS document (DBE, 2011; 10). The three specific aims are as follows; 1) doing science, 2) knowing the subject content and making connections' and 3) understanding the uses of science. The first specific aim requires learners to be able to complete investigations, analyse problems and use practical processes and skills in evaluating solutions. The second specific aim requires learners to grasp scientific, technological and environmental knowledge and be able to apply it in new contexts. The last specific aim requires learners to understand the uses of natural sciences and indigenous knowledge in society and the environment.

To achieve any of the above levels in science literacy (the derived sense of science literacy), learners must first must acquire a fundamental literacy first. Scientific knowledge has always been treasured and seen as a valuable goal to attain. Foucault and Bernstein have argued that science knowledge is thought of as more valuable because of systematic brainwashing. It is used as an ideological apparatus in society to exert power over other forms such as indigenous knowledge systems. Foucault acknowledged that power is everywhere and in all level of society. Power is prevalent in scientific knowledge and other discourses because they are accepted as superior forms of knowledge (Foucault, 1997). The perceived value of scientific ways of investigating and developing knowledge has given it a top priority in society.

Bernstein (1999) categorised the different ways that knowledge is structured, the vertical and the horizontal discourses. Horizontal discourse refers to everyday knowledge such as knowing that a rainbow occurs after it has rained. This knowledge is learned in everyday context through observation. Everyday knowledge is also acquire through segmental pedagogy- face-to-face relations with family, peers and the local community, modelling or demonstration (Bernstein, 1999). The knowledge is mostly orally transmitted, local, context dependent, specific, tacit, multi-layered and contradictory across but not within contexts.

On the other hand, vertical discourse is known as school knowledge. It is continuously and explicitly taught in schools in a coherent, explicit and systematically principled manner (Bernstein, 1999). Unlike everyday knowledge, school knowledge is context-independent as meanings do not change in different contexts. For example, in the science textbook the rainbow is studied in detail as the spectrum of light, each colour has a different wavelength and frequency. The relevance of visual images in the Natural Sciences textbooks is that they convey both the horizontal and the vertical discourse. The use of images when representing abstract concepts or processes assist learners and teachers to stop relying on just imagination. The use of the combination of both concrete and abstract knowledge make it easier for learners to reconcile the two. Refer to the photograph of the rainbow below (Figure 3.3) from Shabangu et al. (2013, p. 106) and Figure 3.2 on page 27.

Figure 3.3 "The rainbow" from Shabangu et al. (2013, p. 106)

A more complex view of science literacy is one that acknowledges that there are various aspects/ dimensions of literacy that are important in the science classroom. Martins (2011) discusses the various dimensions of literacy as outlined by Soares (2003) and how they can be applied to science education. They are namely the 1) historical, 2) anthropological, 3) sociological, 4) psychological and psycholinguistic, 5) sociolinguistic, 6) linguistic, 7) discursive, 8) textual, 9) literary, 10) educational/ pedagogical and 11) political. Important for this study is the idea that these aspects of literacy are communicated in different modes- specifically through written texts and visual image.

The first dimension, the *historical perspective*, has to do with the analysis of the history of reading and writing, readers and their practices as well as the history of writing systems. This is in light of the fact that the relation between texts, readers, reading contexts and practices are changing due to technological advances. More people have access to scientific information through museums, science centres, social media and websites. How science information is presented in the media is very crucial because there is a move towards popular science being acknowledged. Figure 3.4 in the following page from *Siyavula Natural Sciences Grade 8-B* (Beckett, 2017, p. 97) is an example of how historical concept are communicated through visual and written signs. The image here illustrates how people came to know the time of the day before the invention of watches. Currently we use wrist watches, wall watches, our phones, televisions, tablets, laptops and even our microwaves display time and how we know the concept of time has really changed.

Shadows can be useful. Sundials have been used since ancient times as a time-keeping device, like a watch or a clock. As the position of the Sun changes in the sky, the shadow cast by the style moves across the surface of the sundial. The surface is marked with numbers, allowing the shadow to indicate time of day.

Figure 3.4 from Siyavula (2017, p. 97)

The second perspective which is the literacy from the *anthropological dimension* is concerned with enculturation. Enculturation are the "practices aimed at introducing students to scientific culture" (Martins, 2011, p. 94). In school, learners and teachers engage in the science culture and assimilate this culture through the activities and the use of scientific language and methods. *Anthropology* is concerned with equipping learners with authentic science activities that science experts in museums, laboratories and science centre engage in. Literacy from this perspective exposes the problems encountered between science literacy and authentic science activities. Learners are encouraged to carry out practical investigations and write their findings like real scientists do. These helps learners to understand how hypothesis and investigation questions are formulated and tested in the scientific context. This helps learners to understand what is presented in the textbooks. It helps them understand the written text even better. The following practical activity (Figure 3.5) gives learners a skills of making a pinhole camera which is used to practically demonstrate that the image formed on a retina in the human eye is upside down.

INSTRUCTIONS:

1. Measure 5 cm from the bottom of the can (opposite end to the plastic lid) and make a mark all around the can.

2. Cut through the can along the line so that you have cut the can into 2 pieces.

3. If you have a clear lid, put a piece of wax paper on top of the lid before sticking everything together.

4. Place the lid between the 2 pieces and stick it all together using tape.

5. Wrap the aluminium foil around the can to prevent any light from coming in from the sides.

6. Use a drawing pin to make a hole in the centre of the metal base of the can.
7. Go outside with your pinhole camera.
8. Point the metal end with the hole at an object which is in bright sunlight.
9. Cup your hands around the other end and look through the open end.

Figure 3.5 Activity: 'Make a pinhole camera' from Beckett (2017, p. 86)

The third perspective, the *sociological dimension,* is concerned with learning of reading and writing as social practices. It explores how “social variables such as gender, social class, level of instruction influence both access to and the acquisition of knowledge” (Martins, 2011, p. 95). Understanding the socio-linguistic factors that influence literacy acquisition is crucial in ensuring that science education is accessible to everyone to enable social justice. The environment in which one grows up in is likely to influence the language they speak as well as the mastery of other languages. Hence the language one speaks or is not able to speak or comprehend can affect their access to the science knowledge. The use of language in science can make it difficult for one to comprehend the science concepts if they are not fluent in the language.

Figure 3.6 below from Siyavula Workbook (Beckett, 2017, p. 127) shows a male optometrist with a female patient. Siyavula workbook is available for printing and photocopying on the internet for all teachers in schools following the CAPS curriculum to use. It is used to supplement the textbooks utilised which means it is easily accessible to parents, learners or teachers who can access it on the internet. Figure 3.6 perpetuates the status quo whereby men dominate the medical field. Additionally, the image shows two white people who are more likely to have access to the best health care compared to other races in South Africa. This might reinforce negative self-beliefs amongst learners of other races whereby they might assume that such specialised careers are not meant for them but are for white people.

Figure 3.6 “An optometrist holds a lens in front of a patient’s eye to correct her vision” from Beckett (2017, p. 127)

Siyavula workbook is not the only book that perpetuates the status quo. Figure 3.7 from the Platinum textbook (Bester et al., 2013, p. 187) shows a white female (in a white coat) and a white male patient. In this image, at least the optometrist is female however she is white. The image in Siyavula and the Platinum textbook show no diversity in terms of race in spite of the fact that education seeks to promote non-racism, non-sexism and equality. Unfortunately, these are not the only books that are not promoting diversity. The Oxford Successful textbook (Baxter et al, 2013, p. 155) photograph which is figure 3.8 on the next page shows a black male optometrist and a female black patient. The Platinum and Oxford Successful learner books are used by teachers as main textbooks in the grade 8 classroom. What is problematic with the textbooks and the workbook is that they use a photograph of same race doctor and patient, which does not cater for diversity at all. Instead of showing two racially different people they favour one at the expense of others.

Figure 3.7 "Optometrists specialise in eyesight and the treatment of the eye disorders" from Bester et al. (2013, p.187)

Figure 3.8 "Optometrist examines eyes" from Baxter et al. (2013, p. 155)

The *psychological and psycholinguistic dimension*, which is the fourth one looks at how language is acquired and its relation to ways of thinking. This dimension focuses on encouraging learners to read, and relate the new information that they are reading with their prior knowledge. Activities done seek to develop the critical-thinking, problem-solving and analytical skills of learners. The fifth dimension is the *sociolinguistic* which looks at the effects of social contexts on reading, writing and speaking of science language. The context affects how language develops in participants as they use the vocabulary unique to that context.

The sixth perspective, the *linguistic dimension* of literacy emphasizes the aspects of language such as lexicon, syntax and orthography. In the context of Scientific Literacy, the linguistic perspective is about learning scientific vocabulary, terminology, organisational structures and symbols of representation. The inclusion of key concepts in the textboxes as illustrated in the image below is an example of this practice, and is related to this perspective. Learners are given the scientific definitions of the key words which contribute to their science language vocabulary. Images are contextualised to convey science concepts. For instance, the use of angles is common in the Mathematics textbook and in the science textbooks they are used in the concept of reflection. The images (Figure 3.9 and 3.10) below illustrate the linguistic perspective of literacy.

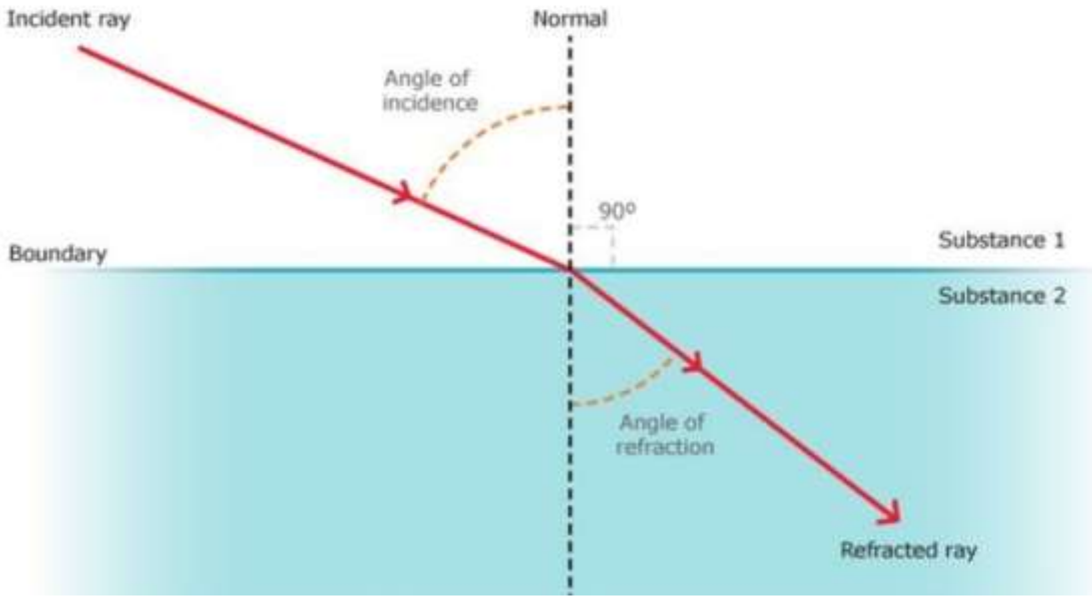
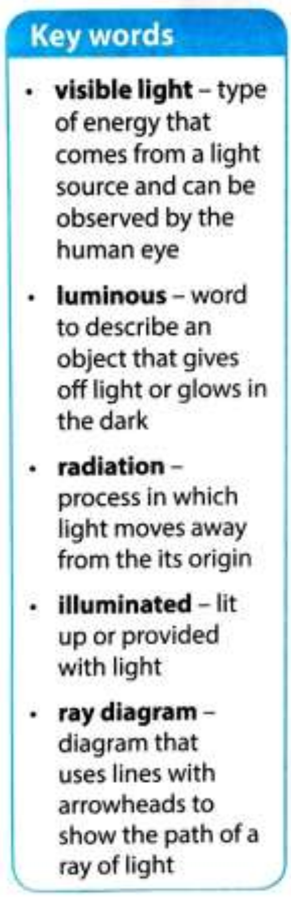


Figure 3.9 "Refraction of light in water" from Shabangu et al. (2013, p. 118)



Key words

- **visible light** – type of energy that comes from a light source and can be observed by the human eye
- **luminous** – word to describe an object that gives off light or glows in the dark
- **radiation** – process in which light moves away from the its origin
- **illuminated** – lit up or provided with light
- **ray diagram** – diagram that uses lines with arrowheads to show the path of a ray of light

Figure 3.10 Keywords from Bester et al. (2013, p. 164)

The *discursive* is the seventh dimension that views literacy as related to meaning-making which is not value neutral but rather is affected by the social conditions of the readers. The meaning communicated by texts is not dependent on the author only, the readers use their own knowledge to derive meaning from texts-the connoted message as believed by Barthes (1997). Meaning is made at three sites, which is the site of production, the site of the image itself and the site of audiencing (Rose, 2001). At the site of audiencing, the social practices and the social identities of the Grade 8 learners influence how they will read the images used in the science textbook. The socio-economic background and their prior knowledge affects how they read images. For some, certain images might pose a challenge for them to comprehend as they never experienced or heard of the concepts/phenomena before.

Written text in Figure 3.11 below relates the scientific concepts such as spectrum of light, wavelength and frequency related to everyday experiences such as sunlight. In this way science vocabulary is foregrounded to give meaning to the visual image irrespective of the many meanings one can make when looking at science images. The written text can direct learners on how to interpret images.

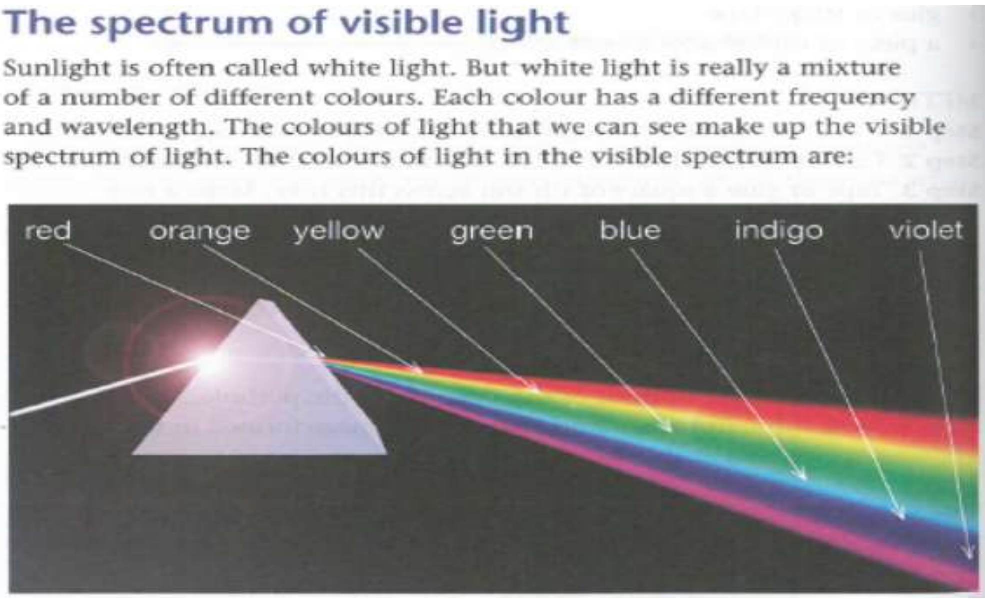


Figure 3.11 “a prism splits white light into different colours” from Baxter et al. (2013: 134)

Meanwhile, the *textual dimension* explores the differences between the oral and written texts. This perspective of literacy has given too much power to written work over aural texts, and other modes of communication as is evident through written assignments, tests and examinations. I argue that it is time to look at literacy that accommodates other modes such as speech, action and visual images. Hence my focus is on the use visual images. The scope of the M.Ed. research report is too narrow to extend my study to the other modes of communication, however such an extension is necessary and would make a valuable contribution to the field.

The *literary dimension* analyses the various textual genres and the social conditions and practices that produce them. In terms of scientific literacy, the different texts are linked to various contexts and specific knowledge production practices. For instance, a scientific report based on an experiment will be different from an essay based on analysing a scientific theory. The practices that produce a scientific report include doing the actual experiment and writing a report about it whereas an essay based on a theory will require one to engage with the theory in order to apply it.

The *educational/ pedagogical dimension* prioritises the development of teaching methods that promote science literacy. Teachers are expected to mediate the process of reading and learning in order to promote science literacy. This literacy perspective is related to my study in the long shot because my concern is to make educational stakeholders aware that there needs to be explicit teaching of visual literacy because learners come across various modes/texts that they struggle with.

The *political dimension* sees the teaching of scientific literacy as a way to empower learners to participate in decision-making as citizens. Literacy as emancipation arises from the view that science is not the only source of true knowledge as it relates to other spheres such as technology, ethics, morals and culture. This allows one to be able to make informed decision which can lead to changes in the society. This view is related to the multi-dimensional level of science literacy by Bybee (1997). Learners use their knowledge of science to make informed decisions in societal issues. The limitation of the political perspective is the top priority is gives to science literacy at expense of other forms of literacies like visual literacy. Science is seen as central in helping one to make decision, while other fields are subordinated to the science field. These perspective advocate for varying aspects of science knowledge related to the three specific aims of science education. However, the *discursive* perspective is more relevant to this study. It advocates that meaning-making of texts is subjective as readers use their own knowledge and experiences to make sense of the text. For learners to make sense of visual images in science, they will rely on their own experiences. This might result in accurate or flawed meaning-making. Hence a teacher must mediate the process of comprehending science images.

3.6 Conclusion

In this chapter, I have used a range of texts to define visual literacy and referred to some examples of visual images and written texts in the science textbooks to illustrate the concept. In addition I have analysed the concept of science literacy from a simple and complex lens. At a simplistic level, I have shown with the aid of the science knowledge in the textbooks, that there are four levels that learners have to go through to be fully literate in science. At the complex level I have discussed various perspectives of science knowledge evident in the science textbooks. In the next chapter, I discuss the multimodality theory of communication as I intend to show that science textbooks are multimedia texts.

Chapter 4

Working with science textbooks

4.1 Introduction

In this chapter I explore the idea that meaning is made in the four domains of social practice as articulated in the multimodal theory of communication by Kress and Van Leeuwen (2001). I then present an argument that textbooks are multimodal texts. I also look at the necessary skills required to decode the meaning of the three modes used in science textbooks. Although the focus of this study is on visual images, I also discuss the relationship of images to text and design elements, since it is difficult to separate different modes of communication in multimodal texts. I conclude the chapter by asserting that learning science using textbooks or workbooks is a multimodal event that requires learners to have multiliteracies especially visual literacy.

4.2 Multimodality

Kress (2004) noted that there is a move away from texts based on written language only (monomodality) to an increased use of images in texts (multimodality). This shift he claims is so significant and radical that it warrants to be termed "a revolution of the two kinds of modes" (Kress, 2004, p. 6). This revolution of modes is possible due to the advanced digital technologies that are prevalent in our everyday lives. Easy access to internet due to free Wi-Fi in some public spaces has also made accessing of images effortless on social media platforms. The use of gadgets such as smart phones, tablets and laptops by more people means that more people have access to camera and photo editing tools which come with these gadgets. As a result more people have the ability to manipulate and create their own images using gadgets. This move towards multimodality is also in the educational materials such as textbooks as discussed in chapter 1. The rise in using multiple modes is also evident in science textbooks (Kress and van Leeuwen, 2010). In fact, any communication or representation is inevitably multimodal (Kress, 2005; Cazden et al. 1996).

Multimodality combines education and communication in that communication is seen as multimodal hence meanings are conveyed using various modes in the school textbooks. Mode is defined by Kress (2005: 6) as "the culturally and socially produced resource for representation". These are the resources used for communication in a certain culture and are governed by rules. Meanwhile, multimodal literacy is defined as "a process of generating meanings in transaction with multimodal texts, including written language, visual images and design features, from a variety of perspectives to meet the requirements of [a] particular social contexts" (Serafini, 2015, p. 413). Multimodality focuses on the "interrelationships between various communicative modes" (Liu, 2013, p. 1259).

Multimodal analysis has been approached in various ways based on Halliday's theories (Adami, 2016). One approach is based on his view that language is shaped to "express and establish social roles and values". The other approach is based on his idea that language is a network of systems that present options which allows one to perform social functions. The former takes a social semiotic route whereas the latter follows the systemic functional grammar framework. The social semiotics has been discussed in detail in chapter 3. The social semiotics focuses on how modes are used to express social functions, ideologies, social values, power roles and identities (Adami, 2016). On the other hand, the systematic-functional grammar to multimodal texts focuses on modes as systems of meaning-making whereby analytical tools, frameworks and descriptions of how each modes functions and their relations is developed. As the multimodality field grows, the two approaches have become hard to separate since they complement each other. Multimodal analysis is done in different fields and not limited to art.

The multimodal theory of communication by Kress and van Leeuwen is very crucial in understanding images as it looks at "common semiotic principles that operate in and across different modes" (Kress and van Leeuwen, 2001, p. 2). It holds that meaning is made at various layers of social practices (four domains), across modes and within various media. The first domain of practice is discourse. Discourse is a socially constructed knowledge. A discourse is grounded on what people do in social practices. How do we discover new knowledge test it and approve it. As a discourse, science knowledge can be realised in different ways and places, for instance in museums, magazines, television programmes using any mode such as speech, moving images or still images. However only semiotic modes that have been developed over time for realising this discourse can be effective in realising it. For instance, various science theories have been realised through writing. A scientific report is one of the valuable tools that was used for reporting discovered knowledge. This rendered the written text as the mode well-developed in the science academia. However there has since been a shift in relying on only written text as the mode to convey science knowledge.

The second domain of practice is design, whereby semiotic resources such as modes are used to convey knowledge. Design allows social interaction, by contextualising a discourse. For instance presenting science knowledge will depend on the target audience. Is it for people at the museum, readers of magazines, radio listeners? Design requires one to select which modes will be used to realise certain elements of the communicative interaction. In the science textbook, three modes are used to effectively communicate the science knowledge.

Production, the third domain, refers to the material articulation of a semiotic event or artefact (Kress & Van Leeuwen, 2001). During production that medium which will be used to convey meaning is selected. For example, a textbook is the material used to realise the expression of the science concepts. Production and design are interrelated, for example one chooses which mode they will use, and modes will also determine the media of its production or vice versa. An actual printed textbook cannot make use of audible musical sounds to communicate as it is impossible to record the sounds onto a book. The printed book can accommodate sound through written modes such as musical symbols and lyrics.

Meaning-making is also made in the fourth domain which is distribution. Distribution involves the preservation and distribution of an expression. Distribution has to do with making an artefact accessible. It is about the transmissions of texts which conveys messages. Various textbooks are distributed to schools and teachers have to choose the textbook they will use. The choice of textbook by the teacher is affected by other factors. For instance, if the previous teachers was using a certain textbook, teachers are often not allowed to order a new textbook. They only have the option of topping up what is in use. Some choose books according to prices, quality of class activities, whether all information in the curriculum is available or not. Some textbooks have less images than others, because it takes a lot of money to print images. Some opt for black and white diagrams instead of colour diagrams to minimise the cost as well.

Essentially, meaning is affected by these four social practices. In summary, the science discourse is socially constructed and has semiotic resources which were developed specifically to realise this discourse. The modes and media used to realise the discourses have changed with time to satisfy new needs, such as advancing technology and the changing communication landscape. Additionally factors such as costs and target market influence the distribution of the science textbook.

Overall, *the multimodal studies* are based on the following four assumptions; 1) all communication is multimodal, 2) focusing only on language cannot adequately account for meaning, 3) each mode has specific affordances and 4) modes concur together with each mode having a specific task (Adami, 2016). As mentioned in chapter 3, modes are socially developed as resources to communicate meaning. In a combination of modes, each mode has a specific role that it plays instead of just being an extension of the written text, hence meaning cannot be attribute to verbal language only. Each mode performs a particular task depending on how it was shaped by cultures or societies. Finally, each affect the overall message being communicated. Intra-modality is how meaning is constructed within modes whereas inter-modality has to do with how meaning is constructed across modes (Serafini, 2015). It is important for teachers to understand the three modes (written text, visual images and design elements respectively) and how they work individually as well as together to convey meaning, in order for them to teach learners to read images.

4.3 Natural sciences textbooks are multimodal texts

It follows from the discussion above, that the use of various modes in the science textbooks make them multimodal texts. Multimodal texts are defined as "print-based and digital texts that utilize more than one mode or semiotic resources to represent meaning potentials" (Serafini, 2015, p. 1). Science textbooks employ three modes which are; written text, visual images and design elements. These modes used in the textbook work together to convey science knowledge.

Figure 4.1 on the page 46 shows a typical science textbook page that I argue is a multimodal text. The page has clear design features that help the reader navigate the text. For example, the written text 'Radiation of light' at the top is the subtopic hence it's a large font. This helps the reader to know that what they will engage in is about the radiation of light. The subtext below has various words in bold such as 'visible light'. These bolded words are isolated and written in the textbox title keywords. Since they are the main concepts under the subtopic. The smaller text on the side of the text box is followed by photograph of the sun rays let through a gap in the cloud. A caption describes the photograph in full and even adds that light rays travel in straight lines.

How the phenomenon of light travelling in straight line can be proven is explained in the second paragraph. A text explains how this observation can be observed using the pinhole camera is also shown. The text is then followed by the image. The first image, shows the sun but it is not mentioned in the written text. Only the idea that light travels in straight-line is discussed in both. The sun is another example of a luminous object. The second image, is described under ‘The pinhole camera’ sub-heading. The image shows the labelled pinhole camera.

Unit 1

Radiation of light

Key words

- **visible light** – type of energy that comes from a light source and can be observed by the human eye
- **luminous** – word to describe an object that gives off light or glows in the dark
- **radiation** – process in which light moves away from the its origin
- **illuminated** – lit up or provided with light
- **ray diagram** – diagram that uses lines with arrowheads to show the path of a ray of light

Visible light (or light) is emitted from a **luminous** object such as a star or a light bulb. A luminous object is any object that gives off (emits) light from its own source, such as the flame of a burning candle or lightning. Light is transferred by **radiation**. When you switch on the light in a room at night, the whole room becomes **illuminated** because light is emitted from the bulb and radiates in all directions.

Figure 2 Light travels in straight lines. In this picture, some light rays from the Sun are let through a gap in the clouds. We can see that the rays of light do not bend as they radiate towards the Earth.

Light travels in straight lines. This explains why you are not able to see light around corners. When light travels from an object that is around a corner, the light is unable to bend around the corner and reach your eye.

A **ray diagram** is a simplified way of showing how light is radiated from a luminous object. The path and direction of one ray of light is represented by a line with an arrowhead. But, remember: light rays radiate in all directions, so a simple ray diagram only represents a few of the rays of light that are radiated by the luminous object.

The pinhole camera

A pinhole camera also illustrates that light travels in straight lines. This is a very simple apparatus that is used to form an upside down image of a luminous object on a screen. The pinhole camera can be constructed by using a shoebox that is painted black on the inside. At one end of the box there is a very small hole. At the other end, the side of the shoebox is removed and fitted with wax- or tissue paper, that will form the screen on which the image forms.

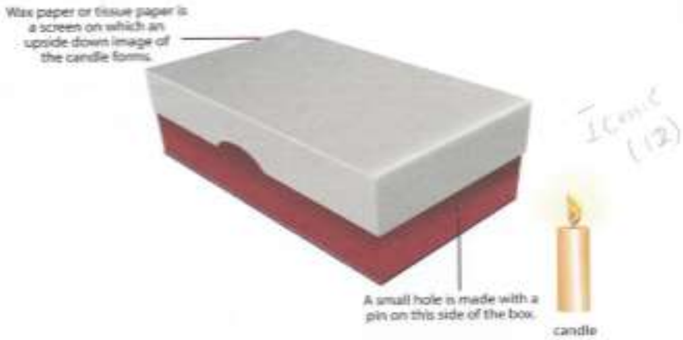


Figure 3 A pinhole camera that forms an image of a candle

Figure 4.1 Page 164 from Bester et al. (2013)

4.4 Types of modes in the Natural sciences textbooks

The purpose of using multiple modes in any text is because different modes offer different potentials. For instance, when describing the process of how a rainbow forms using words, it is said that light rays enter the water droplet, it does not describe where exactly it enters. How the light is reflected within the droplet is left to imagination. The positions of the refracted ray, reflected ray and eventually the refracted ray that leaves the droplet is not discussed in words. Arguably, how all these elements are spatially placed in relation to each other can more effectively shown in a visual image, Figure 3.2 on page 27 instead of the written text. When considering the description of the process with the image of a rainbow it is clear that both modes provide details that the other might fail to cover. The visual image of the formation of the rainbow can be represented with one image whereas it takes a lot of words to explain the process.

The method of representing the same concept using different modes such as written text and visual image is called *synaesthesia*. Synaesthesia is "the process of shifting between modes and representing the same thing from one mode to another" (Cope & Kalantzis, 2009). Synaesthesia is helpful in explaining a concept in various ways as to accommodate various learning styles. Learners with visual intelligence and visual learning styles will benefit more from images whereas learners with linguistic intelligence will be more likely to understand information in the form of words. The structural analytical perspective helps one to analyse how texts are composed and designed (Serafini; 2015).

4.4.1 Written text

Written text and speech have been explored extensively in linguistics. Linguistics is the study of language concerned with the nature of language and communication. The branches of linguistics include phonetics (the study of the production, acoustics and hearing of speech sounds), phonology (the patterning of sounds), morphology (the structure of words), syntax (the structure of sentences), semantics (meaning) and pragmatics (language in context). Written language is seen as derived from spoken language, however Kress (2005) makes us aware that written and spoken language have different affordances**.** This implies that each mode has meaning potentials and limitations in terms of what it can communicate. These limitations and potentials are affected by the social and cultural context in which they are used.

For instance, written text uses words in sequence whereas speech relies on sounds in sequence. When reading or hearing this sentence ‘cells are building blocks of all living matter’ shows that the cell is central in this sentence. The word ‘cells’ comes first because I am defining the term cell. In contrast when trying to define matter, one can say ‘all living matter is made up of cells’. The word cells is placed at the end of a sentence because it is not central. This shows that the position of words helps one to derive meaning. The similarity between the speech and written text is that they are governed by time and sequence which make meaning-making possible.

The materiality of sound allows one to uses pauses, silences, lengthening and intensifying of sounds according to different cultures (Kress, 2005). In this sense, the materiality of sounds helps one to convey meaning. On the other hand, written text is governed by the logic of time or temporal sequence and the meaning is derived from this temporal sequencing (Kress, 2005). In written text, elements such as words and sentences are written in a certain order or sequence whereby one word comes after the other, or one sentence after the other (Kress, 2005). The materiality of words allows one to use punctuations or space to emphasise certain things. This is the meaning potential that the written text have. We can only make meaning from written text by employing the order predetermined by the author.

Written text is valuable in the Western world, however despite the high status that written text has earned, Kress (2005: 5) in his presentation at the Conference on College Composition and Communication acknowledged that it seems that “writing is giving way, as it is being displaced by image in many instances where previously it had held sway”. In addition he pointed out that the medium of distribution is also changing, with the screen replacing the traditional book. However the focus in this study is still on the traditional textbook.

Words just like visual images rely on conventions in society they are used in. For instance, the context of this study will be a Natural Science classroom and the words appearing in the used textbook will have specific meaning due to this context. For example, the rainbow is a spectrum of visible light in the Natural Science textbook, however the rainbow can be used in folk stories or novels in the English textbook. The storytelling books in any language can narrate folk stories about how the rainbow is formed. Another example is the term ‘reflection’ which is a process whereby light is reflected from a reflective surface. At the same time a reflection is an image that forms on the reflective surface. However in the English novel, reflection might refer to the process of thinking seriously about something. Therefore the meaning of words in both contexts is different.

4.4.2 Visual images

Unlike words, visual images are governed by the logic of spatiality, composition and simultaneity (Kress, 2004). This logic applies to the use of the various basic elements of communication. Elements of visual communication include the dot, line, shape, direction, tone, colour, texture, dimension, scale and movement (Dondis, 1973). Dondis acknowledged that irrespective of the medium of visual work, for example, whether something is a drawing, sculpture, painting or sketch made with clay, paper or wood, all of them draw from the basic elements mentioned above.

Spatiality has to do with how elements of the visual image are arranged in relation to each other within the frame. The combination of visual elements to communicate a certain message is central in composition. According to Kress and van Leeuwen (2010, p. 176), the composition of the whole is the "way representational and interactive elements are made to relate to each other [and] the way they are integrated into a meaningful whole". How elements are put together affects or communicate a certain meaning. However, despite how these elements are integrated, they are available to the reader at the same time-simultaneity. Unlike with written texts, there is no given order of how to read these elements; the reading order is the prerogative of the reader, based on their own interest how they view the elements even though they are simultaneously present.

Based on the discussion of the written text and the visual image, their difference is in terms of the logic, the mode of representation and their affordances. The written text is governed by sequence and time whereas the visual image is governed by spatiality, composition and simultaneity. The reading of the written text is pre-ordered by the author. The sequencing of words, sentences and paragraphs does not allow random reading whereas the elements of visual images allows one to order their reading.

Visual images in science textbooks can be classified into various categories. Each type of visual image has its own meaning potentials and also limitations. Each type can also be understood as a different mode. Khine and Liu (2017) conducted a study whereby they analysed the types of images present in a science textbook. They had the following categories; iconic diagrams, schematic diagrams and charts and graphs and augmented reality. Examples of each category as represented in the Grade 8 Natural Sciences textbooks follow:

A. **Iconic diagrams** are photographs and pictures which depict the concrete objects with similar form as the object they represent. Photographs are often seen as truthful as they capture things as they are. Since diagrams are simple drawings illustrating or explaining how something works, the term iconic diagrams might be problematic. This is due to the fact that photographs are a true representation of the object they represent whereas diagrams uses symbols such as lines or any other shape to illustrate or explain how something work or occurs. As a result instead of using the term iconic diagrams, I will refer to them as iconic images. The photograph below represent sunlight being radiated by the Sun in Figure 4.2 below.

Figure 4.2 "Light travels in a straight line" from Baxter et al. (2013; 164)

B. **Schematic diagrams** are diagrams that are abstracted from real-world entities but do not have the same physical relations as the referred object. Schematics are useful in representing concepts and phenomena that occurs at microscopic level (Mnguni, 2014). For example, Figure 4.3 is a schematic diagram showing how a ray of light passing through air into the triangular prims and into the air again and finally enters the screen which displays the 7 colours (of the rainbow) which make up the spectrum of light. What is abstract about this diagram is that we observe visible light as white or yellowish in real life and not as the seven colours it constitutes of as shown on the figure 4.3. It is usually after rain that we see the full spectrum of light as the rainbow, or sometimes when watering the garden using a hose pipe, there is a formation of the spectrum of light.

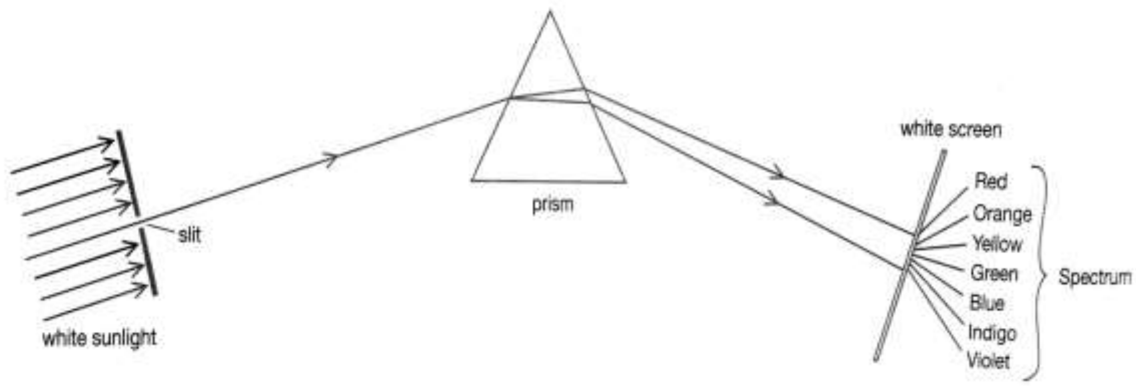


Figure 4.3 "A ray of light as it passes through a prism making a rainbow of colours" from Baxter et al. (2013; 136)

C. **Charts and graphs** depict quantitative and numerical data. They are used to compare data and show patterns. Visible light has various properties. It travels in straight lines and can be reflected by reflective surfaces. How reflections occurs can be represented mathematically using graphs, as seen in Figure 4.4 below, which captures the wavelengths of different colours. To understand graphs learners must be familiar with types of graphs. In this image, the bar graph is used. Learners must have the knowledge of how bar graphs work and also the wavelengths of all the colours of the rainbow.

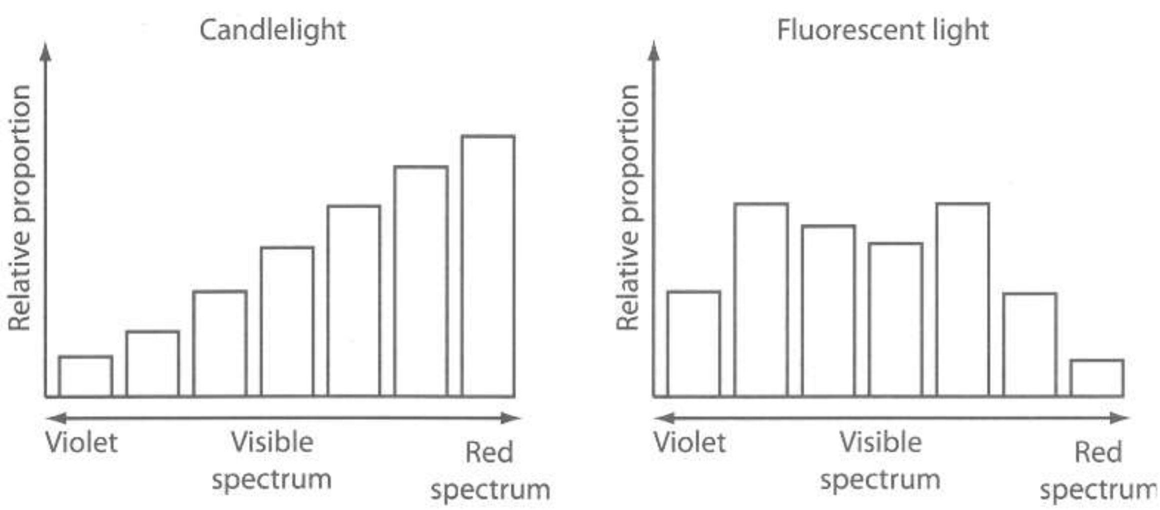


Figure 4.4 "Bar graphs showing the visible spectrum for candlelight and fluorescent light" from Vermaak et al., (2013, p. 146)

D. **Augmented reality** are images that are in between completely synthetic and completely real. An example of an augmented image will be the one that is produced when one looks at a natural object like the model of a cell using a phone app, the app will in turn provide information about the model in front of a learner. For instance, the app may describe the object under study, name the person who discovered it and even label it. However this category was not found in the Natural Science textbooks in the topic ‘Visible light’.

4.4.3 Design elements

The design elements of a textbook contributes to its organization and readability (Serafini, 2014). Design elements include; contrast, typography, consistency, alignment, proximity, white space, graphics, instructional design and color palette (Price, 2012). Written text must utilise consistent font size and type, free of grammatical and spelling errors for basic readability. Keywords and key concepts can be presented in **bold** or *italics* to show emphasis. Highlighted or bolded words helps the reader to understand their meaning in the context they used in. Boldness signifies emphasis whereas italics is often used to highlight a non-English word. Contrast is how elements on the page are visually different from each other in their level of boldness. If everything is in bold or italics then there is no difference it makes and it will fail to emphasise words and highlight new non-English words or new terms.

In terms of instructional design; key words, learning outcomes, introductions, recap of learnt concepts, activities must be easy to read. Key words in textboxes alert the reader to take note of the key words used in the topic/sub-topic. These key words help learners to build science vocabulary as they use them to explain science phenomena. The insertion of science keywords in textboxes is advocated by the linguistic perspectives of science literacy which holds that learners are to be taught the science terminology. Learners must be able to understand science terms and use them to explain phenomena in the conceptual and procedural science literacy level.

Not only the type and size of font are to be consistent, how graphic design elements are used and placed on the page in a focused and similar manner to each other signifies consistency. Consistency from page to page and chapter to chapter makes it easier for one to read as there is repetition. One gets comfortable with the structure of the book and knows where to find what type of information. The written texts and images as well as textboxes on a page must be aligned. Aligning the same line relative to each other makes the page to look neat and organized. Visual images and written texts do not bleed to the edges of the pages neither are they always contained in borders. However, the way they are aligned prevent them from overlapping the margins of the textbooks, which helps in printing so that the images are not cut out.

The idea of placing relevant materials close together so that the reader can visually understand what is and is not related to each other is called proximity. Topics, sub-topics, captions, textboxes and images need to be placed in a way that shows the relation. It will be difficult to read a heading that says “Radiation of light” only to find the text succeeding it discussing world war. The worst case scenario is when the image on the same page shows an advert of Nike shoes. This will be confusing to the reader of a textbook. Even in magazines whereby various topics are discussed, the materials belonging together are placed in a clear relation to one another. Proximity helps the reader to make connections in the knowledge presented. One good example of proximity is when the caption of an image must be close to it for easy relation.

To avoid a textbook page looking overloaded and overwhelming white space must be sufficient. There must be enough space in the margins of the books, space between written texts, textboxes, graphics so that the information can be processed with ease. Important for this study is the use of graphics. Graphics must not be blurry or too small to be seen in detail unless whereby scaling is being taught to learners. Color graphics must be used where necessary instead of black and white since it will be hard to determine certain information. However black and white graphics are still relevant if colour as one of the visual element to communicate meaning as colours have various social or cultural meaning. The labels and size need to be big enough for learners to see. In addition, relevant images must be used. Relevancy in this case has to do with the effectiveness of the image in communicating knowledge. Color palette used should contribute to making reading easier. It will be hard to read a blue text against a brown background. It will also be difficult to read yellow text against the white background. As such it is very important to use a colour stem that makes reading an easy task. In figure 4.5 on the next page, I have used textboxes and arrows to show that these elements are used in science textbooks. Figure 4.5 is a page from the Oxford Successful textbook (Baxter et al., 2013, p. 147)

Contrast

Key words in bold

No grammatical and spelling errors

Typography- correct and consistent font

Instructional design-key words are present

How the eye works

Light enters the eye and is focussed to form an image on a layer of specialised **receptor cells** at the back of the eye called the **retina**. The receptor cells are sensitive to light.

Different receptor cells are stimulated by certain frequencies or colours of light. This means that they can detect colours. These cells are called **cone cells**. There are three types of cone cells: one type can detect red light, one type detects blue light and one type detects green light. The frequencies of light that are absorbed by the surface do not reach the eye.

The cone cells in the retina change light energy into electrical signals or nerve impulses. The impulses travel along the **optic nerve** to the brain. The brain interprets these impulses into our perceptions of light, or, simply put, to form a picture. The image on the retina is upside down, in the same way that a pinhole camera turns the image upside down. The brain turns the picture around so we see things upright.

The ray diagram below shows how an image is formed on the retina of the eye.

New words

receptor cells – cells which are sensitive to stimuli such as light, movement or chemicals

retina – the light-sensitive layer of cells at the back of the eye

cone cells – cells in the retina which are stimulated by different frequencies of light

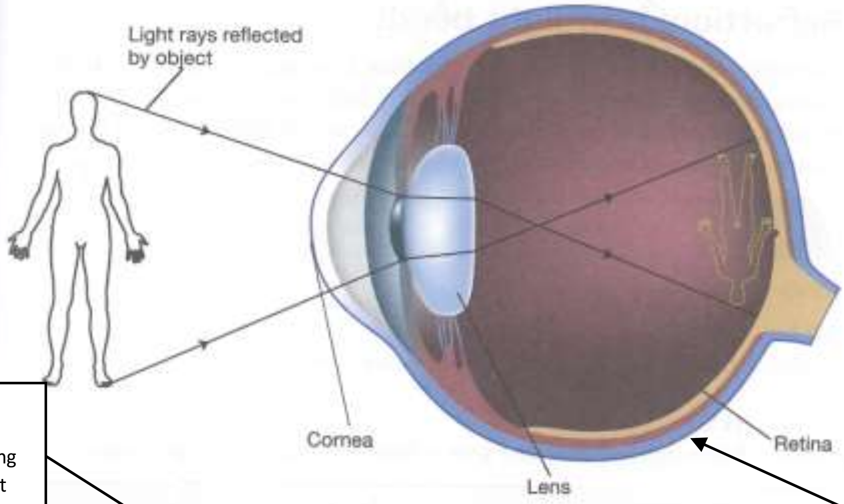
optic nerve – takes electrical signals from the eye to the brain

Color palette

The eye has different colours differentiating its parts

White space-the page is not overloaded with information as there is enough white space

Alignment- The first paragraph, image and the activity are aligned which makes the separate keywords to be easily recognised



Proximity

Caption explaining the image is right under the image

Graphics

Very clear, colour is used and labels are big enough to be read

Figure 3 Ray diagram to show how an image forms in the human eye

Activity 1 Explain why we see different colours

Individual work

1 Explain why a blue car looks blue.
2 Explain why a sunflower looks yellow.
3 Explain why a red apple looks red.

Instructional design-key words are present

Clear instructions on the activity

Unit 12 Visible light: Seeing light 147

Figure 4.5 page 147 from Baxter et al. (2013, p. 147)

4.5 Reading multimodal texts

It follows that if the texts we are using to learn with are multimodal, then learners need to be literate in those multiple modes. Thus, competence in science education depends on various literacies. The need to be literate in multiple literacies is well captured by the New London Group (1996). The term 'multiliteracies' was coined by the new London Group in 1996 (Cazden et al., 1996; Cope and Kalantzis, 2009) to emphasise "how negotiating the multiple linguistic and cultural differences in society is central to the pragmatics of the working, civic and private lives of students" (Cazden et al., 1996, p. 60). The New London Group consisted of experts in language, literacy and communication and were concerned with the changing landscape of communication.

The New London Group saw a need to develop new pedagogies that will prepare students for the increasing multimodality, multiculturalism, multilingualism and multi-skills in the everyday life, work life and civil society life. Pedagogy is explained as "a teaching and learning relationship that creates the potential for building learning conditions leading to full and equitable social participation" (Cazden et al., 1996, p. 60). However, this study does not focus on teachings strategies but uses the following concepts from The New London Group; 1) communication is multimodal, 2) each mode offers distinct potentials and 3) meaning-making is active and transformative. Multiliteracies theory advocates that learners need to have multiple literacies to adapt to the current social, technological and political changes.

Even though learners need to develop multiple literacies, the scope of the M.Ed. research is not large enough to explore all the literacies so I am focussing on visual literacy since images are dominant in the science textbooks and classroom and visual literacy skills are lacking in science teachers and learners. Since visual literacy is undervalued in science education, there is a need to explore its significance in science learning. Visual literacy can be crucial considering the low fundamental literacy levels in our country.

4.6 Learning science using the textbook is a multimodal event

From the above discussion about the various modes of representation dominant in the Natural sciences textbook, it is undeniable that reading science textbooks involves visual literacy skills such as understanding the meaning of typography, colour palette, text boxes and borders. Understanding the concepts represented involves the ability to read elements of visual images and the use of text in relation to the visual images. It is clear that learning science using the textbook (with the help of a teacher) is a multimodal event. “The reading of a specific visual image or multimodal text is always a particular interpretation, in a particular context, at a particular in time” (Serafini, 2015). Learners bring their experiences, negotiating meaning.

Jewitt, Kress & Tsatserelis (2001) highlight how learning occurs in a multimodal classroom. They conducted a study to explore the multimodal environment of a science classroom. Learners conducted an experiment whereby they were studying onion cells under the microscope. The lesson involved studying an ordinary everyday item such as an onion and studying it as ‘collection of cells’ in the science field. At the beginning of the lesson the teacher described the cells as ‘building blocks’ and ‘a honeycomb’. The description of the cells was conveyed using speech as a mode. Based on the two analogies and their observation of the onion skin under the microscope (visual representation), learners were asked to produce what the cells look like. Learners came up with different diagrams of the onion cells despite having looked at the same onion under the same microscope. The following images were produced by the learners who participated in the study. Even though the drawings had elaborated written text of the procedure followed, I have only included the drawings of the learners (Figures 4.6-4.9), however some have the teacher’s comments as the teacher marked the drawings and wrote the feedback next the drawings.

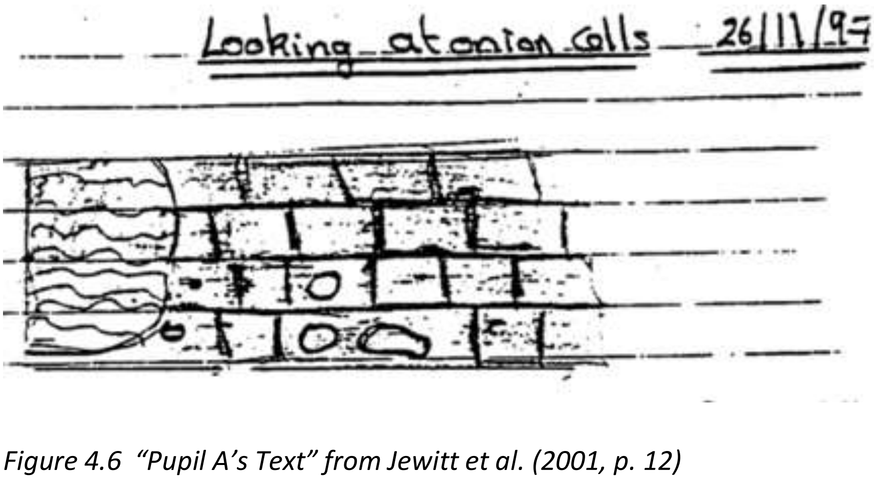


Figure 4.6 “Pupil A’s Text” from Jewitt et al. (2001, p. 12)

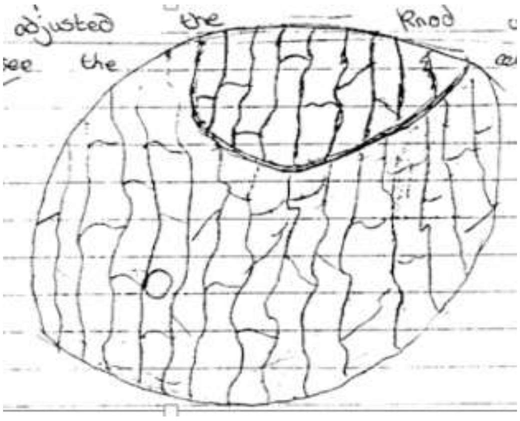


Figure 4.7 "Pupil B's Text" from Jewitt et al. (2001, p. 13)

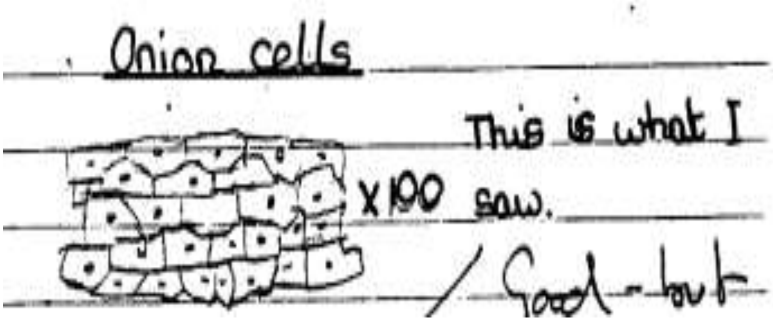


Figure 4.8 "Pupil C's Text" from Jewitt et al. (2001, p. 14)

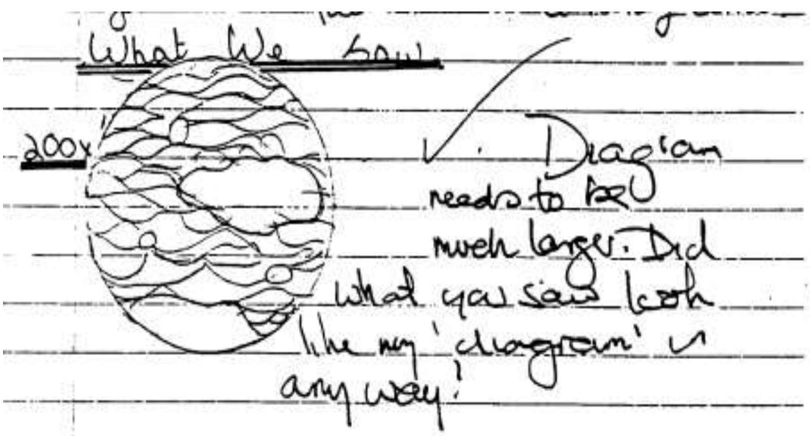


Figure 4.9 "Pupil D's Text" from Jewitt et al. (2001, p. 15)

What is useful in the study is that learners had to deduce information from multiple modes such as the teacher's speech, what they observed under the microscope and their written report. The teacher referred to the cells using the two analogies; 'building blocks' and 'honeycomb' and learners reconciled the analogies from prior knowledge with what they observed under the microscope. Learners had to negotiate between their everyday knowledge of the building block and honey-comb and the scientific knowledge of the collection of cells observed under a microscope. Jewitt et al. (2001) concluded that, different drawings produced by learners (A-D) are as a result of their uniqueness when selecting the best representation for the analogies presented. Learners' visual images were not free from their personal interest and the context of learning. Thus, Jewitt et al. (2001, p. 5) suggested that learning occurs "through the interaction of the visual, actional and linguistic communication and involves the transformation of information across different communicative modes". The study by Jewitt et al., shows one example of how the science classroom is a multimodal event.

4.7 Conclusion

I have discussed the theory of multimodality to show that every communication is multimodal. I have illustrated with examples that textbooks are multimodal as they use images, written texts and design elements to communicate science knowledge. These three modes were discussed individually to show how they work to communicate science knowledge. Written text and visual images in science have their own potentials and limitations. Written text relies on sequence whereas elements in an image are simultaneously present. The presence of design elements makes reading easier for the textbook users as illustrated with a page from on the textbooks. Thus learners need visual literacy to be able to decode meanings communicated by the three modes. I have also stressed the need to focus on visual literacy as one of the multiliteracies needed in science education given the scope of this study. I have looked at how not only are textbooks multimodal texts, using textbooks during the process of teaching and learning is a multimodal event as it involves observing, doing and verbal communication which are different modes. Thus learning of science occurs in multimodal environment. Images can help in developing understanding of science concepts- especially in countries with low literacy levels, hence there is need to develop science learners' visual literacy.

Chapter 5

Analysis of visual images

5.1 Introduction

In this chapter, an analyses of the frequency and types of images used per topic and in each book is presented. The chapter is structured in a manner that follows the process I went through to obtain the data. I explain how I counted the number of images in each textbook to determine which books use more images, and to better understand the range of images used. After counting the images in each textbook, I then decided to categorise types of images to determine the type of skills learners need to be able to master a certain topic. Finally, I argue there is a progression of knowledge from the concrete everyday knowledge to abstract scientific knowledge as illustrated by images used.

5.2 Types and frequency of visual images used to explain the topic 'Visible light'

The bar graph below (Figure 5.1) summarizes the types and frequency of images found in the four science textbooks and one workbook.

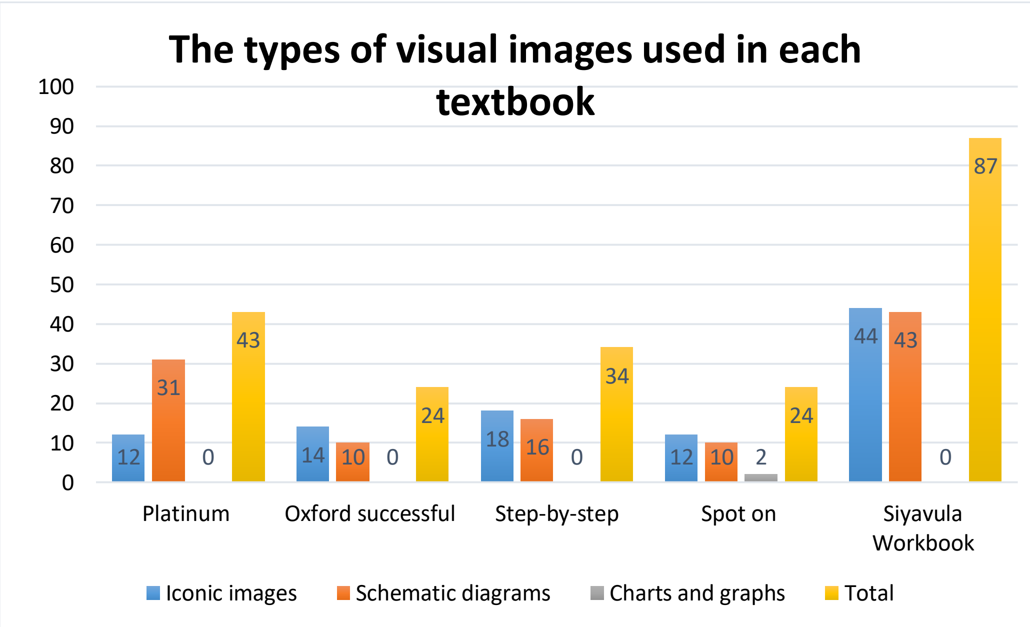


Figure 5.1 A bar graph showing the types and frequency of images in each science book.

It is clear that the *Platinum Natural Sciences textbook* has more images compared to the other three textbooks. However the *Siyavula workbook* has twice the images found in the Platinum textbook. The reason for the high prevalence is that workbooks are meant to make content more accessible since they are developed to supplement the textbooks. They are good remedial resources for learners who are struggling in the subject. The most dominant images are the iconic images in 3 textbooks; *Oxford Successful*, *Step-by-Step*, *Spot On* and the *Siyavula* workbook. As discussed in chapter 2, iconic images are photographs or images depicting everyday knowledge and they make science learning a lot easier as learners are familiar with what they depict. The charts and graphs are the least used images. Only the *Spot on* textbook has two graphs in the revision section, however the bar graph communicates information about sub-topic 2. This is due to the type of content being presented in a topic. Since graphs are used to communicate numerical data, most these topics are still sufficiently explained using the iconic images and schematic diagrams.

5.2.1 Subtopic 1: Radiation of light

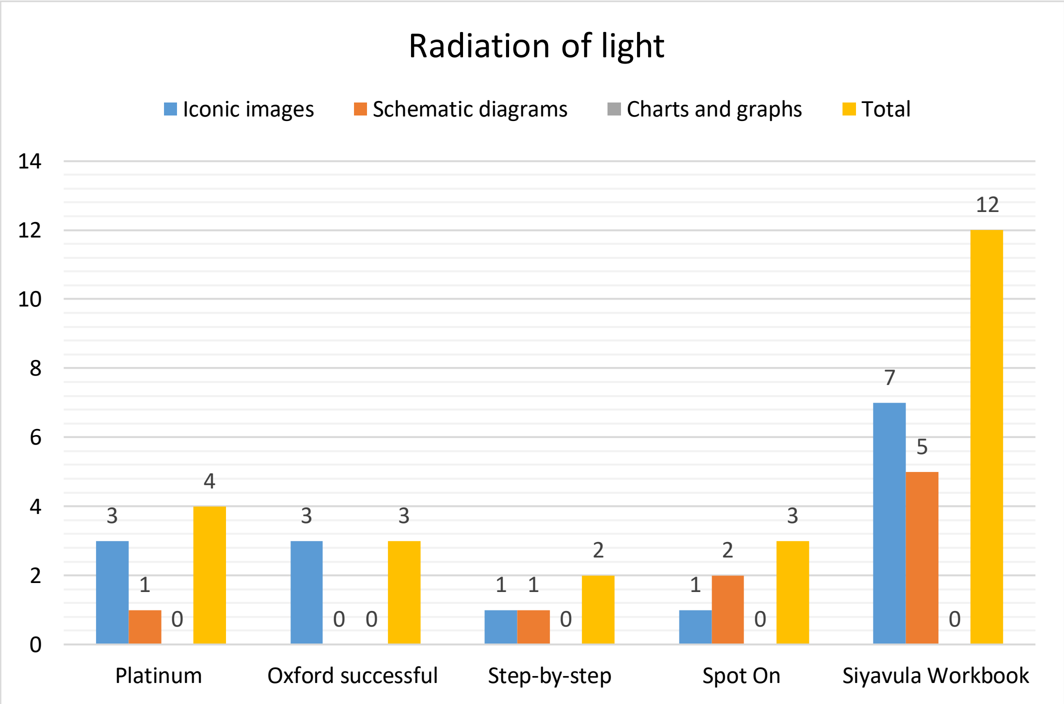


Figure 5.2 A bar graph showing the types and frequency of images in 'Radiation of light'.

The radiation of light is mostly based on what objects emit visible light. And what the visible light constitutes of the seven colours of the rainbow. As a result the books text to use both the photograph of the rainbow and its abstract version in the form of a wave, as can be seen on page 166 of *Platinum*, reproduced in this study on page 70. None of the textbooks used charts and graphs in the section under study, whereas two books, namely *Platinum* and *Oxford Successful* have more iconic images than schematic diagrams. *Step-by-step* has an equal number of both the schematic and the iconic images. Meanwhile, *Spot On* has more schematic than iconic diagram.

5.2.2 Sub-topic 2: Spectrum of visible light

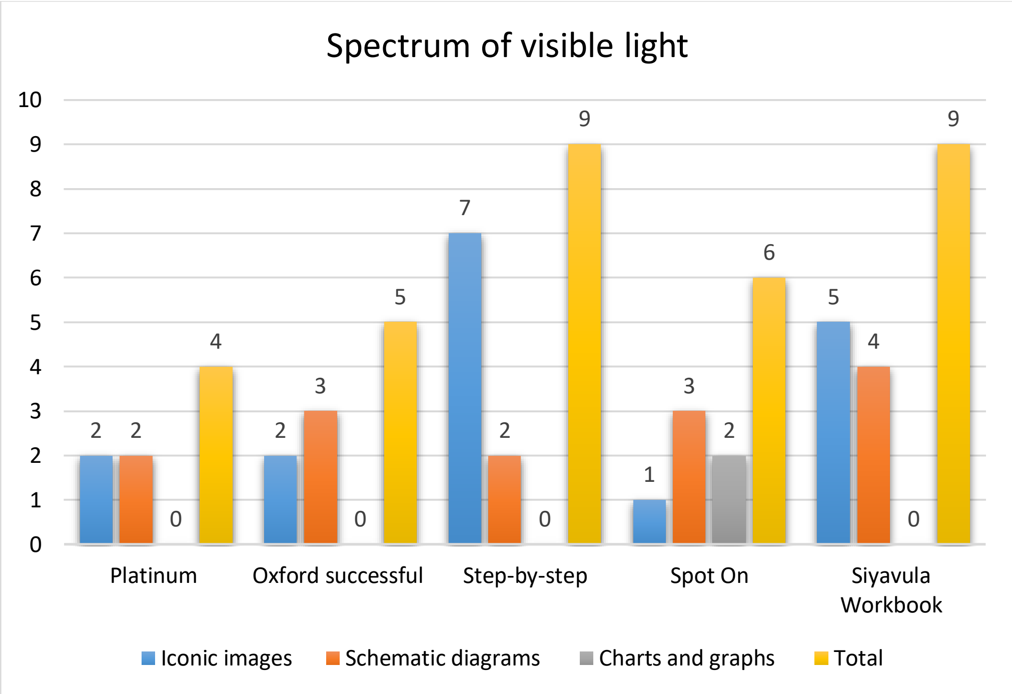


Figure 5.3 A bar graph showing the types and frequency of images in 'Spectrum of light'.

Only two bar graphs were used in *Spot On* to explain the concept of spectrum of visible light. The spectrum of visible light is basically a wave of light. Hence most of the textbooks use the photograph of the rainbow alongside schematic diagram representing the spectrum of light in the form of a wave. The *Platinum* textbook used the equal number of the schematic and the iconic images. *Step-by-Step* and the *MST workbook* used more iconic images and the *Oxford Successful* and *Spot On* used more schematic diagrams.

5.2.3 Sub-topic 3- Opaque and transparent substances

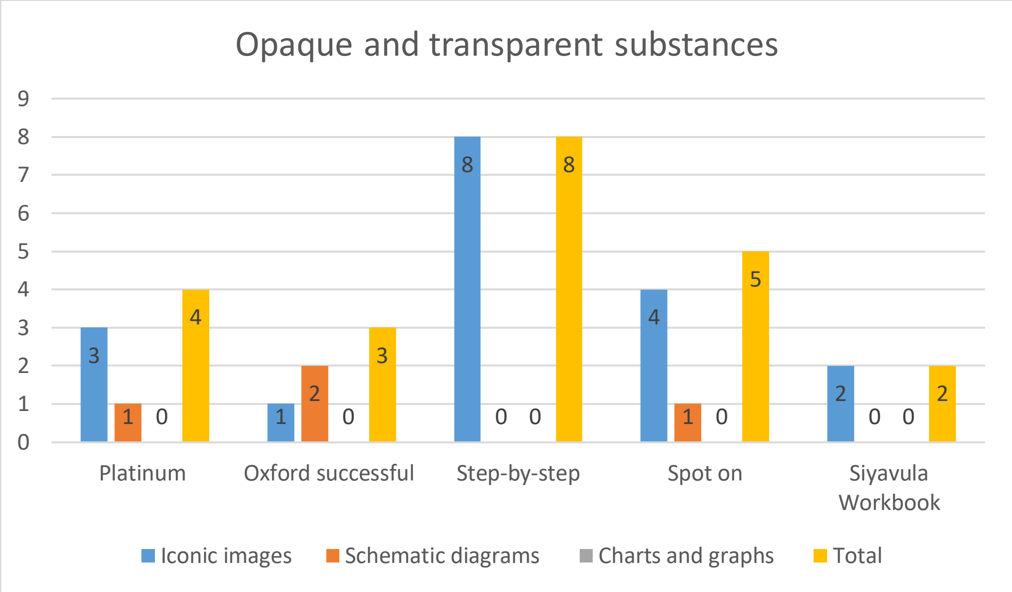


Figure 5.4 Bar graph showing the types and frequency of images in 'Opaque and transparent substance'.

The subtopic 'opaque and transparent' has no charts and graphs for the same reason as topic 2 "The spectrum of light". Only *Oxford Successful* used more iconic images than iconic images. *Step-by-Step*, *Platinum*, *Spot On* and the *MST workbook* used more iconic images than schematic diagrams. The overall dominant image in this subtopic is the iconic image. Opaque and transparent objects look at how shadows form, by looking at the distance between the source of light and the object which is opaque (does not let it). The transparent objects on the other hand let light in.

5.2.4 Sub-topic 4: Absorption of light

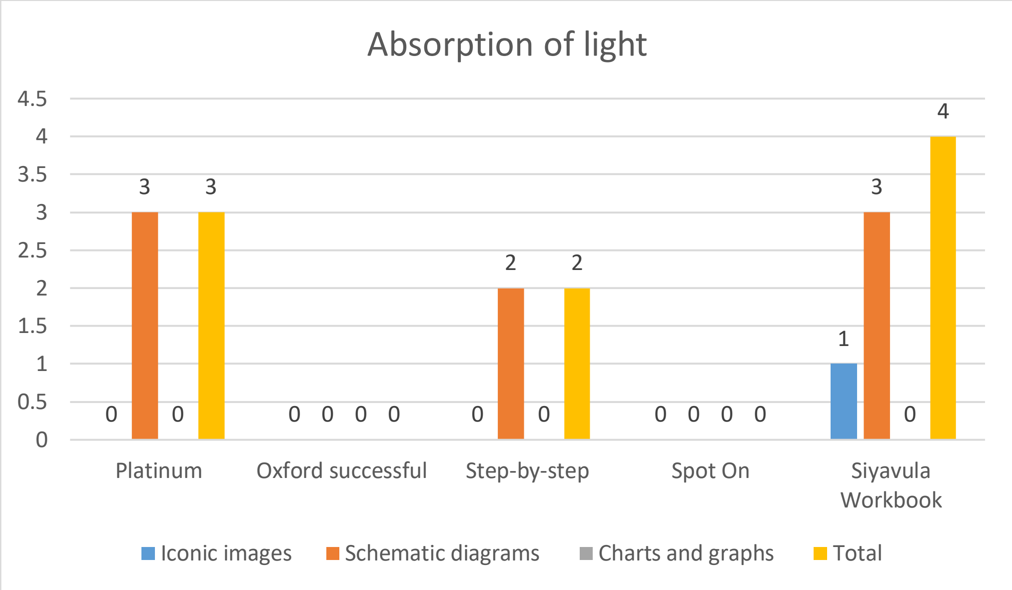


Figure 5.5 A bar graph showing the types and frequency of images in 'Absorption of light'.

Two books which are *Oxford Successful* and *Spot On* did not have images, and their scope on the topic is also quite limited. The subtopic 'absorption of light' has no charts or graphs. Only the *Siyavula* workbook used more iconic images than schematic diagrams. *Step-by-Step* and *Platinum* used only schematic or scientific diagrams. The overall dominant image in this subtopic is the schematic diagram. The reason for more scientific diagrams in this topic is due to the fact that learners are already familiar with the topic and at this point they do not rely on the images of the everyday knowledge.

5.2.5. Sub-topic 5: reflection of light

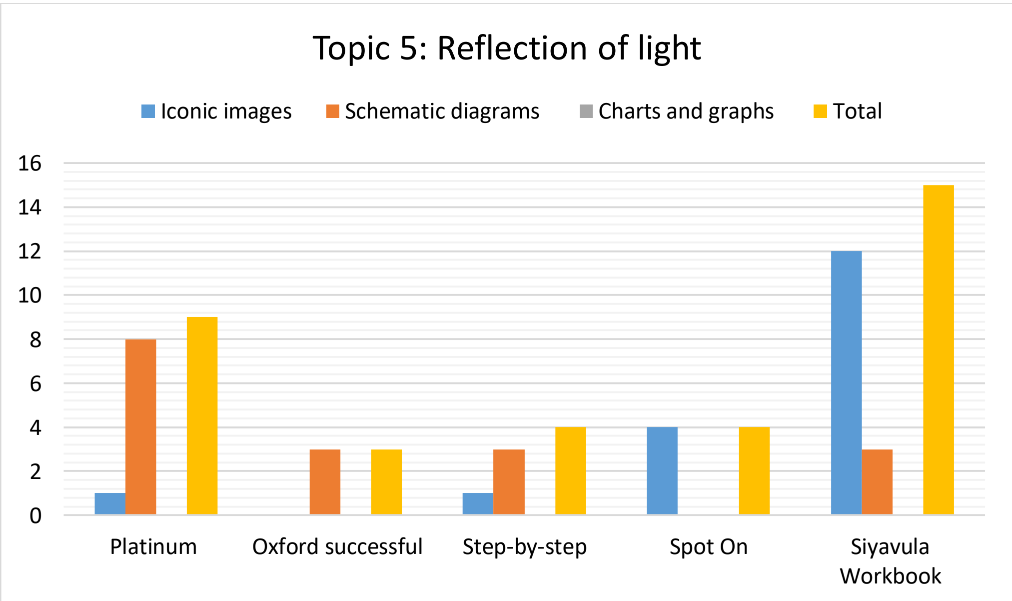


Figure 5.6 A bar graph showing the types and frequency of images in 'Reflection of light'.

In the subtopic ‘Reflection of light’ only the *Siyavula* workbook had more iconic images than schematic diagrams. Only iconic images were used in the *Spot On* textbook. *Platinum, Oxford Successful* and *Step-by-Step* used more schematic diagrams to explain the reflection of light.

5.2.6 Sub-topic 6- Seeing light

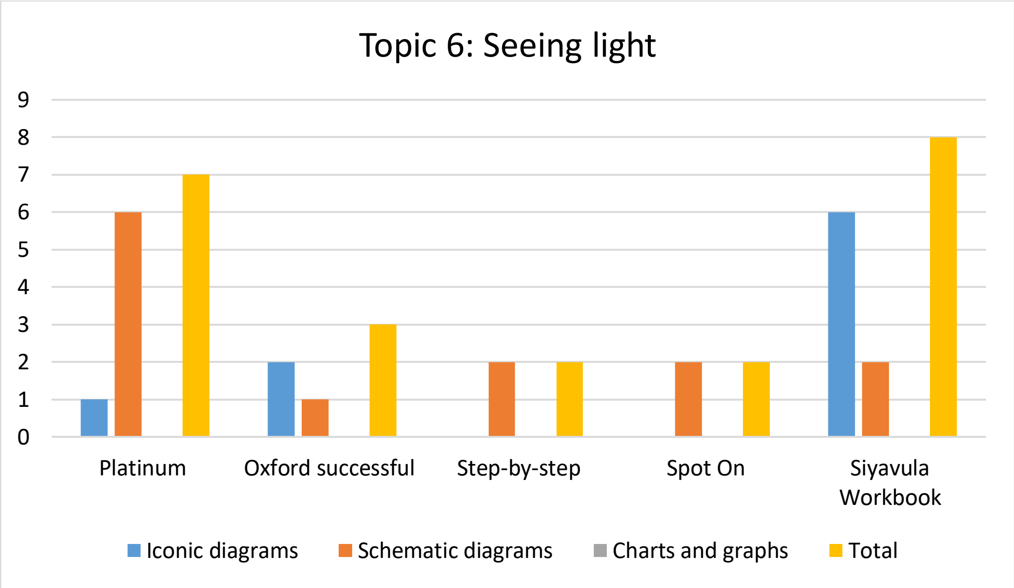


Figure 5.7 A bar graph showing the types and frequency of images in ‘Seeing light’.

Three books used more scientific diagrams than photographs of everyday things, namely *Platinum*, *Step-by-Step* and *Spot On*. *Oxford Successful* and the *Siyavula* workbook used more iconic images than schematic under the topic “seeing light”. No graphs and charts were used since the sub-topic focuses on how the eye observes images. The outer side of the eye is concrete and learners are definitely familiar with it, however the longitudinal/ cross section view is only captured in images and models and is not exposed for learners to see. This makes the eye and the process of seeing abstract, hence all the books use the schematic/scientific diagram.

5.2.7 Sub-topic 7: Refraction of light

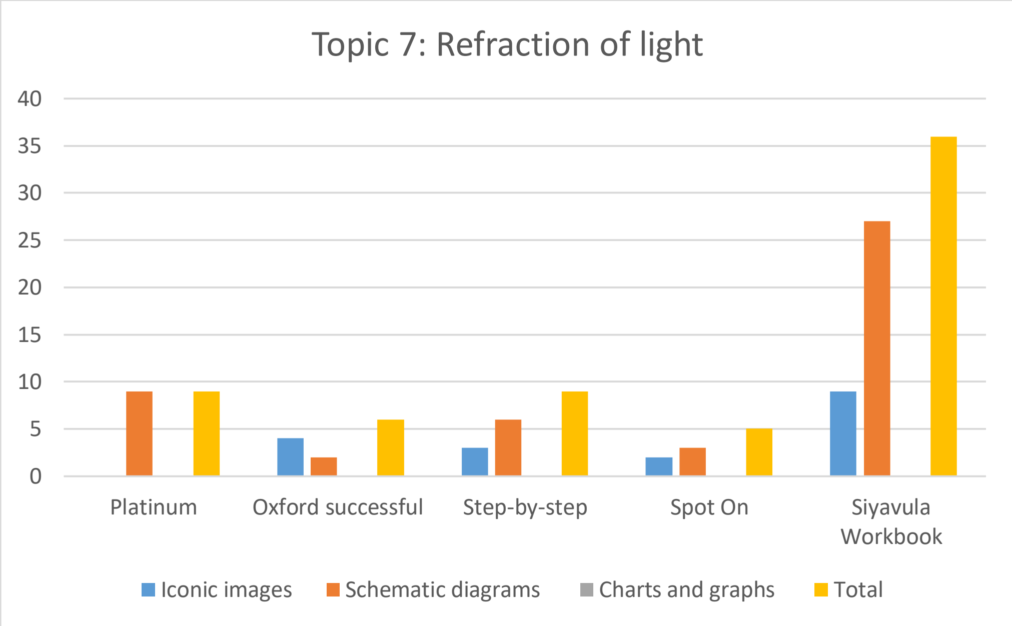


Figure 5.8 A bar graph showing the types and frequency of images in 'Refraction of light'.

The *Siyavula workbook, Platinum* and *Step-by-Step* have more schematic than iconic images. As explained earlier schematic diagrams show abstract scientific phenomena and it is often used alongside the iconic images (photographs) for easy understanding. Refraction just like reflection is effectively depicted by the use of schematic diagrams in graphs.

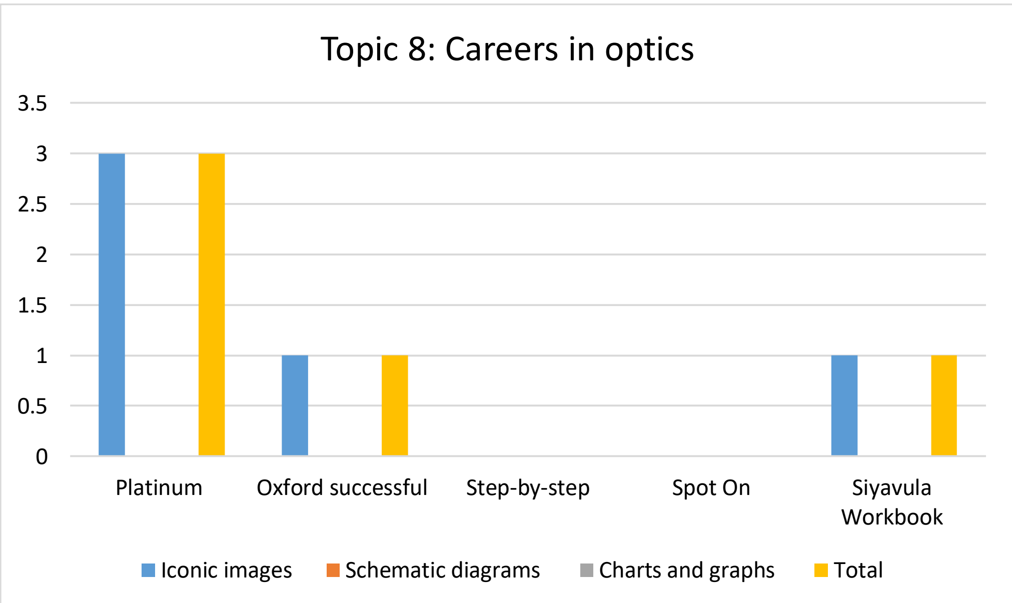


Figure 5.9 Bar graph showing the types and frequency of images in "Careers in optics'.

Only photographs were used under the topic "careers in optics", and by only three books; *Siyavula workbook*, *Oxford Successful and Platinum*. *Step-by-Step* and *Spot On* did not have images used under this topic. Learners are already familiar with optometrists hence photographs are used instead of schematic diagrams. When it comes to the use of properties of light, a welding process is shown and the optical fibre cable is shown in Bester et al. (2013). These uses together with careers in the field is easily accessible to the learners in the form of iconic images.

The quantitative findings on the types and the frequency of images per topic were used to determine which type of image was used by most of the textbooks under each topic. During this survey, I noticed that types of image or their combination relate to the kind of information being communicated.

5.2 From concrete to abstract knowledge

Page 153 of the *Spot On* Natural Sciences Learner's book (Baxter et al, 2013) reproduced as figure 5.10 on page 67 in this paper is a good example of how images are used to show the build-up of knowledge. On this page, a photograph (iconic image) of a convex lens showing the process of refraction is used first, followed by a schematic diagram. The photograph is labelled to show how incident rays bend when they enter and leave the convex lens becoming refracted rays which meet at a focal point. The iconic image relays concrete knowledge to learners as indicated by Barthes that an image is believed to be a true representation of a reality (1997). The schematic diagram has an element that was not on the iconic image. Instead of light only passing through the convex lens, an object is observed using the lens. This means the first image is simpler compared to the second image. The knowledge conveyed by the second image is more advanced and abstract, requiring learners to rely on their prior knowledge and the first image. In this way, the use of images is intentional and helps learners to construct their own knowledge. Hence science images aid in closing the gap between everyday knowledge and school knowledge.

It is very important to take note of the importance of the written text in facilitating the construction of knowledge based on these two images. The multimodal nature of the science textbooks help learners to actively build on their prior knowledge. Both the iconic and schematic diagrams are related to each other by text. The written text preceding both images explain the concepts and process in the images. For example, in the first image only the term “convex lens” is used. In the second text, the convex lens refers to a magnifying glass. Some learners might have heard the experience of observing an object using the magnifying glass, whereas others might have never done that. The way the two images are setup however, helps learners with and without prior knowledge to understand refraction using the magnifying glass.

The progression from concrete everyday phenomena to scientific and abstract phenomena is evident in all the science textbooks. Figure 5.11 on page 68 features another page from a different textbook, the *Platinum* Natural Sciences Grade 8 Learner’s book as another example of the move from concrete to abstract knowledge. The first diagram on the top shows how one views objects at an angle when looking at their reflection on the mirror. The first diagram is concrete as this is something almost everyone has experienced in their daily lives, however this occurrence in a daily lives is a scientific process known as reflection. Reflection is abstract as it uses terminology and concepts that the reader might not be familiar with, for example, normal, incident and reflected rays and angle of incidence and angle of reflection. The process of reflection is abstract since learner do not even see any of these concepts at play when looking into the mirror. The two diagrams at the bottom are thus explaining the abstract knowledge building on the image on top.

I have shown the types of images used per sub-topic and how frequent they are used. To provide an answer on how these science images work to explain science knowledge, the trend of progression of knowledge from concrete to abstract knowledge was discussed. However to further explore how science images convey science knowledge, 5 images common from the sampled books under the three categories of images, respectively iconic image, schematic diagram and graphs and charts will be analysed. The instrument of analysis was used to analyse the five images.

Refraction makes light rays bend as they pass into and out of the lens. Some lenses are shaped so that the refracted rays come together to focus at a certain point. These lenses are called convex lenses. They are curved on both sides and are thickest in the middle.

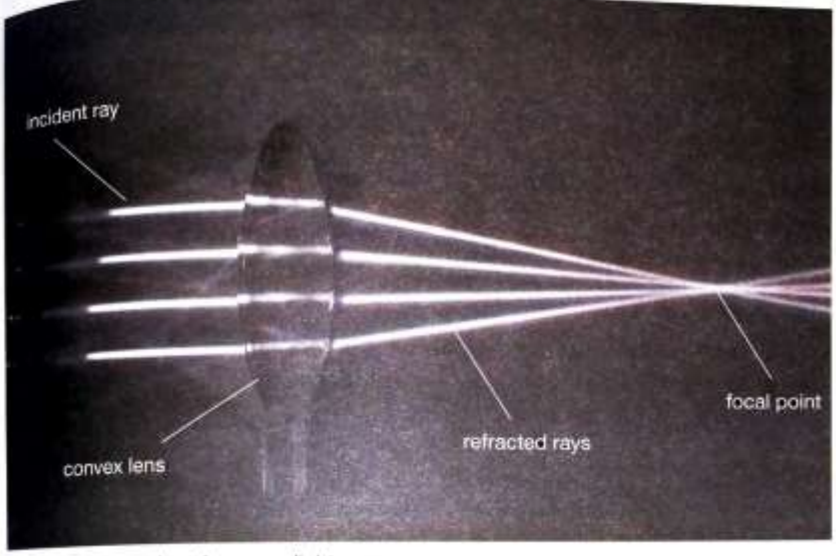


Figure 5 A convex lens focusses light rays.

How magnifying glasses work

A magnifying glass is a convex lens that bends light rays to make things look bigger than they are. We see an enlarged or magnified image of the object.

To enlarge an object, you need to place it on one side of a convex lens. The object must be closer to the lens than the point of focus (focal point). Because the eyes will only be able to focus at the focal point, they will see a virtual (not real) image at the focal point on the same side of the lens as the object. This image will be enlarged or magnified.

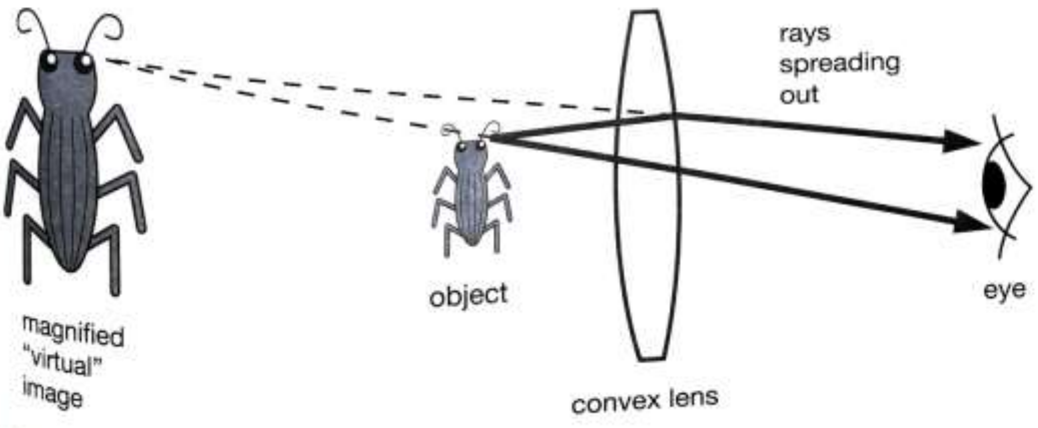


Figure 6 A magnifying glass bends light rays to enlarge objects.

Figure 5.10: page 153 from Baxter et al. (2013, p. 153)

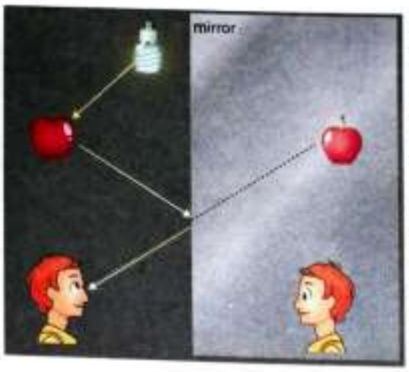


Figure 18 How an image forms in a mirror when you look at the mirror at an angle

Sometimes when you look at a mirror at an angle, you see an image of another object. Figure 18 shows how this happens.

In the diagram, the red light that shines on the mirror is radiated at an angle. When it is reflected, it is also reflected back at the same angle.

When the reflected ray reaches your eye, your brain receives a message that a light ray that travelled a distance equal to the size of arrows 1 and 2 combined, entered your eye. Your brain then forms an image this same distance away from the eye.

In order to explain how reflection works in scientific language, it is important that we use the following terminology:

Normal: The normal is an imaginary line on a reflective surface that forms an angle of 90° to the surface.

Incident ray: This is the light ray that travels to the reflective surface. You can think of the incident ray as the 'incoming' ray.

Reflected ray: This is the light ray that is reflected by the reflective surface. You can think of the reflected ray as the 'outgoing' ray.

Angle of incidence: This is the angle that is measured from the normal to the incident ray.

Angle of reflection: The angle that is measured from the normal to the reflected ray.

The laws of reflection can be summarised as follows:

1. The incident ray, the reflected ray and the normal (to the reflection surface at the point of incidence) lie in the same **plane**. A plane is an imaginary flat area that only has a length and width, but no depth.
2. The angle that the incident ray makes with the normal is equal to the angle that the reflected ray makes with the same normal.
3. The reflected ray and the incident ray are on the opposite sides of the normal.

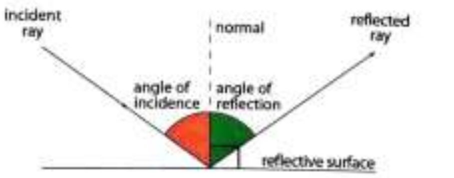


Figure 19 A ray diagram showing how light is reflected off a reflective surface.

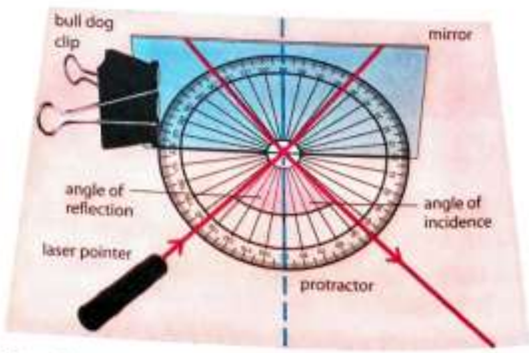


Figure 20 A protractor and laser pointer can be used to show how and where the angle of incidence and the angle of reflection can be measured.

174 Term 3

Figure 5.11: Page 174 from Bester et al. (2013, p. 174)

5.4 Analysis of visual images

I have looked at various images from chapter 3. In chapter 3, I have used various images to illustrate what science literacy is and also show the dimensions of science. In chapter 4, I used science textbook pages to show that science textbooks are multimodal. In the next section (5.4.1-5.4.3), I will provide an analysis of five images across the five textbooks using the questions on the instrument of analysis on page 15 in chapter two. The analysis looks at the connotative and the denotative messages guided by the questions from Rose (2001). I have analysed two visual texts under each category of images.

5.4.1 Iconic images

Iconic image A

Figure 5.13 "Examples of luminous objects" from Baxter et al. (2013, p. 130)

This set of two juxtaposed images, reproduced from Oxford Successful (Baxter et al, 2013, p. 130) shows different examples of luminous objects from everyday life in the form of photographs (iconic images). These images tap into what learners already know and builds on it for better comprehension. Luminous objects are the ones that give off light or glow in the dark. The denoted meaning from this group of images is that the two objects are giving off light. The first photograph is of a shining light bulb with its holder (known as a lamp) that seems to set on a surface. The middle photograph shows 2 burning candles closer to the camera and one green candle burning in the background.

The photographs convey the following science knowledge; it is due to the light produced by the luminous objects that we can see the other contents/ elements in the image. The background against the light bulb is visible because the light bulb is on. The topic of the iconic image says “examples of luminous objects”. This caption focuses our attention on the science concept being conveyed that luminous objects emit light. This is the denotative message communicated by the iconic image despite that multiple interpretations can be attributed to these images.

The text preceding the images, states that light comes from different sources. “Objects that give off their own light are luminous” whereas objects that do not give off their own light are non-luminous. The text further says that the biggest source of light is the sun, which is our nearest star (in the textbook, the photograph of the sun appears alongside the two images, however due to copyright issues the photograph is not included). Other luminous objects include electric light bulbs and candles. The text under the photographs explains that light travels in straight lines hence one cannot see around the corners. The written text foregrounds the idea of light been given off by luminous objects and further gives more information about light. This helps learners to not insert their own interpretations that are not in line with the text.

What is not yet known to the learners is that the light produced by the light bulb, the candle and the sun are made of seven colours (colours of the rainbow). However these colours are only observed in the presence of prism such as water droplets. Hence we only see white visible light. This is dealt with in the next subtopic ‘The spectrum of light’ as I have discussed previously that there is a move from concrete to abstract content throughout the sub-topics. The textbooks explain that what is known as visible light is “really a mixture of different colours” (Baxter, 2013, p. 134), specifically colours of the rainbow.

Looking at the 2 photographs, the connotative message may vary. A lamp as a cultural artefact is seen as symbol of knowledge, enlightenment, hope and intelligence. When looking at the photograph of a lamp, learners can associate it with the cultural meanings it possess. Candles are items normally used in prayer, relaxation, traditional consultations of ancestors, decorations and celebrations. In South Africa, it can be seen as a sign of electrical power cuts. These are some of the meanings learners can have looking at the photograph of the candle. Possible connoted messages can arise from the two juxtaposed iconic images. It is through the caption and the written text that the denoted message which is the science knowledge is conveyed. The caption and the written text helps learners to understand the iconic images.

Iconic image B

Figure 10.10a): The sun is behind the man, so the shadow forms in front of him. The sun is high in the sky, so the shadow is shorter than the man.

Figure 10.10b): The shadow forms on the right-hand side of the man indicating that the sun is on the left-hand side. The sun is lower in the sky than in Figure 10.10a) as the shadow is larger than the man.

Figure 5.14 Shadows from Vermaak et al. (2013, p. 138)

The iconic images (figure 5.14) above were taken at different times and different places judging by the background, and the shadows of the people in the images. Instead of analysing one of the above images, I decided to analyse them together since they appear alongside each other in the textbook. Each image shows a man. The man in the first image is standing outside what looks like a workplace which can be a bank, university or company. The man in the second image is casually dressed and his sleeves are rolled up and he seems to be waiting or busking in the sun. He is leaning against the wall, his feet and the lower back is in contact with the wall. The sizes of men's images are also not equal. We can see the full body of the man in formal wear whereas the casually-dressed man's image not showing the legs. The two men are looking away from the reader. The man on the left has a shadow shorter than him because the sun is high above him whereas the man on the right has a shadow that is bigger than him because the sun is closer to him

The main focus of each image is to show where the shadow forms in relation to the source of light which is the sun as it is made clear by the caption. The caption anchors the denotative message of the image as it describes it, making the reader aware of its meaning in this context. The caption of the first image states that *"the sun is behind the man, so the shadow forms in front of him. The sun is high in the sky, so the shadow is shorten than the man"*. This caption helps the reader to focus on the components it describes such as the size of the man's shadow. The second images is captioned "*the shadow forms on the right hand side of the man indicating that the sun is on the left* *hand side. The sun is lower in the sky than figure 10.10a as the shadow is larger than the man".* This caption requires one to look at the sizes of the men's shadows in relation to the position of the sun.

The science knowledge communicated by this images is that opaque objects do not let light to pass through them. When light falls on opaque objects, a shadow of the object will be formed. The size of the shadow of the object will depend on the distance between the source of light and the object. When the source of light is closer to the object, the shadow will be bigger than the object. When the source of light is far from the object, the shadow will be smaller than the opaque object. Additionally, the position of the source of light also affects the size of the shadow. For example, when the sun is high in the sky so the man's shadow is small, whereas the shadow is bigger when the sun lower in the sky.

The caption and the preceding text help to contextualize the images above which helps to avoid the various interpretations of the images. However, other interpretations are inevitable. The man's formal wear suggests that he might be at work. The sociocultural perspective of science literacy requires that we analyse how various cultures, ethnicities, races and genders are represented in multimodal texts (Serafini, 2015). Texts are sociocultural artefact because they are influenced by the sociocultural, political and historical contexts. Men have always occupied most important and white-collar jobs. This image shows a white man standing next to an upmarket building with large glass doors which suggest his important job. Modes are used to "make meaning and express and shape values, ideologies and power relations" (Adami, 2016, p. 452).

As much as the image about showing the shadow, it is also used to express the ideology of masculinity and the power relations in a society which is the connoted message. The sociocultural perspective requires that we analyse how various cultures, ethnicities, races and genders are represented in multimodal texts (Serafini, 2015). Texts are sociocultural artefact because they are influenced by the sociocultural, political and historical contexts.

However, the caption guides the readers to only focus on the formation of shadows, instead of analysing the power relations manifested in this image. In this instance, we can see that as much as there are many meanings that can be attached to an image, the context in which the image appears engenders and favours a certain meaning which is the denoted message. The learners must be able to identify the differences between the two images- other than the obvious differences of subject and context in which the men appear. The size, length, shape and position of the shadow in relation to the position of the sun. No knowledge is excluded from the images as learners are all familiar with shadows. In topic four, how we perceive colour of other objects is explained using a schematic diagram.

5.4.2 Schematic diagrams

Schematic diagram A

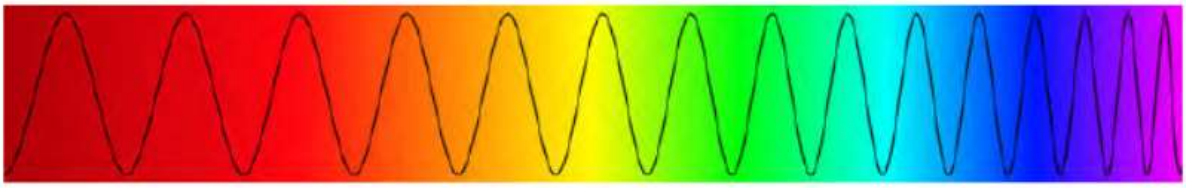


Figure 5.15 "Of visible light, red and orange have the longest wavelengths (and lowest frequency) and violet, indigo and blue have shorted wavelengths (and highest frequency)" from Beckett et al. (2017, p. 93)

As discussed in 5.3 most textbooks start by using the photograph followed by the schematic diagram. Figure 5.15 looks like just an artistic colourful wave pattern. However it is not, instead the caption says that "of visible light, red and orange have the longest wavelengths (and lowest frequency) and violet, indigo and blue have shorted wavelengths (and highest frequency)". This caption prompts a learner to compare the order of the colours on the wave and that of the rainbow. In essence the caption links the wave patter that visible light makes as it moves (abstract) to the rainbow (concrete). Additionally, the caption points out the length of each colour wave, leading learners to compare the lengths and link it to the frequency.

The schematic diagram uses a wavy line and colours as elements to convey science knowledge. A wavy line normally represent a rhythm of movement. Since the spectrum of visible light has only seven specific colours it would be misleading to use any random colours such as red, pink or maroon in figure 5.15. The colours are also in the order they appear in, on the rainbow. Science knowledge communicated by the diagram goes as follows; when we receive sunlight or light from any luminous object, it always has seven colours even though our eyes perceive them as white light. White light instead of colours of the rainbow is detected by our brain due to the biological process of sight that occurs in the eye and the brain. The retina contains photoreceptor cells called cones which provides colour vision. There are three cones with varying sensitivity across the spectrum of light and only respond to green, blue and red light (Reece et al., 2011). When these colours are detected at the same time, we see white light. Additionally, white light forms waves as it travels.

Not only does the visible light have seven colours, each colour has a different wavelength and frequency. The colours have different lengths with the red colour having the longest wavelength whereas violet has the shortest wavelength and highest frequency. Wavelength is the length of one wave pattern and it allows us to perceive colour. Looking figure 5.15 one notices that moving from violet all the way to red, the wavelength of each colour increases and is longer than the color before it. Frequency is the number of complete waves that move past a certain point in one second. This means that the longest wavelength will have shortest frequency. The concepts of the wavelength and frequency are explained by the written text in a caption below the schematic diagram in the textbook.

From the schematic diagram, one can relate the wave-like pattern of light to the seawater waves. Waves in the ocean follow an up and down movement making a pattern. Wind, duration, depth of the water and the area where waves form affects waves. As a result, their shape, height and duration varies greatly. This is not the same as light waves, their wavelengths follow a certain pattern, with red being the longest and indigo being the shortest. This never changes unlike waves in the ocean. We are able to see the ocean waves but we do not see visible light as waves. Light rays are also represented using a line because they reach the earth or surroundings in straight lines. This makes the comparison of the spectrum of light to a wave a bit challenging as it is abstract.

Schematic diagram B

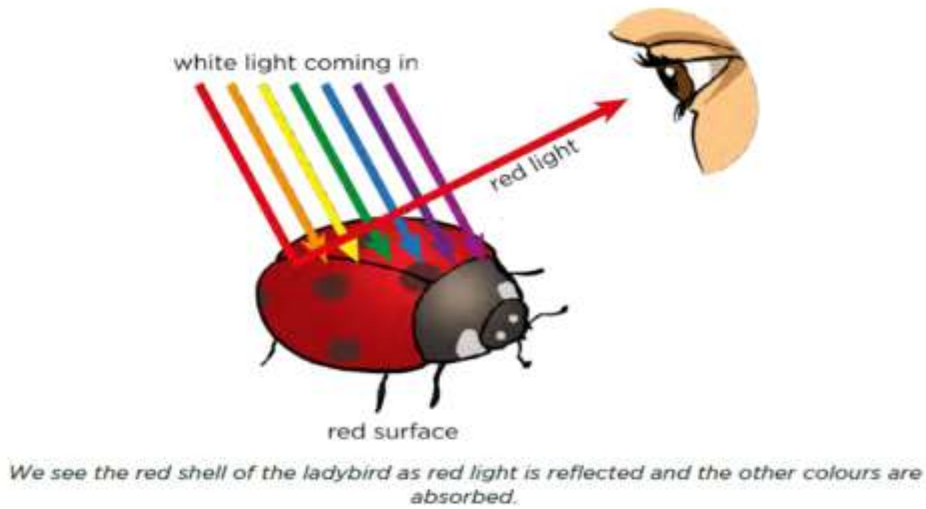


Figure 5.16 "we see the red shell of the ladybird as red light is reflected and the other colours are absorbed" from Siyavula (2017, p. 98)

The diagram above is schematic. Lines and arrows are used to show how visible light from the luminous objects such as the sun, light bulb or candle is made up of seven colours. For a human being to observe the ladybird, light travels from the luminous object to the ladybird. All the colours of visible light will be absorbed whereas red is reflected to the human eye. If the ladybird was yellow, only yellow light ray was going to be reflected to the eye. However we are able to see all the black parts of the ladybird because no light is reflected back to the eye from those areas.

The elements used in figure four are; lines (with arrows), color and representations of an eye and a bug. A line as an element in the visual arts is decisive as it shows direction and purpose. In this image, the arrow shows the direction and the movement of sunlight. In addition, a line can be used to make visible what cannot be seen and what does not exist except in the imagination (Dondis, 1997). For instance, in real life we do not see the light rays in a straight line in front of us. However the study of properties of light has shown that light indeed travels in a straight line hence it does not bend around a corner of an object. Thus, a line function to "capsulize visual information, boiling it down to a state of reduction where all superfluous visual information has been stripped away and only the essential remains (Dondis, 1997, p. 43). In normal and real life, only visible light which is white is observable by the human eye, in this case seven lines are used to represent millions of light rays extending from the sun. Instead of using many light rays only a few are utilised. The same applied to the light ray that extend from the ladybird to the human eye, only one line is shown instead of many.

The diagram shows how visible light has various colours, and they travel to the ladybird as indicated by the arrows. The lines do not show the waves of light- instead their direction is shown. The use of colour is crucial here as the aim is to show that all the other 6 colours are absorbed. Various images are used depicting an object with different colours. Only the light of the colour of the object will be reflected whereas the other 6 still disappear (see figure 5.17 on page 77 in this study). The various colour rays seem to be coming from above (position of the sun). From the ladybird, only the red arrowed line emerges and it goes to the human eye. The red ladybird signify any type of ladybird, it can be a yellow one. In fact the red ladybird represents any object that has colour in it. The seven arrowed lines, represent the spectrum of light or what we see as sunlight rays. The red arrowed line, represents the colour that we observe when we look at the object with colour (i.e. red).

The human eye signifies a person. Because for us to see the image, our eyes receive the stimuli and the brain will tell us what we are seeing. So the process of seeing does not involve the eyes only, hence the eye represents the whole human being who sees a red ladybird and may even admire it and attempt to touch it. The science knowledge being represented is the process of absorption and reflection. When visible light travels to the object, we see that only 6 colours will be absorbed whereas only one colour (red) is reflected to the eyes, hence we are able to see the colour.

The diagram in figure 29 can be misinterpreted in various ways. One can think that red is made up of the 6 colours of the visible light hence only red is reflected. Since white light which travels to the lady bird is made of seven colours, however we only observe red, one might think that all the other colours combine to form the red colour which we observed. Alternatively, learners can assume that the other 6 colours disappear hence we only see red. One might wonder what happens to us being able to see the spots, the upper body as well as the head as black and eyes as white. This observation is not illustrated in the diagram, however it is explained and diagrammatically represented in other textbooks such as Platinum Natural Sciences Learner’s book (Baxter et al., 2013). That is why it important to read the image in conjunction with the text, which states "we see the red shell of the ladybird as red light is reflected and the other colours are absorbed".

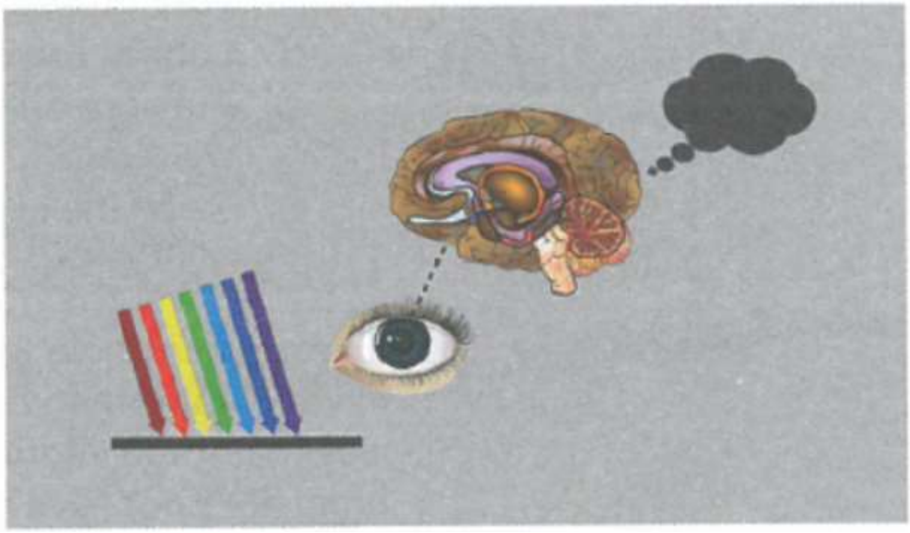


Figure 5.17 "When no light is reflected form a surface of an object and the object is not luminous, the brain interprets black" from Bester et al. (2013, p. 179)

5.4.3 Graphs and charts

Image A

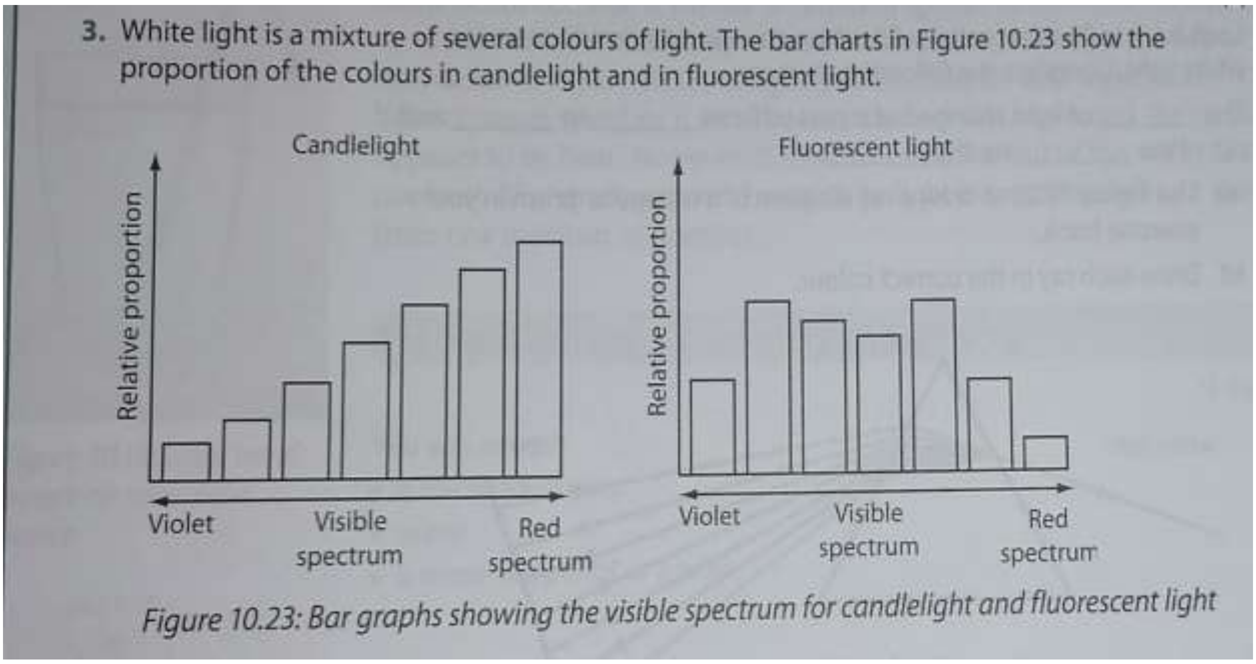


Figure 5.18 "Bar graphs showing the visible spectrum for candlelight and fluorescent light" from Vermaak et al. (2013, 146)

Data analysis is an important part in science education other disciples such as mathematics and social sciences. It refers to "visual display of quantitative data using graphical representations such as bar and line graphs, pie charts and scatterplots" (Alacaci et al, 2011, p. 3). The communication of quantitative data using graphs and charts is limited in this topic as shown by the types of images and their frequency at the beginning of this chapter. This is the least used type of visual image in the five science textbooks. It is worthwhile to note that the type of graphs used in a topic or task depends on the type of data and the purpose of analysis. Bar graphs are mostly suitable for showing frequency (Alacaci et al., 2011). Each bar conveys certain information and the bars being next to each other makes comparison judgement possible irrespective of the discipline in which they are used (connoted message). Let us look at how the structure of the bar graph make comparison possible.

All graphs have four common components which are the; framework, specifiers, labels and background (Friel et al., 2001). The framework involves elements that show the types of measurements used such as axes, scales and grids. The graph above has the L-shaped framework. The specifiers are the elements used to plot the data on the graph. Graphs in Figure 5.18 use bars as specifiers, whereas lines are used in line graphs and angles in pie charts. Labels include the name of the quantities in axes and the title of the graph. These labels capture the quantities on the axes and their relationship. The title of the bar graphs above states "Bar graphs showing the visible spectrum for candlelight and fluorescent light". This title captures how the x-axis quantities (visible spectrum) are related to the y-axis quantities (relative proportion). The y-axes use proportion instead of an absolute number meaning that the amount of the seven colours present in the candlelight or fluorescent light are relative to each other. In addition, only two colours of the visible spectrum have been labelled. Meaning the reader must be able to identify each colour (represented by bars) based on their knowledge of the spectrum of visible light. The bars plotted are of varying height, which can be compared. The fact that there various bars instead of one also helps one to compare them and the information they individually communicate. The last structural components of graphs is the background which has to do with shading, colouring or pictures used to make the graph pleasant. Figure 5.18 does not have shading or colouring.

Graph comprehension is critical in data analysis, especially since the main purpose of graphs in a schooling content is to communicate quantitative data. Question asking and question posing by the reader is central in graph comprehension (Friel et al., 2001). There are three levels of graph comprehension which are elementary, intermediate and advanced levels (Friel et al., 2001). At the elementary level, questions askes require one to extract data from the graph. Intermediate level questions require one to identify the relation in the data presented in the graph. The advanced level questions require the extrapolation from data and the analysis of implicit relations in data. Questions about the graphs helps the reader to make sense of what is being communicated. To answer any questions, one must be able to read and understand the functions of the framework, specifiers, labels and the background. To sum up, graphs can be misinterpreted if one has no knowledge of how they operate.

5.5 Conclusion

In this chapter I began with a survey of the types and frequency of images to show how much content is communicated through images. I have shown what science knowledge does each type of image communicates under each sub-topic. I have also explored how images are used to facilitate the progression of knowledge by aligning iconic images with schematic representations. Then through a close analyses of common images used by a range of textbooks, I identified the connoted and denoted meanings to demonstrate how crucial images are for communicating science concepts in these textbooks. In the next chapter, I summarise the main findings in relation to the main research questions and the four sub-questions. The implications of the study are discussed in detail taking into consideration the limitations of the study. Recommendations for future research based on the contribution of this paper are outlined.

Chapter 6

Summary and conclusions

6.1 Introduction

In this study, I have explored what science literacy and visual literacy are. In my discussion of science literacy I have shown how images convey science knowledge through multiple modes of representation. When closely analysing images from textbooks (chapter 5), I have shown how various images convey both the denoted and connoted science messages. I have also shown how images work together with written text and design elements to convey table science knowledge. This chapter will summarise the findings in answer to the research questions, as such I have structured the chapter according to the research questions. I conclude the chapter by recommending what still needs to be researched in future studies.

6.2 What is visual literacy?

We assume that most learners in grade 8 are capable of reading and writing. In this light, visual literacy becomes one of the necessary multiple literacies that all learners should acquire in order to be fully literate, and visual images. It refers to the ability to interpret, negotiate and make meaning from information presented in the form of an image and the ability to convey context-specific and universal meaning using visual images. Visual literacy is important for science literacy because images are used socially as Kress and van Leeuwen have pointed out, and the survey of the types of images found in chapter 5 shows. The semiotic study of signs explains how images work like language to communicate denotative and connotative messages to readers. Learners who are visually literacy will be able to read the denotative and connotative messages of science images.

6.3 What is science literacy?

I have found that science literacy includes the mastery of knowledge, scientific concepts and processes for personal benefit and civic participation. I have argued that to achieve any of the four levels of scientific literacy which according to (Bybee, 1997) are; a) nominal, b) functional, c) conceptual and procedural and d) multi-dimensional literacy, one needs to possess fundamental literacy and visual. Science literacy requires learners to be able to read and write first so that they can be able to read the written texts in the textbooks.

6.4 What types of visual representations are used in the Grade 8 Natural Sciences textbooks and how frequently are the different types used for different sub-topics?

As shown in chapters 3, 4 and 5, science textbooks do not rely on one type of image, but use a variety of types of images to communicate different concepts. These concepts work together to build knowledge as there is a progression from images of everyday examples to more abstract scientific diagrams. How the images are used is dependent on the authors who are taking into consideration the target audience of the books as well as the cost of production. The Siyavula workbook for instance uses double the number of the images found in other textbooks. The reason for this is that it is a remedial book meant to support learners who are not doing well in the subject. Some books have more schematic than iconic images whereas other books have more iconic images than any type of image. However, in all the books, the graphs and charts are least used and are utilised in two subtopics which are the refraction of light and the refraction of light. As such the type of visual representation used relies on the content being relayed.

6.5 How do visual representations work to explain science concepts?

As mentioned above, various types of images are used to convey different concepts. Iconic images are mostly used to bring the everyday life of learners into the science knowledge. Iconic images are mostly followed or used in conjunction with the schematic images which depict abstract knowledge, for example figure 5.10 on page 67 of this study. The sequence of the different types of images helps learners to relate abstract scientific concepts and phenomena to their everyday life, which in turn facilitates learning. The sequencing also helps to make science knowledge more accessible to learners. The charts and graphs are mostly used to depict the scientific concepts using quantitative and numerical data. They are usually utilised to compare data and show patterns such as in refraction and refraction of light.

Science images work together with written text to convey meaning in textbooks. The use of written texts is crucial because what images denote and connote is not always obvious. The images have meaning based on context and it is the written text that helps with providing context just as the images help to explain the written text. Additionally, some learners may possess linguistic intelligence and they might be comfortable with getting information from written text, whereas other learners might have visual intelligence making them comfortable to learn using images and diagrams. Other learners possess both the visual and linguistic learning styles. In this way, the use of images and in conjunction with written text caters for various learning styles and multiple intelligence.

6.6 Implications of the research findings

Visually literacy is necessary to enable learners to understand visual images and the design elements of a textbook used in the classroom. Different skills are needed to read each type of image. The prevalence and range of images in the selected science textbooks shows that the provision for formal visual literacy learning in the science classroom is long overdue. Despite that science textbooks and classrooms are multimodal, language and written text have always been given more attention over images, disadvantaging learners from fully accessing science knowledge. To address this, teacher education and training needs to include methods of teaching visual literacy in all subjects so that science teachers can better assist their learners to read the images used to communicate science concepts.

It is my contention that an improvement in visual literacy skills will contribute to an improvement in science literacy. Clear teaching guidelines should be included in science curriculum and other subject curriculums to assist teachers to teach this pre-requisite skill in science. Formal and informal activities should be formulated and administered to cultivate visual literacy skills across various subjects and in earlier grades. Drawings of learners should be used to develop the skill to create other forms of images instead of treating them as leisure activities. Learners need to be encouraged to present their conceptual knowledge of a topic using diagrams and marks should be awarded for such tasks, without always favouring assessment based on written tasks. In this way, learners will appreciate the use of images and also find it rewarding to represent information visually.

6.7 Limitations of the study

The research methods in this study include conceptual and content analysis. The focus was in the first instance on defining science literacy and visual literacy in order to determine their relationship. Then I conducted my own visual analyses of images in science textbooks in order to show that learners need to possess visual literacy skills in order to improve their science literacy. Due to the scope of the study I only focused on visual literacy as one of the many literacies that learners need in the changing world.

Meanwhile, due to dearth of studies in grade 7-9 Natural Sciences, the study drew from the limited data gathered from other research studies in the higher grades and tertiary institutions. Additionally, the visual literacy skills and science literacy levels of grade 8 learners were not researched due to the scope of the study. In addition, teachers' visual literacy skills were not researched. As a result, only the need for visual literacy and teaching have been discovered by analysing modes used in the grade 8 textbooks. Hence, the gaps in visual literacy and science literacy skills of both teachers and learners cannot be confirmed.

6.8 Future research

Based on the limitations of this study, future research could focus on the level of visual literacy that the grade 8 learners are at and this needs to be linked to their science literacy levels to establish the best guideline for teaching visual literacy in that grade. Secondly, teachers visual literacy skills and how they are training needs to be investigated. This will help educator trainers to design the best programmes for science teachers. Another angle can be to investigate how teachers use the different modes in the textbook to facilitate science learning. In addition, further study might be to investigate which books learners and teachers find easier to use. How learners feel about images used in the books can also be explored. Since the scope of this study was limited and only looked as visual literacy, future studies can focus on multiliteracies in science education.

6.9 Conclusion

Based on the findings in this study, it is plausible to conclude that for learners to better comprehend science content, they must have acquired the fundamental literacy. The ability to decode the linguistic and visual meaning is imperative in conceptualising science content. Hence, visual literacy and multimodal literacies are necessary for learners to achieve the four levels of science literacy. If learners are taught visual literacy skills they will be able to master the science context and the performance in Trends in International Mathematics and Science Tests will drastically improve. The performance in science education will improve in the country.

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