Overview and Orientation 1

1.1 Introduction

This thesis documents an empirical study that used quantitative methods to investigate the relationship between cognitive load and cognitive style when using animation and static images in instructional material.

This chapter presents:

- the rationale and purpose of the study.
- an orientation to the design and implementation of the study.

1.2 Purpose of the study

The purpose of this study was to explore the role that cognitive load and cognitive style play in the successful achievement of learning outcomes when narrated animation and static images are used in multimedia learning formats in an authentic learning environment. The study also investigated the relationship between cognitive load, which is influenced by both the nature of the content and the specific design strategies used, and the cognitive style of the individual who uses different multimedia formats.

Schnotz and Lowe (2003) are of the opinion that new technologies in general, and multimedia in particular, play an increasingly important role in education. They describe multimedia as:

> *…the combination of multiple technical resources for the purpose of presenting information represented in multiple formats via multiple sensory modalities.*
>
> *(Schnotz & Lowe, 2003, p 117).*

Multimedia resources can be considered at three levels: a technical, semiotic and sensory level. The technical level focuses on the effect of the medium per se on learning, while the semiotic level refers to the effect of the representational format of the content, be this text, pictures or sound. Early research often focused solely on the media-effects (technical level) (Erwin & Ricardo, 1999; Mayer, 1997a; Quealy & Langan-Fox, 1998; Williams, Aubin, Harkin & Cottrell, 2001). The current view is that it is misguided and overly simplistic to compare different technical media with regard to their effects on learning without taking into consideration the semiotic and sensory effects (Mayer, 1997a; Mayer & Moreno, 2002; Schnotz & Lowe, 2003).

Cognitive science and educational psychology literature calls for the continued investigation of the conditions under which different forms of representation of specific media, such as texts and graphics (either static or animated), influence comprehension and learning (Goldman, 2003; Mayer & Moreno, 2002). The quest for finding evidence for optimal presentation formats and factors that need to be considered when designing multimedia instruction has not lost momentum in the new millennium, as evident from the number of special issues devoted to cognitive load and multimedia learning since 2002 (Kirschner, 2002; Paas, Renkl & Sweller, 2004; Paas & van Gog, 2006; Ploetzner & Lowe, 2004; Robinson, 2002; Schnotz & Lowe, 2003; van Merriënboer & Ayres, 2005).

There is considerable empirical evidence, to be discussed in Chapter 2 of this thesis, that cognitive load and cognitive style are two factors that impact on learning effectiveness and efficiency. Exploring cognitive load and cognitive style, and the **relationship between these two factors**, as an instructional designer becomes meaningful and worthwhile if the empirical evidence or outcome of such exploration can build on the available design principles and heuristics for designing effective instruction.

1.3 Defining core concepts and terminology

This section provides a brief explanation of the core concepts and terminology in order to facilitate the reading of this thesis. Chapter 2 will discuss these concepts and their position within the theoretical frameworks used in this study in more detail.

Four concepts are described:

- Cognitive load
- Cognitive style
- Learning style
- Multimedia learning

1.3.1 Cognitive load

Understanding the concept cognitive load requires taking a step back to consider the process of acquiring and understanding information. An understanding of cognitive load is based on several important assumptions:

- Working memory has limited capacity for information processing.
- In contrast, long-term memory has unlimited capacity for storing information.
- Information is also stored in long-term memory for an unlimited duration.
- Information is stored in knowledge structures called schemas.

- A schema categorises elements of information according to the manner in which they will be used. It is a hierarchically organised, domain-specific structure.
- There are many different schemas in long-term memory and they vary in complexity.
- The effectiveness of retrieving information from long-term memory depends on the quality of schema construction and automation.
- Controlled and conscious use of schemas also uses up working memory capacity (Kalyuga, 2006; Paas, Renkl & Sweller, 2003; Sweller, van Merriënboer & Paas, 1998).

With this as background, one perspective is to view information, which enters working memory via the senses for the first time or as a schema from long-term memory, as a burden. This is a negative perspective. Instead, cognitive scientists have conceptualised this as the cognitive load.

The literature is elusive when it comes to providing a formal definition of cognitive load. Explanations of cognitive load are provided within the framework of cognitive load theory (CLT) (Chandler & Sweller, 1991; Sweller et al., 1998; Sweller & Chandler, 1991). The only concise definition of the broader concept of cognitive load is that of Paas and van Merriënboer (1994a):

> *Cognitive load is generally considered a multidimensional construct that represents the load that performing a particular task imposes on the cognitive system of the learner*
>
> *(Paas & van Merriënboer, 1994a, p353).*

In-depth descriptions and explanations of cognitive load theory in the literature consider the concept of cognitive load in terms of three types of cognitive load. Each type of load has a specific source. This conceptualisation is summarised here in Table 1.1.

	Types of cognitive load	**What determines this load**
Cognitive load	Intrinsic load	The actual material/information to be learned.
	Extraneous load	The way in which the material/information is presented
	Germane load	Processes that contribute to the construction and automation of schemas.

Table 1.1: Cognitive load - types and sources of load (Kirschner, 2002; Paas, Renkl & Sweller, 2003).

This study measures the cognitive load of two presentation formats (animation and static images) used to teach Physiology to adult learners in an authentic learning environment.

1.3.2 An introduction to style

The literature on styles is vast. A search of the Academic Premier Database returned over 600 references for learning style and approximately 450 references for cognitive style.

It is a very controversial area of research that has been criticised in many areas, including the:

- plethora of style models found in the literature (Riding & Cheema, 1991);
- confusion between cognitive and learning style and the inter-changeable use of these two concepts (Ford & Chen, 2001);
- difficulty in measuring styles;
- low reliability and validity of the instruments used to assess styles (Curry, 1990; Peterson, Deary & Austin, 2003a, 2003b).

In spite of the criticism the research has continued. In fact there has been a renewed interest in both cognitive and learning styles research in recent years. Riding and Cheema (1991) note a resurgence of interest in this field after a decline in the prominent interest of the 1960s and 1970s. A review of the more recent literature does seem to provide ground for this opinion (Calcaterra, Antonietti & Underwood, 2005; Chen, Ghinea & Macredie, 2006; Ford & Chen, 2001; Guinea & Chen, 2003; Graff, 2005; Smith & Woody, 2000; Triantafillou, Pomportsis, Demetriadis & Georgiadou, 2004).

Cognitive and learning styles have emerged as a key dimension of individual differences (Ford & Chen, 2001). But what is the difference between these two constructs, if any at all? There are a great variety of so-called 'cognitive styles' and 'learning styles' (Riding & Cheema, 1991). Some authors use the terms interchangeably, while others consider them to be different concepts. Ford and Chen (2001) interpret learning styles as 'cognitive styles entailing information processing taking place specifically in a learning context.'

When can patterns of behaviour be called a style? What is the difference between a style and a strategy? When an individual displays a consistent tendency to behave in a certain manner, or, in an educational context, consistently uses a selected combination of strategies, this tendency is called a style. Witkin, Moore, Goodenough and Cox (1977) view style as the:

> *'….characteristic approach the person brings with him to a wide range of situations….'*

They go on to state that when this approach involves both the person's perceptual and intellectual activities it is called their cognitive style (Witkin et al., 1977). Style probably has a physiological basis and is fairly fixed for an individual. Strategies however, are ways that may be learned and developed to cope with a variety of situations and tasks, including learning tasks (Riding & Rayner, 1998).

The position taken in this study is that cognitive style and learning style are two different but related concepts.

1.3.3 Cognitive style

> *Cognitive style is seen as an individual's preferred and habitual approach to both organising and representing information*
>
> *(Riding & Rayner, 1998, p8).*

This study uses a model that conceptualises style on two bi-polar dimensions: the Analytic-Wholistic and the Verbaliser-Imager dimensions.

An extreme analyst, who picks up a textbook to study, will look at the Index and then read systematically through the text. The extreme Wholist will look at the Table of Contents and the Executive Summary (if it exists). He or she might not look at anything else, but rather go and have a cup of coffee with their buddy. The extreme Verbaliser will read all the text and glance over the diagrams, while the extreme Imager will primarily look at the images.

This study measures the cognitive styles of the participants before they learn content that is presented using either animation or static images.

1.3.4 Learning style

Running parallel to the body of research on cognitive style is another research stream that seeks to better understand individual differences between students. The focus has been on an individual's active response to a learning task as opposed to the more internal processes inherent to cognitive style. Learning style therefore addresses the way a learner approaches a learning task. The results of learning style research are focused on ways to design better learning environments that would more effectively meet individual learning needs (Howard, Ellis & Rasmussen, 2004; Laight, 2004; Sabry & Baldwin, 2003; Sonnenwald & Li, 2003; Wieseman & Portis, 1990).

Riding and Rayner (1998) surveyed the literature on learning style theory and categorised the various models into four style groups. These style models are based on the learning process, orientation to study, instructional preferences and cognitive skills development. These will not be discussed further in this thesis.

1.3.5 Multimedia learning

The most simplistic understanding of the concept 'multimedia' would be that of many different forms (multi) of media – text, sound, video, static images and animation.

The Oxford English Dictionary Online (2006) defines multimedia as:

> *'The use of a variety of artistic or communicative media; (Computing) the incorporation of a number of media, such as text, audio, video, and animation, esp. interactively.'*

Wikipedia, an online encyclopedia (2006), defines multimedia as:

> *'…the use of several media (e.g. text, audio, graphics, animation, video) to convey information. Multimedia also refers to the use of computer technology to create, store, and experience multimedia content.'*

The definition of multimedia by Schnotz and Lowe (2003), quoted on page 1 of this thesis, emphasises the multiplicity of the field: multiple technical resources, multiple formats and multiple sensory modalities. The possibilities for including media in instruction today are vast. Design decisions address the question of which media or media combinations to use. Instructional designers must be critical of the practice that allows technology to generate the learning experience rather than using the growing knowledge of cognitive processes to guide the decisions regarding effective technology utilisation. Any approach to instruction that ignores cognitive processes is likely to be deficient (Chandler, 2004).

The field of multimedia learning therefore not only considers the media to be used, but also the impact of this media on the cognitive processes. There is a very close link between the theory of multimedia learning (Mayer, 2003) and cognitive load theory. The theory of multimedia learning will be considered in more detail in Chapter 2.

The multimedia formats used in this study are animation and static images. Both formats will be used to teach the same Physiology content to young adult learners.

1.4 Background to the study

As a multimedia instructional designer working in the context of tertiary health science education, I often reflected on the following questions:

1. Is multimedia development worth the effort in terms of the time and resources (financial and human) that need to be allocated to such development?
2. To what extent do multimedia learning resources contribute to the achievement of learning outcomes?
3. How do learners use and learn with these resources and learning materials?
4. How can the instructional design be improved in order to facilitate learning and meet the learning needs of diverse learners?

These questions, and the fact that as an instructional designer I have both overseen the design of the learning materials and frequently designed them myself, provided the direction for a review of the literature. The first area covered in the literature was that of multimedia learning. It was then that I started looking more closely at both the theoretical and empirical literature on cognitive load. The second area of review initially considered both learning and cognitive styles, but I eventually narrowed my focus to the cognitive style literature as I view these as two related but different concepts.

Questions of a similar nature are often asked by clients in corporate settings. These questions are being asked increasingly by management who must allocate resources from an often shrinking resource base.

Answering the question 'To what extent do multimedia learning resources contribute to the achievement of learning outcomes?' will provide part of the answer to the first question I asked: namely, 'Is multimedia development worth the effort in terms of time and resources (financial and human) that need to be allocated to such development?' The question implies some sort of measurement of these learning outcomes. There are however many factors that influence the successful achievement of learning outcomes, including the design of the learning materials, the learning environment, the learning strategies used by the learner, motivation and many more. It is also no great secret that we are all different, but to what extent do these differences apply to learning? Answers to this question and the question 'How can the instructional design be improved in order to facilitate learning and meet the learning needs of diverse learners?' seem to point in the direction of individual differences of learners.

The question 'How do learners use and learn with these [multimedia] resources and learning materials?' is one that instructional designers do not consider often enough. The common practice, particularly in the environment where there is a team approach to development, is for the designer to hand the final product over to the client or lecturer who is responsible for integrating it into the teaching and learning environment.

There is still much that needs to be discovered about how learners, in particular those studying at a distance, use and learn with electronic multimedia learning materials. This question indicated the need to explore the relationship between multimedia and learning behaviour in general. Exploring learning behaviours will assist in the identification of those behaviours and instructional conditions that enable and facilitate rather than hinder learning. When learning behaviour, or a particular instructional condition (animation or static images), increases the range of possible cognitive processes and therefore allows more cognitive processing to take place learning is enabled. When learning material has been designed to make processing and schema acquisition easier, or the interaction with the program is made easier (easier navigation for example) then learning is facilitated (Schnotz & Rasch, 2005). Designers must consider both the enabling and facilitative function of multimedia learning resources.

There are many studies in the literature describing the attitudes and perceptions of learners towards a wide array of technology-based learning materials and environments (Collaud, Gurtner & Coen, 2000; Ghinea & Chen, 2003; Jha, Widdowson & Duffy, 2002; Kerfoot, Masser & Hafler, 2003; Regnard, 2000). Attitudes do not always translate into action. I feel that it is important to consider what learners DO with the electronic learning materials, rather than looking only at how they FEEL about these materials? How does the design influence their use and the learning processes? Since these electronic learning materials must often stand alone in their ability to teach, does the design enable, facilitate or hinder the learning process? What learner support is needed to ensure that they use these learning materials optimally? How must learners be helped to make the transition from using paper-based to electronic learning materials? How should these electronic materials be designed to meet different learning needs and styles? Which designs will achieve the best learning outcome – for the majority of learners and for learners with specific learning styles?

1.5 Rationale of the research

The constructs cognitive load and cognitive style are both widely researched in their own right. The research spans close on twenty years (Paas & van Gog, 2006; Peterson & Deary, 2006; Sweller & Chandler, 1991; Thornell, 1976). New uses of educational technology in teaching and learning provide the rationale for re-visiting old research questions (Mayer, 1997a). The results from empirical studies serve to guide the practice of instructional designers, teachers and facilitators (Leahy, Chandler & Sweller, 2003; Mayer, 2003; Mayer & Moreno, 2003; Riding & Rayner, 1998). Chapter 2 will provide a critical review of this research.

This section builds the immediate case for the research question. The case is built by exploring the theoretical, empirical, methodological, media and contextual dimensions in cognitive load, cognitive style, learning style and multimedia learning literature.

1.5.1 The empirical imperative

Recent empirical research in the field of cognitive style and multimedia either fails to address the fact that the outcomes of the research might be due to cognitive overload (Ghinea & Chen, 2003) or only hints that there might be a relationship between cognitive style and cognitive load (Graff, 2003b). This is an avenue of research that does not seem to have been explored yet in great detail.

The results of Riding, Grimley, Dahraei and Banner's study (2003) seem to indicate that effective working memory capacity has a major influence on the performance of learners with specific styles. These researchers call for more investigation into this finding.

This study will look at working memory from a cognitive load perspective.

1.5.2 The theoretical imperative

As early as 1994 the literature on cognitive load theory stated that there are three factors that contribute to cognitive load: task characteristics, learner characteristics and the interactions between these two (Paas & van Merriënboer, 1994a). One of the learner characteristics listed included cognitive style. Other learner characteristics include cognitive capabilities, preferences and prior knowledge.

Cognitive load research has explored the influence of prior knowledge and learner experience on cognitive load in considerable depth (Kalyuga, 2006; Kalyuga, Ayres, Chandler & Sweller, 2003; Kalyuga, Chandler & Sweller, 2001), but the field has been strangely silent on the influence of cognitive style.

This study will investigate the theoretical link between cognitive style and cognitive load.

1.5.3 The methodological imperative

Methodological limitations in previous research include:

- studies that did not measure achievement directly (Riding, Grimley, Dahraei & Banner, 2003).
- small samples of under 100 participants (Ayres, 2006a; Dutke & Rinck, 2006; Mayer, Sobko & Mautone, 2003; Riding & Grimley, 1999; van der Meij, & de Jong, 2006).
- cautions that not all findings are easily generalisable to the classroom setting (Tabbers, Martens & van Merriënboer, 2004) since the context of the study was the laboratory setting.
- failure to measure the cognitive load of the intervention (Chandler & Sweller, 1991; Ghinea & Chen, 2003; Mayer, Moreno, Boire & Vagge, 1999; Moreno, 2006).
- giving the participants material to learn that is generally not relevant to their own coursework (Mayer, Fennell, Farmer & Campbell, 2004; Moreno, 2004).

This study will measure achievement, use a larger sample than many of the studies reviewed in the literature and will take place in an authentic learning environment.

1.5.4 The media imperative

Why consider animation and static images above other media options? The use of static images and text in instructional resources has received considerable attention in the research community since the early 1980s (Carney & Levin, 2002; Mayer, 2003; Mayer & Gallini, 1990; Mayer, Mautone, & Prothero, 2002; McKay, 1999; Moreno & Valdez, 2005; Verdi & Kulhavy, 2002). Graff (2003a) acknowledged in his research that incorporating other multimedia components in the instruction could lead to different findings. More recent research considered the use of text, images and sound in

varying combinations (Ginns, 2005; Jeung & Chandler, 1997; Kalyuga, Chandler & Sweller, 1999; Leahy, Chandler & Sweller, 2003; Mikk & Luik, 2003).

Improvement in technology has seen the increased use of sound, video, animation and 3D presentation formats in instructional materials. It is time to research the impact of these newer media formats on cognitive processes with the same rigour and vigour that have been applied to researching the use of text and images.

Chandler noted the following:

> *…despite this seemingly endless potential and unbridled enthusiasm for technology-based instruction, there is little empirical evidence to indicate that the widespread use of dynamic visualisations has resulted in any substantial benefit to learners.*
>
> *(Chandler, 2004, p 353).*

Of even more concern is the reflection by Kalyuga, Chandler and Sweller (1999, p369):

> *Many multimedia instructional presentations are still based on common sense rather than theory or extensive empirical research. Visual formats tend to be determined purely by aesthetic considerations while the use of sound and its interaction with vision seems not to be based on any discernible principles.*

This study is an empirical investigation of the use of animation and static images in health science education.

1.5.5 The contextual imperative

The content domain of a large majority of the studies includes mathematics, science, technical subjects such as electrical circuits, computer applications or statistics. These are conducted primarily within primary, secondary and vocational education contexts. Table 1.2 and 1.3 summarise a selection of these studies.

There have been calls in the cognitive load and cognitive style research literature to consider replication studies using other contexts and subjects fields. The context of Graff's study (2003a) was psychological ethics. He indicated that it is possible that an instructional system with information on a different subject may yield a different finding. Riding et al. (2003) call for further research that includes designing a similar study for another context.

Content	Primary School	Secondary School	Vocational education	Higher Education
Statistics		Paas (1992)		Bodemer, Ploetzner, Feuerlein & Spada, (2004) - Exp 2
Mathematics and Science	Ginns, Chandler & Sweller (2003) – Exp 2 & 3 Jeung & Chandler (1997) Leahy, Chandler & Sweller (2003) Marcus, Cooper & Sweller (1996)	Ayres (2006a) Ayres (2006b) Clarke, Ayres & Chandler (2005) Kalyuga (2006) Kalyuga & Sweller (2005) Kalyuga & Sweller (2004) Kester, Kirschner & van Merriënboer (2004) Sinclair, Renshaw & Taylor (2004)		Bodemer, Ploetzner, Feuerlein & Spada, (2004) - Exp 1 Gerjets, Scheiter & Catrambone (2006) Große & Renkl (2006) Mayer et al., (1999) Reisslein, Atkinson, Seeling & Reisslein (2006) Schnotz & Rasch (2005)
Technical subjects			Kalyuga, Chandler & Sweller (2001) Kalyuga, Chandler & Sweller (2000) Kalyuga, Chandler & Sweller (1999) Pollock, Chandler & Sweller (2002) Van Gog, Paas & van Merriënboer (2006)	
Computer applications			Chandler & Sweller (1996)	Ginns, Chandler & Sweller (2003) – Exp 1 Catrambone & Yuasa (2006)
Instructional Design				Tabbers, Martens & van Merriënboer (2004)

Table 1.2: Contexts of cognitive load research

Content	Primary School	Secondary School	Higher Education
Natural Sciences	Riding & Grimley (1999)(Gravity & Motion, Reptiles)		
Mathematics / Accounting			Riding & Staley (1998) (Accounting)
Social Sciences	Griffin & Griffin (1996) (Map reading) Riding & Grimley (1999) (Geography)		
Psychology			Rush & Moore (1991)
Computer applications / Information Technology (IT)/ Computer literacy			Cunningham-Atkins, Powell, Moore, Hobbs & Sharpe (2004). Graff (2003b) Riding & Staley (1998) (IT) Triantafillou, Pomportsis, Demetriadis & Georgiadou (2004) Workman (2004) (Programming)
Various subjects - excluding health science subjects	Douglas & Riding (1993) (Prose)	Riding & Agrell (1997) Riding & Caine (1993) Riding, Grimley, Dahraei & Banner (2003)	Calcaterra, Antonietti & Underwood (2005) (History) Graff (2005) (History) Riding & Staley (1998) (Management)
Nursing			Luk (1998)

Table 1.3: Contexts of cognitive style research, using Riding's Cognitive Styles Analysis (CSA) and other measures of cognitive style

Cognitive and educational psychology research in the health science education domain seems to lag behind other science-related disciplines. A literature search using the search terms (health science education OR medical education OR paramedical sciences) AND (cognitive load OR working memory) AND (cognitive style) did not find any relevant studies. There have been studies that explored learning styles in health sciences education (Laight, 2004; Martin, Stark & Jolly, 2000; McNeal & Dwyer, 1999; Ross & Schulz, 1999) but a clear distinction has been made in this chapter between cognitive style and learning style.

The context of this study is health science education. What makes health science a suitable context, beyond the fact that I worked in this field?

Medical curricula across the globe are undergoing major changes (Rees, 2000). Health science education in recent years has moved from a subject-based approach to curriculum development to a more systemic, problem-oriented, integrated approach (Treadwell, de Witt & Grobler, 2002). For example, when considering cardio-vascular disease the students will study the relevant Anatomy, Physiology, Pathology, Pharmacology, diseases processes and the appropriate medical and other interventions in an integrated fashion. In order to make clinical diagnoses and prescribe the correct medication health practitioners must understand and apply their knowledge of physiology, pathophysiology and pharmacology. Element interactivity is high. The cognitive skills that must be acquired, such as decision-making and problem-solving, are complex and of the higher-order variety. Medical education is also using a variety of technologies to support learning. Cognitive load research has not extended to tertiary health science education in a meaningful way. It is therefore appropriate and necessary to encourage research in this field and in this context.

1.5.6 Other considerations

Technology has enabled choices that did not exist ten years ago. Learners like to be able to choose. Cognitive style influences this choice. Will the learner's choice result in cognitive overload? How will we design the correct combination of media so that it aligns with individual choice and need, especially if there is a relationship between cognitive load and cognitive style?

1.5.7 Pulling it together

Having considered these imperatives the case for this study can be summarised as follows:

- The empirical, theoretical and media imperatives suggest that there may be a relationship between cognitive load and cognitive style.
- The existence and nature of such a relationship has not been explored in any depth.
- Issues in both cognitive style and cognitive load are under-researched in health science education.

- There are limitations in current research designs that this study will try to overcome.
- There is a lack of research in authentic learning environments.
- Instructional design can benefit from more and specific guidelines for design, especially when new technologies are introduced.

1.6 Research questions

There is one major research question with five sub-questions in this study:

> **Question**: What is the relationship between cognitive style and cognitive load as factors in the achievement of learning outcomes when someone learns the same content by means of different multimedia formats?

i. What were the cognitive styles of the participants who took part in the study?

ii. How did the participants rate the cognitive load of selected multimedia content?

iii. What was the correlation between the participant's self-report of cognitive load and the direct measure of the cognitive load of the content?

iv. To what extent did the presentation formats influence cognitive load?

v. How was learning performance influenced when content with different cognitive load was studied by learners with different cognitive styles?

This study did not measure the cognitive load using the direct measurement technique. The results of the direct measurement of cognitive load, needed to answer sub-question iii, were obtained from Smith (2007) who was a research assistant for this study. She used the same instructional materials and sample for her study.

1.7 Research design and methodology

This quantitative study used an experimental and correlation design to determine the answers to the research questions. In keeping with typical approaches in experimental research a pilot study was undertaken before commencing with the main study.

Both the pilot and the main study were conducted in an authentic learning environment. The multimedia intervention used for the study is part of the prescribed course work in Physiology for health science learners at second year level. The authentic learning environment for participants in the study included using a computer laboratory on campus in order to learn and interact with the prescribed learning material.

It was therefore possible to control several of the variables that are normally difficult to control in authentic learning environments. Some of these extraneous factors include:

- time on task,
- lack of ability to focus on the task at hand due to many other distractions,
- collaboration with peers instead of working individually on the task,
- providing a uniform hardware platform on which the multimedia was delivered,
- access to other resources such as textbooks, journals and other notes, and
- control during the testing phases of the study.

Data collection was electronic in nature. The participants **received** the relevant questionnaires electronically and were required to **complete** these electronically. Data that tracked the respondent's use of the program and response to various stimuli was recorded automatically as the respondent worked through the multimedia intervention.

Table 1.4 lists the research sub-questions and indicates the instrument(s) used to collect the data. The measurement scales used in this study are also presented in this table. The research design and methodology are described in detail in Chapter 3 of this thesis.

Research question		Research instruments				Measurement scale and nature of data
		Questionnaire	**Log of user interaction**	**Paper and pencil test**	**Computer-based test**	
i.	What are the cognitive styles of the participants taking part in the study?				✓	Ratio scale
ii.	How do the participants rate the cognitive load of selected multimedia content?	✓				Category-ratio scale
iii.	What is the correlation between the participant's self-report of cognitive load and the direct measure of the cognitive load of the content?	Answered by means of statistical analysis				
iv.	To what extent do the presentation formats influence cognitive load?	✓	✓			Categorical data (formats) and continuous variables (cognitive load)
v.	How is learning performance influenced when content with different cognitive load is studied by learners with different cognitive styles?			✓	✓	Ordinal scale, variables (pre- and posttest score) are continuous

Table 1.4: Summary of the research instruments and nature of the data

1.8 Analysis of the data

Table 1.5 summarises the analyses that were done to address the hypotheses and answer the research questions. Demographic data was analysed by looking at frequency distributions, which were often presented as two-way frequency tables. Chi-square analyses, used to establish the relationship between frequencies for nominal and ordinal data (Cohen, Manion & Morrison, 2000) were conducted for these tables. Reliability of the various instruments was determined using Cronbach's Alpha.

Research question	**Analyses**
What are the cognitive styles of the participants taking part in the study?	Frequencies, Chi-square analyses, regression analyses followed up with confirmatory general linear modeling (GLM).
How do the participants rate the cognitive load of selected multimedia content?	Frequencies and Means procedures. GLM procedures and t tests of significance for independent samples to establish significance.
What is the correlation between the participant's self-report of cognitive load and the direct measure of the cognitive load of the content?	Pearson's Correlation procedure.
To what extent do the presentation formats influence cognitive load?	GLM procedures and t tests of significance for independent samples to establish significance.
How is learning performance influenced when content with different cognitive load is studied by learners with different cognitive styles?	Correlation procedures. Multiple regression analyses were used to extract the variables of interest. GLM procedures to analyse the variance and establish main and significant effects between the dependent variable (performance in the posttest) and several independent variables.

Table 1.5: Summary of the methods used to analyse the data

1.9 Limitations and strengths of the research

As much as I would have liked to have a study that only has strengths and no limitations, such a situation is rarely, if ever, possible.

The strengths of this study include the fact that the study:

- is one of the first studies to explore the relationship between cognitive load and cognitive style in detail.

- addressed an authentic learning environment as a response to the call for more research in such learning environments, and this authenticity was directed at the curriculum, the physical learning environment and the profile of the participants.
- used a larger sample than many empirical studies in the cognitive style and cognitive load research streams.
- explored a subject domain that has been neglected in both the cognitive style and cognitive load research streams.

The limitations of the study include the fact that:

- the very same authenticity, which was also a strength, made it very difficult to control the variables as rigorously as they are usually controlled in an experimental laboratory.
- seventy participants used the intervention simultaneously in contrast to a experimental laboratory where it is unusual to test more than 3 – 5 participants simultaneously, which made the control of the environment difficult.
- the limited time available in interacting with the participants excluded the possibility of any follow-up to explore further some of the qualitative aspects of the study.
- there was no time constraint for studying the content.

1.10 Organisation of the thesis

The outline of the chapters in the research report is presented below.

Overview and Orientation

This chapter introduces the study by defining the key constructs and discussing the purpose, background and rationale of the study. The research questions are presented. The research methodology and design is introduced. A summary of the limitations of the study provides additional context for the reader.

Literature Review

Chapter two presents the theoretical frameworks guiding this study and continues the argument for the rationale of this study. This critique of the literature is organised around the research questions and includes a review of the major studies related to the questions guiding this study.

3 **Research Methodology and Design**

Chapter three has three distinct sections. Section 1 describes the research approach and design, the sampling strategies used, the data and the design of the instruments. Section 2 describes the multimedia intervention used in the experimental design. Section 3 describes the implementation of the research design and methodology, for both the pilot and main studies.

4 **Presentation and Analysis of Empirical Data**

Chapter four presents the findings of the study. The data analysis includes both descriptive and inferential statistical techniques to confirm or reject the hypotheses. Each sub-question is addressed individually. The analysis then considers the interrelationship between the independent and dependent variables. Where appropriate, the findings are discussed relative to cognitive load and multimedia theory and research.

5 **Discussion and Recommendations**

Chapter five summarises the most important results and interprets these by considering the broader research field. This chapter also discusses the relevance, value and limitations of the research. Design guidelines for instructional designers are presented, with particular reference to designing for health science education. Recommendations are presented at the conclusion of the thesis.

1.11 Summary

This chapter has provided an introduction and orientation to the study. The constructs that will be used in this study were defined. A discussion of the background to and rationale for this study was presented. This culminated in the formulation of the research questions. An overview of the research design was presented, together with a brief description of the limitations of the study.

Chapter 2 will provide a critical review of the relevant research literature.

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