THE ROLE OF ANIMATION IN THE COMPREHENSION OF VISUALLY

ILLUSTRATED INSTRUCTIONAL MESSAGES

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This serves to confirm that that the contents contained in this dissertation is my

original work, does not violate any contractual agreement and has not been submitted

to any other University for a degree.

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ABSTRACT

Contradictory results are reported regarding the value of external representations such as dynamic and static visuals in a learning environment (Lowe 1999; Hanzen, Narayanan & Hegarty 2002; Weiss, Knowlton and Morrison 2002; Bodemar, Ploetzner, Feuerlein & Spada 2004; Bodemar & Ploetzner 2004; Moreno & Valdez 2005; Höffler & Loetner 2007). Some of the recent findings indicate little or no significant differences between static and dynamic visuals. This study looks at studies that used a variety of external representations to facilitate different learning tasks. A "two journal article" format was adopted for Chapter 2 and 3 respectively. The first article, i.e. Chapter 2, is a review of the literature and provides a theoretical background to the research topic. Chapter 2 reviews theories and empirical studies regarding learning with text, dynamic and static visuals, and examines the conditions under which external representations facilitate learning. Subjects' prior knowledge, the content of the instructional material and the testing method are but some of the variables that can determine if graphic medium can increase a subject's comprehension and if such comprehension can be accurately measured. Chapter 2 also presents a model that suggests how dynamic and static visuals can be used in a learning environment. The second article, i.e. Chapter 3, presents an animation for a specific learning task in order to test the hypothesis that this external representation may improve the comprehension of a linear scientific process. Tertiary students ($N =$ 61) participated in a pre-test and post-test experimental study during which they were exposed to 4 treatment variables: text (T), video and text (VT), illustration and text (IT), and animation and text (AT). It was hypothesised that the group who received the animation and text treatment would comprehend the linear process better than the control group (text only) and the other two groups (text and illustration; text and

video). The question that was asked to explore this comparison therefore was: Can animation be used to improve comprehension of instructional text? The results indicate that no significant differences in achievement existed among the treatment groups. The results of the study show that dynamic visuals with text can have essentially the same effect on students' understanding of a particular process as static visual with text. It is further acknowledged that the subjects' prior knowledge, the content of the instructional material and the testing method are but some of the variables that can determine if an external representation can increase a subject's comprehension and if such comprehension can be accurately measured.

TABLE OF CONTENTS

LIST OF TABLES AND FIGURES

TABLES

FIGURES

THE STRUCTURE OF THE DISSERTATION

This dissertation is divided into four chapters. Chapter 1 presents the introduction, problem, the purpose, the method and defines the terms and concepts. A "two journal article" format was adopted for Chapter 2 and 3 respectively. The first article, i.e. Chapter 2, is a review of the literature and provides a theoretical background to the research topic. This chapter reviews theories and empirical studies regarding learning with text, dynamic and static visuals, and examines the conditions under which external representations facilitate learning. The second article, i.e. Chapter 3, was accepted for publication by the *South African Journal of Higher Education* (SAJHE) in 2009 and reports on an experimental study on using dynamic and static visuals. The report is on an experiment which was conducted to investigate the effectiveness of dynamic and static visuals in learning. Chapter 4, being the final and concluding chapter and furthermore provides remarks on the results and furthermore provides a conclusion and summary of the study.

The Bibliographies are also provided at the end each of these two chapters as they were meant to be sent to different journals. The Bibliography at the end of the dissertation is a combination of all the references from these two articles as well as the first chapter.

CHAPTER 1: INTRODUCTION TO THE STUDY

1.1   INTRODUCTION

Various external representation techniques differ in facilitating different learning tasks. The use of dynamic visuals such as animated design, for example, can assist students to understand a complex process such as the working of a mechanical object, for instance Newtonian mechanics, (Chan & Black 2006). Static visual can be used for instructional and presentation purposes such as a pie chart which helps to communicate financial information. Furthermore, multiple external representations can be used to complement each other, allowing for a more unified representation of a particular subject because they can portray different information that require different process tasks (Ainsworth & Van Labeke 2004). For some years, there has been considerable interest in developing external representations that can enhance learning tasks of students in various courses. One reason for this interest is that using external representations such as dynamic and static visuals to present educational information is generally thought to improve learning, (Lai 1998; Schnotz 2002; Suwa & Tversky 2002; Hibbing & Rankin-Erickson 2003; Mayer 2003). However, to take advantage of external representations to improve learning, we need to understand why external representations may help people to learn. Since external representations can be employed for many different kinds of learning tasks, this study reviewed studies that used a variety of external representations to facilitate different learning tasks. This study also developed an animation for a specific learning task, in order to test the hypothesis that this external representation could improve the comprehension of a linear scientific process. It is hoped that a better understanding of these representations will assist instructional designers, web designers, and graphic

designers to consider what type of external representation technique is the most appropriate for developing particular learning task.

Linear scientific process refers to a process in which something changes or moves from one stage to another, and has a starting point and an ending point. The conveyor belt used for the empirical component of this study conduct is a good example of a linear scientific process because this process shows function of the machine as a linear set of steps in which items are transported on a conveyer belt from scanning through recognition and to a point where the items are removed from the belt.

1.2   STATEMENT OF THE PROBLEM

Today technology provides us with new techniques and methods of presenting information for educational purposes (Chandler 2004). In view of understanding how technology can be used to aid the learning process, it seems useful to look at the potential effects that different external representations, may have on learner performance during the learning process. Conflicting results are reported in the literature on the value of various external representations in a learning environment. Some authors claim that external representations aid comprehension, particularly when they are made to be dynamic and interactive (Hanzen, Narayanan & Hegarty 2002; Bodemar & Ploetzner 2004; Moreno & Valdez 2005). Other authors suggest that external representations improve learning mostly when learners are learning complex new ideas (Mayer 1989; Lowe 1999; Weiss, Knowlton and Morrison 2002; Moreno & Valdez, 2005). There are also some authors who claim the external representations consign specific demands on learners, such as the need to understand and interpret different representations, to control and evaluate interactions with these

representations, and to construct logical mental models of these representations (Bodemar, Ploetzner, Feuerlein & Spada 2004; Höffler & Loetner 2007).

Considering the previous studies on external representations, the question to ask is: to what extent do external representations improve or do not improve comprehension? The problem statement is therefore defined as:

To what extent can external representations, such as animation as developed by graphic software programs, improve comprehension of a linear scientific process?

1.3 PURPOSE OF THE STUDY

The purpose of this study was to examine the value of dynamic and static visuals and to explore the conditions under which dynamic and static visuals can be used to achieve meaningful learning. Although dynamic or static visuals may extend beyond the content described in the text that it accompanies, this study only focused on the functions that a particular external representation offer in supplementing text to foster meaningful learning. The study also through a quasi pre-test, post-test experimental design, tested the hypothesis that a group of learners who received a dynamic visual and text treatment will comprehend a linear process better than the control group (text only) and the other two groups (text and illustration; text and video).

1.5 DEFINITION OF TERMS

Animation – Animation has been defined in various ways. Wells (1998) states that the words 'animation, to animate, animated and animator' are all derived from the Latin verb *animare*, meaning 'to give life to'. Höffler and Loetner (2007) also used this term to define as a series of rapidly changing computer screen displays suggesting movement to the viewer. They further remarked that it aims to give an exact

presentation of a process or procedure to facilitate generating an adequate mental model. In this context, Animation refers to the type of dynamic visual in which the creation of movement is applied to static object/s, particularly those that are manipulated on computer.

Comprehension – Schnotz (2002) claimed that comprehension is usually task-oriented. In other words, the mental construction is performed by the individual in a way that allows him or her to deal effectively with current or anticipated requirements. The term comprehension in the context of this study refers to the ability to understand effectively and be aware of a situation or facts.

Cognitive load – This concept is used to refer to a multi-dimensional construct representing the load that performing a particular task imposes on the learner's cognitive system (Khalil, Paas, Johnson & Payer, 2005). According to Sweller, Paas & Merrienboer (1998) and Paas, Renkl & Sweller (2003) there are three types of cognitive load: (a) intrinsic, (b) extraneous, and (c) germane. Intrinsic cognitive load occurs during the interaction between the type of material to be learned and the prior knowledge of the learner. Extraneous cognitive load is caused by factors that are not central to the material to be learned, such as external representation used or activities that split attention between multiple sources of information, and these should be minimized as much as possible as they can impose a high extraneous load which is not relevant to learning. Germane cognitive load enhances learning and results in task resources being devoted to schema acquisition and automation.

Dynamic visuals - These displays are often characterised as realistic, because they portray a visible sequence of events in real time, or at least proportional to real time. In this type of visualisation, one state of the system is visible at a time, as it is in the real world (Hegarty 2004).

External representations – Schnotz (2002) defines external representations as texts and visual displays. According to Schnotz, these external representations are understood when a reader or observer constructs internal mental representations of the content described in the text or shown in the picture. According to Scheiter, Wiebe and Holsanova (2009) external representations can be described in terms of their structural correspondence to what it stands for. In other words external representation can evoke similar responses to the real or imagined world, for example, text can be used to represent things and occurrences in the real world.

Multimedia – Multimedia has been defined in many ways including the use of several media for the purpose of communicating information and entertainment to a person. For instance, using a combination of moving and static pictures, sound, music and text, especially in computers (Najjar, 1995 &1996). Najjar also stated that these applications seem to share a common assumption that multimedia information helps people learn. Schnotz and Lowe (2003) defined multimedia as the combination of multiple technical resources for the purpose of presenting information represented in different formats by means of several sensory modalities. Mayer (2001) used the term multimedia to refer to the presentation of material using both words and pictures.

Spatial Abilities – Refers to the cognitive abilities that enable a person to deal with spatial relations, in other words the ability to visualise objects in space (Guan 2002).

Static visuals – This term has been used to refer to external representations such as charts, illustrations, signs, maps and diagrams (Guan 2002).

Text – Large (1996) made a distinction between procedural and descriptive texts. Procedural texts consist of a number of procedures in successions which are executed by someone or something so as to achieve a particular objective. Descriptive texts describe an object, scene, or location. Schnotz (2002) in a discussion on representational issues, state that both text and visual displays are forms of external representations. When reading text or viewing a picture, one is able to create an internal mental model of what is described in the text or in the picture. Wade and Moje (2000) reviewed research to answer two questions about the role of text in classroom learning. Their findings suggest that text can be described as "organized networks [of meaning] that people generate or use to make meaning either for themselves or for others". The term *text* in the context of this study refers to words, sentences, paragraphs of any printed or written material.

Text and animation – These terms are used in this study to refer to external representations (see page 4) in which animated artwork is accompanied by text interpreting it. In his research, Large (1996) states that, in general, animation improves the comprehension of a procedural text more than a descriptive text. This, according to Large, is because procedural texts are more likely than descriptive texts to require animation that demonstrates a particular action or procedure. Studies conducted by Mayer and Anderson (1991), in which they researched the use of verbal

narration together with animation, showed that understanding concepts using animation was significantly improved if verbal explanation ran concurrently with the animation. Although some research has reported learning enhancement regarding text accompanied by animation, other research has found little or no positive effect with the use of animation (Tversky, Morrison & Betrancourt 2002; Hibbing & Rankin-Erickson 2003; Schnotz & Rasch 2005; Lin, Chen & Dwyer 2006; Betrancourt & Chassot 2008; Boucheix & Schneider 2009).

Text and illustration – For the purpose of this discussion, illustration is defined as an external representation (see page 4) made with pen/pencil/computer accompanied by text interpreting it. The relationship of text and illustration referred to here typically concerns the way their different structural characteristics impact on information processing tasks such as acquiring and application of information to a new situation. Using text and illustrations or pictures as complementary media is generally believed to be a more effective approach in increasing knowledge acquisition (Large 1996; Lai 1998; Hibbing & Rankin-Erickson 2003; Mayer 2003). Both sources of information are processed separately in order to acquire the entire meaning of their combination (Mayer 2003). As Guan (2002) stated, the role of static visuals such as illustrations is dependent upon the type of text they accompany. Illustrations may become more helpful as texts become more difficult (Carney & Levin 2002; Liu, Kemper & McDowd).

Text and video - External representation (see page 4) made on videotape for viewing on television. Video shares similar characteristics with animation as there are moving pictures and is regarded as a form of dynamic visual (Ogunyemi 1997; Carroll 2004) for the purpose of this discussion.

Visual Literacy – Has also been defined in various ways. According to (IVLA) International Visual Literacy Association, the term *visual literacy* refers to the ability to construct a set of mental images from viewing or seeing visuals. Through the use of these mental images, a visual literacist is able to comprehend, interpret and communicate with others. De Lange (1999) used this term to refer to the ability to comprehend and communicate the language used in visual imagery. De Lange further suggests that factors such as prior knowledge and openness to visual media, educational and socio-economic abilities can determine the visual literacy level of an individual.

**CHAPTER 2: LEARNING WITH DYNAMIC AND STATIC VISUALS:
A REVIEW OF THEIR VALUES IN A LEARNING ENVIRONMENT**

2.1   INTRODUCTION

As instructors discover new ways of presenting complex concepts and data to students, there is an increased interest on the use various external representations such as dynamic and static visuals in learning (Lowe 2001; Reimann 2003). However the reported effectiveness of dynamic and static visuals in a learning environment varies (Large 1996; ChanLin 1998; Lai 1998, Rieber 2000; Mayer & Moreno 2002; Tversky, Morrison and Betrancourt (2002); Van Schaik & Ling 2004; Lin, Chen & Dwyer 2006). Upon closer inspection, it seems that several factors can contribute to a positive or negative effect for a particular external representation. For example, some authors suggest that by looking at the functions that these visual methods can fulfill, many of these varying results could be accounted for, (Ainsworth & Van Labeke 2004). Other authors suggest that the use of dynamic and static visuals must take into consideration the cognitive capabilities, (Chandler 1995; Bodemer, Ploetzner, Feuerlein & Spada 2004; Rieber 2000; Lewalter 2003), prior knowledge (ChanLin 1998) and spatial abilities of the users (Guan 2002). One way to investigate these issues is to examine the value in learning of both dynamic and static visuals as representation strategies. After reviewing some of the theories and empirical studies dealing with the effectiveness of external representation in learning, it was necessary to investigate the above issues and several other factors that may impact on the effectiveness of dynamic and static visuals. Particularly when considering that much of the information in most courses, contain content in the form of texts, static or dynamic visuals. The aim with this review was to extract specific conditions where techniques may or may not work, and also if the implementation of several techniques conflict with or cancel out the effects of one another.

2.2   DEFINING EXTERNAL REPRESENTATIONS

In order to conduct this review on the value of dynamic and static visuals, it is first necessary to look at the general description of external representation. According to Jolly (2003), external representations are visual representations of data, information or knowledge using items such as maps, charts, diagrams, models, static graphics, computer animations, hypertext and multimedia that are incorporated into instruction. Jolly further claims that external representations demonstrate a spatial relation and may refer to the concrete objects and real-world relations. This paper has adopted the view that external representations are data structures for communicating information. As such, visual representations can be used as aids to facilitate innovation and learning by providing an efficient structure for communicating knowledge.

The general assumption behind the use of external representations is that they have an essential instructional effectiveness in presenting unfamiliar or difficult subject matter. For instance, extracting information from animation of weather maps (Lowe 1999), to provide an explanation on how a particular process works, Mayer and Anderson's (1991) bicycle pump or clarity on abstract matters like economics (Weiss, Knowlton & Morrison 2002). External representations are also believed to be beneficial for learning. However, theoretical and educational research has shown that learning with visualisations is not always beneficiary. For instance, Rieber's (2000) behavioural and cognitive learning theories suggest that there are times when visuals can aid learning and times when they might interfere with learning. The behavioural theory suggests that this interference might occur where students are unable to shift their attention from a given graphic to text. The cognitive theory suggests that if appropriately designed, visuals can be helpful for learning processes such as encoding and retrieval of information. Appropriately designed visuals in this context refer to the

congruence principle as suggested by Tversky, Morrison and Betrancourt (2002). In other words visuals are appropriately designed if there is correlation between both the visual and the content to achieve the desired structure and content of the internal mental model. In addition, some authors have also stated that the use of external representations such as dynamic visuals can impose a high working memory and that these visuals are always not easy to understand (Hegarty 2004; Lowe 2004).

2.3   THE IMPORTANCE OF EXTERNAL REPRESENTATIONS IN LEARNING

The use of external representations offers various advantages in learning. One such advantage is that students can learn more deeply from appropriately designed visual images which consist of words and pictures than from the normal method of communication which comprises words alone (Mayer 2003). According to Mayer, students are usually better able to integrate verbal and visual representations when they receive both verbal and visual materials, rather than when they receive only verbal material. When only verbal material is presented, the learner may construct an impoverished visual mental model that may be insufficient to integrate with the verbal mental model. Suwa and Tversky (2002) list a number of benefits for which external representations serve on facilitatory roles. One such benefit is on memory. According to Suwa and Tversky, external representations provide extra symbols for those elements that must be kept in one's mind. As a result, the memory is freed from working on mental calculations of the elements, instead of keeping elements and working on them.

Rieber (2000) lists a number of instructional graphic principles appropriate to all materials. These principles are based on the following four instructional applications:

(a) cosmetic, (b) motivation, (c) attention-gaining, and (d) presentation. The list below is a summary of some of his recommendations, since they are significant to both dynamic and static visuals.

1. The first important principle of instructional learning is that there are conditions in which pictures aid learning, do not aid learning but do not harm, and do not aid learning and are distracting. This, according to Rieber, is important as it channels all the challenges that exist in designing graphics, if the aim is to aid learning.

2. When choosing a particular type of visual, the needs of the learner, the content and the nature of the task must be considered.

3. Graphics should not distract attention from the type of objective to be achieved.

4. Graphics should be designed in such a way that the functions for which they were designed, will be attained. For example, they should form part of integration into the instructional design from the beginning stages right up to the end.

5. Cosmetic functions of graphics are of no value to learning. They are mainly used to create a centre of attention. This can both be good, as it makes the instructional material exciting, or bad, because it might drag the learner's attention away from the learning objective and therefore be distracting.

6. The best remedy for the use of cosmetic graphics is to consider graphics that can motivate students and these must be incorporated in the whole process.

7. Graphics can also be used to draw a learner's attention to the learning content, either because of the graphic's visual appearance or the meaning projected by displayed graphics.

8. Graphics should be equivalent and relevant to the corresponding text or the consequences of negative effects that may occur.

In their research with subjects who struggle with reading comprehension, Hibbing and Rankin-Erickson (2003) found that if students are not able to construct internal mental images, because they are using all their mental energy to interpret words, external visual images can be used to develop understanding. They found that using illustrations, pictures in books as well as moving pictures, provide students with the ability to build their own internal mental pictures.

Lai (1998) compared the three methods of visual displays (text, static graphics and animation) in terms of their equivalence on learning computer programming language within Computer Based Learning (CBL). Lai's aim with the experiment was to measure concept recall and attitude toward the analogy using different visual displays. He found that in order to enhance the level of concept learning for computer learning, text should be accompanied by appropriate static graphics. According to Lai, static graphics may allow learners more space for interpreting the given information and this may subsequently help them in their understanding of a new concept. It was also interesting to note that students who used the CBL with static graphics performed better in recall and recognition than those who used CBL with text and animation.

2.4   CHARACTERISTICS OF DYNAMIC AND STATIC VISUALS

Dynamic and static visuals are regarded as forms of external representations and will be used for the purpose of this discussion. Dynamic and static visuals have different characteristics in terms of what they are able to represent (Lin, Chen and Dwyer 2006). Perhaps some of the obvious typical features of dynamic visuals are that they

are able to provide users with two different elements, namely: images and movement (ChanLin 2000 and Rieber 2000) and their ability to show direct visualisation of changes that occur over time (Betrancourt & Chassot 2008). ChanLin lists a number of areas for which dynamic visuals, such as animation can be used in a learning context: One of these areas is for comprehensibility and memorisation, another area; animation, can be used in a variety of ways, such as in attention-gaining strategies or pointing arrows for emphasising a point. Dynamic displays can also be used to represent theoretical concepts, such as statistical concepts, as can be seen in a study by (Bodemer et al., 2004) changes in population over time (as studied by Ainsworth & Van Labeke, 2004) as well as computer algorithms (Narayanan & Hegarty 2002).

Dynamic visuals are generally considered to be a subdivision of static visuals (Rieber 2000; Weiss et al., 2002). Due to the advent of the computers, it is now possible to make static graphics into dynamic graphics (Narayanan & Hegarty 2002; Jolly 2003). This can be achieved by using additional features such as arrows, dotted images or shading techniques to symbolise these dynamics (Lewalter 2003; Pramono 2005). Ainsworth and Van Labeke (2004) used the functional taxonomy of multiple dynamic representations to show the characteristics of dynamic representations in learning. According to them, there are three classes of dynamic visualisation; (a) time persistent, (b) time implicit, and (c) time singular representations. These different types of dynamic visualisations are discussed in terms of their processing opportunities and constraints. Time-persistent representations show a series of values over the specific time. Time implicit representations on the other hand only show these values but does not show the specific times, while time-singular only displays a single point of time. Furthermore, they discovered that by combining different types of representations, learners can be able to benefit from the complementary, constrain

and constructive functions of these representations. However, they also urged caution with regard to the cognitive tasks associated with the content and the visual representations.

Static visuals such as pictures, illustrations and signs have been used since the ancient times as a basic method of communicating information. Even in today's computerised society, static visuals seem to have a place of importance (Hegarty 2004). Software programmes such as *Adobe Illustrator,* as well as *Macromedia Freehand,* are still used for the creation of static visuals which are applicable for both web and print media. According to Guan (2002) the role of static pictures is dependant upon the type of text they accompany. For example, children's book illustration where the picture or a drawing elaborates the text and gives a possible interpretation of it. Guan further state that the positive attributes of pictures on learning can only be realized when three conditions are met. First, the type of text and pictures must match each other well. Second, pictures must be used to instruct the learners who can benefit from the support of pictures. Third, an appropriate test must be employed to assess learning performance.

According to Rieber (2000); Carney & Levin (2002), most of the research findings prior to 1970 indicated that static visuals generally did not aid learning, and were sometimes distracting learners from processing printed text. Perhaps one of the reasons why the effectiveness of pictures was found after 1970, could be that the conditions where they might aid learning had been made clearer. As Chandler (1995) and Rieber (2000) suggested, the majority of traditional visuals representations may have been designed without taking into consideration the cognitive capabilities of the learners and as a result, learning by overloading a learner's working memory may have occurred. Dominant conclusions drawn from this and other static visual research

are: (a) pictures are important aids for building internal mental models, (Mayer, 2003 and Hibbing & Rankin-Erickson, 2003); (b) pictures are important aids for recall and recognition tasks, (Lai 1998); (c) the more complex the text, the more likely that pictures are helpful (Carney & Levin, 2002; Liu, Kemper & McDowd 2009). In particular explanative (or interpretational) pictures function as useful mental models if (a) the text describes complex processes and (b) the learners are relatively inexperienced in the content domain. Goldsmith (1984) compiled an extensive review of literature about the uses of illustrations in educational context. Goldsmith identifies three main semiotic levels of unity for illustrations, namely: (a) syntactic: refers to the manner in which the reader comprehends and interprets some parts of the image in order to make sense of the whole image; (b) semantic: refers to the necessity for which images have to be easily identifiable, regardless of the nature of material to be learned and (c) pragmatic refers to the readers familiarity with the material to be learned. According to Goldsmith, in order for an image to be successfully understood by the learner, it must succeed in all of these three levels.

Anglin, Vaez and Cunningham (2004) conducted a literature review on the effect of static and animated graphics on learning. Their findings suggest that static visuals can facilitate the acquisition of knowledge, particularly when they are accompanied by text-redundant information. However, according to Anglin and his colleagues, the facilitative effect of static visuals was not applicable to all learning situations. This is possibly due to the lack of connectivity between the reviewed studies (functional and theory-based studies). They further added that illustration attributes such as size, page position, style, colour and the level of accuracy may direct attention but may not significantly aid in learning.

Houts, Doak and Loscalzo (2006) conducted a research on the role of pictures in improving health communication. The aim was to examine the effect of pictures on the following variables: attention, comprehension, recall, and adherence. Findings from this study suggest that pictures can be especially helpful to patients with low literacy skills. Understanding health information, recalling health instructions and adhering to health instructions are the areas where research results have been promising. Research also suggests that spoken information can, with the help of pictures, be recalled to rather accurately by people with low literacy skills.

2.5   ADVANTAGES AND DISADVANTAGES OF DYNAMIC VISUALS

Lewalter's (2003) experiment suggests that dynamic visuals are conducive for communication of spatial aspects and dynamic processes as it allows a complete visualization of spatial constellations and dynamic processes, while with pictures, static indicators such as shading or arrows must be used to represent this information. According to Tversky, Morrison and Betrancourt's (2002) analysis, there are two principles stating the specifications at which dynamic visuals, such as animation, may be successful in learning, even though these do not confirm the superiority of animation to the static images. These are the congruence principle (external visuals must be created/structured similarly with the internal), and the apprehension principle (graphics should be recognised and visualised correctly).

A paper by Hegarty (2004), states that dynamic visuals can be used to depict processes that are visible in the actual world, such as a machine that is in motion. Dynamic visuals can also be used to present procedures that are hidden, but are spatially distributed, for instance changes in temperature in a weather map, (Lowe 2003; Hegarty 2004). Dynamic visuals can directly display changes in space over time, either incrementally or constantly (Ploetzner & Lowe 2004). Furthermore, if

dynamic visuals are also made interactive, learners can be given some control over how these changes are presented to them (Chan & Black 2006).

According to Lowe (2001), in order for a dynamic visual such as animation to fulfill its potential as a tool for learning, its function must not only be to be attractive but must also consist of the cognitive function that can be used to develop other important parts of learning such as comprehension, recall and problem-solving. The following is a summary of some of the advantages of animated visuals over static visuals as listed by Lowe with regard to cognitive functions:

- More helpful in terms of revealing the given information than equivalent static visuals.

- Animated visuals offer a better match between the subject matter and its representation because of its capacity to represent the dynamics explicitly.

- Clearer to the viewer because the subject matter can be viewed from different angles. The depiction can hence advance from description to explanation. This is similar to what Tversky and Kessell (2006) as well as Rasch and Schnotz (2009) stated: that the one advantage that animated visuals seem to have over static visuals is that static visuals include only structural (visuo-spatial) information, while animated pictures entail structural as well as temporal information.

- Clearer because unlike static graphics, they do not require various additional symbols (such as arrows, dotted lines, etc.) to convey the dynamic aspects of the content indirectly. This means the display can be less cluttered and learners are not required to carry out the decoding processes necessary to interpret these symbols in order to understand the changes that the subject matter undergoes.

One other interesting notion that is shared by the researchers is an appreciation of the fact that dynamic displays are not always easy to understand and may also impose additional cognitive demands that are not available to static visuals to the learner when creating a mental representation of the dynamic content. For example, when viewing a frame-by-frame animation or video, one views one frame at a time, and once the animation or video has advanced beyond a given frame, the previous frame is no longer available to the viewer (Hegarty 2004). Therefore this may be severe on the working memory, especially in cases when information presented earlier in the animation should be integrated with information that is presented later. In contrast, when viewing a static display, viewers can re-examine different parts of the display as much as they wish (Ainsworth and Van Labeke 2004). However, it can also be said that the ability to introduce each step independently in animations reduces the clutter of static illustrations, in which all of the steps are shown at once (Stith 2004).

Researchers have also indicated that when compared to static visuals, the creation process of dynamic visuals requires more time, programming skills and is costly (Fengfeng, Huifen & Yu-Hui 2006; Zhu & Grabowski 2006).

2.6   ADVANTAGES AND DISADVANTAGES OF STATIC VISUALS

In spite of the above-mentioned benefits of animation on learning, a considerable number of studies revealed that there was little or no significant difference between animation and static illustrations in promoting conceptual understanding (Tversky, Morrison & Betrancourt 2002; Hibbing & Rankin-Erickson 2003; Lin, Chen & Dwyer 2006; Boucheix & Schneider 2009). In the review of literature on the psychology of text-image interaction, it seems that, static and dynamic visuals share similar characteristics, except that static visuals seem to be more appropriate for the display

of static aspects of a tactic employed, such as using a pie chart to help communicate financial information (Guan 2002). Several reasons can be put forward why text-image combination improves learning. For example, Mayer (1989) has extensively reviewed the use of illustrations in facilitating students' understanding of scientific explanations. The findings from Mayer's review suggest that, in order to understand scientific explanations, coordination between words and pictures must be achieved. Mayer further lists 4 decisive factors that should be considered to realise the usefulness of illustrations: (a) the participants should not be familiar with the content; (b) the content should describe each stage of a cause-and-effect process; (c) words and pictures must correlate with one another, and (d) dependent measures should also be relevantly chosen. Pictures can be used to accompany texts in order to improve their comprehensibility and memorability (Large 1996). According to Large, the theoretical basis for visual effectiveness rests on competing theories such as dual coding, single coding, and mental models.

Carney and Levin (2002) have suggested five primary functions for pictures: (a) Decoration: pictures that are used for visual embellishment with little or no connection to the text content; (b) Representation: pictures that reflect part or all of the text; (c) Organisation: provide a significant structure for the text content; (d) Interpretation: simplify concrete information, and (e) Transformation: useful for recall and retention purposes.

When compared to dynamic visuals, static visuals are also considered to be of good value as far as the costs and design processes are concerned. In a study in which they compared the instructional effects of static against animation strategies, Zhu and Grabowski (2006), for example, recommend the use of static visuals, particularly

because they found them to be equally as effective as animated visuals (see also Lin, Chen & Dwyer 2006).

According to Wiebe (1991) and Pramono (2005), the most obvious disadvantage of static visuals is that they are unable to present the dynamic character of a particular situation fully and clearly. For example, it is difficult to use static visuals to represent a process which includes a sequence of changes in a particular direction, specifically for inexperienced learners or if the content is new to the learners.

Berends and Van Lieshout (2009) examined the effect of four different types of illustration on children's performance on arithmetic word problems. The findings demonstrate that using illustrations to guide arithmetic word problems can negatively impact on the performance of children. The four types of treatments employed included: (a) bare: text was presented without any illustration; (b) useless: in this treatment, text was accompanied by an illustration which did not contain numerical information and did not add information to the text; (c) helpful: this treatment was the same as the preceding treatment, except that the illustration included numerical information that was also presented in the text, and (d) essential: this treatment contained an incomplete text information as well as a graphic that contained the missing numerical information. Three of the above treatments (useless, helpful and essential) were found to have induced working memory load by requiring inhibition of irrelevant information, providing redundant information, and increasing element interactivity. However, according to Berends and Van Lieshout, these results do not necessarily imply that illustrations are harmful to the learning process, but that illustrations can slow down processing.

The advantages and disadvantages of dynamic and static visuals impacting on learning are summarised in Table 1 on the next page.

Table 1.
Advantages and disadvantages of dynamic and static visuals impacting on learning

Dynamic visuals	
Advantages	Disadvantages
1. Provides user with movement and picture (Chanlin 2000; Rieber 2000) and therefore can be used for: • Comprehensibility (ChanLin 2000). • Visual enhancement and entertainment (Rieber 2000). • Emphasising a point (Rieber 2000). • Drawing attention (Chanlin 2000; Weiss et al. 2002; Large 1996 & Rieber 2000). • Motivation (Rieber 2000). • Memorisation (Chanlin 2000; Suwa & Tversky 2002). • Construction, constraining and complementing (Ainsworth & Van Labeke 2004). 2. Suitable for communication of spatial aspects and dynamic processes (Lewalter 2003). 3. Can be used to depict processes that are visible in the actual world (Hegarty 2004). 4. Can be used to present hidden procedures which are spatially distributed (Hegarty 2004; Lowe 2003). 5. Can provide information that is either implicit or unavailable in static graphics (Lowe 2003). 6. More helpful in terms of revealing the given information than equivalent static visuals. As a result, the viewer is able to view the given information more comprehensivley because the subject matter can be viewed from different angles (Lowe 2001). 7. Offer a better match between the subject matter and its representation because of its capacity to	1. Can be distracting (Rieber 2000; Weiss et al. 2002). 2. Complexity (Large 1996; Hergaty 2004; Lowe 2004). 3. If not projected equally with text, can produce negative results on comprehensibility (Large 1996; Rieber 2000). 4. The creation process of animation is said to be time consuming and costly (Zhu & Grabowski 2006). 5. Not always easy to understand (Hegarty 2004). 6. Can also be very demanding for learners and can impose a high work memory (Hegarty 2004; Lowe (2001).

8. Clearer because unlike static graphics, they do not require various additional symbols (such as arrows, dotted lines, etc.) to convey the dynamic aspects of the content indirectly (Lowe 2001) 9. Can display changes in space over time, either incrementally or constantly (Ploetzner & Lowe 2004). 10. The steps independently shown in animations may reduce the clutter of static illustrations (Stith 2004). 11. If interactive, users can have control over how these changes are presented to them (Chan & Black 2006). 12. If projected equally with text, can produce positive results on comprehensibility (Large 1996; Lai 1998; Tversky, Morrison & Betrancourt 2002). 13. May simplify information of complex subject because they can display structural as well as temporal information (Tversky & Kessell; Rasch & Schnotz 2009).	

Static visuals	
Advantages	Disadvantages
1. Can also be used as an aid to comprehensibility and Memorability, Large (1996) and also has similar characteristics to animation (Lin, Chen & Dwyer 2006) and video except that there is no movement (static) • Visual enhancement (Rieber 2000). • Presentation (Rieber 2000; Carney & Levin 2002). • Draw attention (Rieber 2000). • Recall and recognition (Lai 1998; Carney & Levin 2002). • Helpful for building internal mental models (Hibbing & Rankin-Erickson 2003; Mayer 2003). • Construction, constraining and complimenting (Ainsworth & Van Labeke 2004). 2. If projected equally to text, can produce positive results on comprehensibility (Mayer 1989). 3. Can be especially helpful to viewers with low literacy skills. 4. Can facilitate the acquisition of knowledge, particularly if they are accompanied by text-redundant information (Anglin, Vaez and Cunningham 2004) 5. When viewing a static display, viewers can re-examine different parts of the display as much as they wish (Ainsworth & Van Labeke 2004). 6. May simplify information of complex subject (Carney & Levin 2002; Lin 2006). 7. More cost-effective and cost-efficient than animation (Zhu & Grabowski 2006).	1. Can also be distracting (Carney & Levin 2002; Rieber 2000). 2. Complexity (Hegarty 2004; Lowe 2004) because they can only display structural (visuo-spatial) information. 3. No movement to support picture and therefore considered to be less effective on comprehension 4. Inability to present the dynamic character fully and clearly (Wiebe 1991; Pramono 2005). 5. Can impose a high working memory (Lowe 2001). 6. Applicable for static aspects of a situation (Guan 2002).

2.7   THEORETICAL MODELS AND THEIR ASSUMPTIONS

Researchers and theorists have developed several theoretical models in order to explain and understand the process of learning with dynamic and static visuals. This section aims to highlight major differences among the models of learning in terms of their roles, goals and suggestions.

The role of conceptual models can be found in the work of Mayer (1989) in which he explains why models can be used. Mayer explains that conceptual models can be used to provide an assimilative context for students to construct meaningful mental models, particularly if the aim of instruction is to help student to understand explanations. Furthermore, (Mayer 1999; 2001 & 2005) presented two models which suggest different channels for processing and storing information according to the concept of dual coding theory: (a) a cognitive model from a multimedia perspective (CTML) and (b) the intergraded text and picture model (ITPC). According to these models the learner is regarded as a constructor of his/her own knowledge, actively seeking to build connections between visual and verbal representations through the selecting, organising, and integrating processes.

However, Schnotz and Bannert (2003) argue that Mayer's model is questionable as the sign structures and principles used for texts and pictures are different. They then suggest a model of text and pictorial understanding, to explain why the type of visualization used in a picture affects the structure of the mental model created during picture comprehension. Their model is based on the characteristics of description (symbols describing an image) and depiction (physical models which possess particular structural characteristics that allow a viewer to extract relevant information). The model suggests that static visuals can function to remove any possible uncertainties in the verbal presentation of a particular subject matter by

providing additional information. It should, however, be noted that this advantage can only be realised if both textuals and visuals are complementing each other.

Theoretical models can also be used to build a network of hypotheses which can guide the development of existing and future theoretical models on the learning environment. The model can be complemented by other multimedia elements (like animation, pictures, and video) and therefore build a comprehensive basis for testing the effects of instructional representations. For example, Hart (2003) introduced a theoretical learning model which suggests that learning by doing, provides the interaction that is present in the interaction learning theory. According to this model the emphasis is on the interaction between the learner the animation, and the teacher resulting in a cyclical communication process. The interaction between the learner and the animation provides immediate information to each other. In that case the learner is then able to gain knowledge through practice. The function of the presenter or teacher is to help control the learning situation and to act as a learning facilitator for the student.

A further theoretical model that explains visual information processing in the context of learning is provided by Wickens (2002). This theory suggests the existence of separate resources, resources that are defined in terms of four dimensions: (a) the information processing stage (perception / cognition against response); (b) the processing code (verbal against spatial); (c) the input modality (visual against auditory), and (d) the visual channel (within the visual modality; focal as opposed to ambient). According to this theory, resource contest generally results from interference at each of these levels. Scheiter, Wiebe and Holsanova (2009) state that understanding the perceptual and cognitive processing of visuals is crucial to

understand the differences between text and visual representations and how they can be designed for effective learning.

As discussed above, Dual Coding Theory (DCT) can also be regarded as another explanation for the effects of visuals on learning. Najjar (1995) used this theory in order to describe the effects of multimedia in learning. According to his findings, it appears as if people learn better when related information is concurrently presented with verbal and pictorial media than when information is presented with verbal or pictorial media alone. This, according to Najjar, happens specifically when there is a natural link between verbal and imagery systems which consequently guides the learner to better understanding. This is also found in research by Mayer & Anderson (1991). They conducted an experiment to investigate how students use words and pictures to build an effective visualisation to understand how a particular system works. Their results suggest that, in order for both words and pictures to be helpful in an instruction, verbal and visual explanations need to correlate as much as possible as there is a need for coordination of verbal narration when simultaneously displayed with animation. McKenzie and Danielson (2003) encourage a mural method, which is a dual coding by which information can be presented both verbally and visually with a picture. According to Mckenzie and Danielson, this will allow subjects to memorise, recall and also to construct meaningful ideas from facts or images presented, particularly unknown topics.

In summary, the models that are discussed in the preceding paragraphs appear to be linked to one another in terms of their roles in a learning environment. It seems as if both Mayer (1991) and Schnotz and Bannert (2003) developed their models with two common elements; (a) the first element explains why the type of visualisation used

can affect the structure of the mental model created during picture comprehension. This element is based on dual coding theory (DCT) provided by Sadoski, Paivio and Goetz (1991). This theory suggests two ways through which knowledge is developed: (a) firstly, by means of a verbal system otherwise known as *logogens* which deals with language, and (b) secondly, as an imagery system (imagens) which is related to pictures and sounds. (b) The next element is that each channel of information has a limited capacity for processing information, based on Baddeley's (2002) and Sweller's, Van Merrienboer's and Paas's (1998) working memory theory and Chandler (1995) cognitive load theory. Lastly, all these models assume that humans, in actively attending to important information and organizing the selected information into internal representations, are in active learning.

From the above, it seems as if both dynamic and static visuals are somehow related concerning their characteristics as presentation strategies in learning. Looking at the characteristics, their advantages and disadvantages have let us to much more interesting issues of the applicability and the conditions to which the dynamic and static visuals can be used. When looking closely at characteristics of both types of visuals, it seems as if there are some areas where dynamic visuals can be used and other areas where pictures and other static visuals are more appropriate. For example, Weiss et al. (2002) remarked that users should not use dynamic visuals such as animation to depict a fairly simple procedure if the procedure can be communicated in a simpler medium, because in those cases animations can be distracting. It is also interesting how various types of external representations with text have varying functions and help create a "mental model", rather than simply receiving or absorbing knowledge. This then means that care has to be taken to characterise dynamic and static visuals independently from learning because the type of visualisation used

affects the structure of internal mental models acquired during learning. It should also be taken into account that probably not all viewers are familiar with and benefit from either static or dynamic visual to the same extent, individual characteristics and age may have influence on the expressions types in response to the visuals.

2.8 FACTORS THAT MAY IMPACT ON THE EFFECTIVENESS OF EXTERANAL REPRESENTATIONS

This section highlights the factors which were identified to have an influence on learning, when used in association with various external representations. The factors are discussed under five main categories, namely: subject's characteristics, type of material to be learned, method of instruction, cognitive and design factors. This however does not imply that the above factors can be generalised without careful inspection. These factors should be regarded as guidelines that can be used to the value of dynamic and static graphics in a learning environment. More factors could be identified according to the specific needs and requirements of a particular learning content.

Dynamic and static visuals are all around us, in newspapers and magazines, in advertising, on television, and on the Web. These visual displays appear to be of great importance not only in our daily life, but also in the field of learning and instruction where instructional materials nowadays include more animations, pictures, diagrams and graphs than a few years ago (Schnotz 2002, Van der Meij & De Jong 2006). One question that arises concerning learning with dynamic and static visuals is the manner in which learners construct visual meaning. The effectiveness of dynamic and static visuals on learning depends on a number of aspects of which the cognitive load (Chandler 1995; Sweller, Van Merrienboer & Paas 1998 & Sweller 2006, Scheiter,

Wiebe & Holsanova 2009), the content, the individual characteristics of the learner and design aspects are significant. For example, when information is presented to the learner with either dynamic or static visuals, the learner must have the ability to extract information from them, to correlate information presented in various representations, to apply this information to the new context, to decode one type of representation into another, as well as to be able to produce an efficient and optimal new representation for specific information and goals (Lowe 1999, Ainsworth 2006, Seufert & Brünken 2006, Van der Meij & De Jong 2006, Eilam & Poyas 2008).

Subject's characteristics

Individual characteristics such as spatial ability (Höffler & Leutner 2007) or prior knowledge (ChanLin 2001; Schnotz 2002; Kozma 2003; Falvo 2008) can also influence whether static visuals or dynamic visuals are better in a particular domain. According to Seufert and Brünken (2006) and Falvo (2008) "solid foundational (prior) knowledge prepares students to learn and retain structured information and process concepts conveyed by animations". In the case of lack of prior knowledge, learners who do not know or have less information about the particular domain concentrate more on explicit information to construct understanding (Seufert 2003; Boucheix, Lowe, Soirat 2006). This then means that learners select information that is easily identifiable. It is for this reason that in some domains dynamic visuals are preferred over static visuals because they help in mentally visualising a process or a procedure (Yarden & Yarden 2009). With static visuals, the learner is required to construct a dynamic internal mental model using the static information provided. For instance, it would be difficult for a learner to construct a mental model from static information of a molecular chemistry concept in which all the associated elements and the ways that

they change evolve during the process. With dynamic visuals such as animation, the corresponding changes are apparent (Falvo 2008).

One other possible instructional medium that may help improve spatial visualization skills is through video instruction (Carroll 2004). Video shares similar characteristics with animation as there are moving pictures and therefore video is regarded as a form of dynamic visual for the purpose of this discussion. The strengths of video become apparent exist mainly when it is important to show how the information changes over time. Carroll (2004) compared the effective use of video with the use of text and static graphics for instructing spatial tasks. The aim of Carroll's study was to find answers to the following questions:

1. Will students complete video-based exercises in less time than when using traditional static graphics and text?
2. Will there be a difference in the frequency of errors between students viewing an instructional video compared to reading instructions for completing a spatial task?
3. Do students retain more information with video instruction than with text and static graphics-based instruction?

Carroll's study indicated that students using video can complete a given task in less time than those using static graphics and text and that there is a low occurrence of errors for students viewing instructional video when compared to reading instructions. Carroll came to the conclusion that the best way of communicating spatial information is by using spatial mediums such as video and not spoken or written mediums.

In another study, Ogunyemi (1997) described the capabilities of video component in an Interactive Videodisc (IVD) delivery system. He stated that one of the advantages of this component is a direct viewing and application of theoretical and practical situations. Ogunyemi furthermore indicated that it is possible to use sequences to demonstrate experiments, illustrate guidelines for use of movement over time and space and also to provide students with study materials and interactivity options. As at present, it is possible to record video in a series of digital pieces in order that it can be edited and developed with the help of computers.

In another study it was found that children at primary level appeared to be more attentive to animations than older persons (Large 1996). Large highlights a number of reasons for these findings, including the complexity of textual information and for the fact that children are more used to viewing animations or moving pictures than older persons and are usually also more fascinated by animations and moving pictures. The other possible reason could be that adults have different learning needs than children do. According to Sleight (1994), children's learning needs reflect their growth patterns; different types of concepts are learned at different ages. Learning is also done for the sake of learning, not to accomplish specific tasks as opposed to adults who have varying levels of expertise and different reasons for learning.

From the above, it seems as if children process graphics differently than adult learners. However, it should be said that this and other factors, e.g. the speed of processing the use of visuals as processes of control and prior knowledge, are in need of continued empirical research.

In his doctoral thesis, Guan (2002) discussed a number of factors including prior knowledge, spatial and reading abilities. Guan claims that prior knowledge is important because it acts as a foundation from which a learner can develop new information and therefore gives the learner the ability to process new information without resorting to pictorial aids.

Kleiman and Dwyer (1999) examined the effect of specific visual skills in facilitating information acquisition. In summary, the authors concluded that (a) specific visual skills are related to academic achievement; (b) the possession of specific visual skills seems to facilitate achievement; (c) the possession of specific visual skills does not facilitate achievement equally well at different levels of educational objectives; (d) colour is confirmed as an important instructional variable for facilitating achievement, at least at the concept level of learning and (e) that the analysis and scoring of visual skills by computer can be effective and efficient. These conclusions were drawn in the context of an experimental study where students were assigned to a 1800-word instructional module describing the human heart. The description included the parts of the heart, their location, function and the internal processes that occur during the systolic and diastolic phases of the heart's operation. The instructional modules were also divided into two categories: (a) those that had colour-enhanced visuals, and (b) those modules that had black and white enhanced visuals.

Culture also appears to influence learning and the understanding of visual instructions. For example, cultural groups such as the Chinese are said to have a tendency to think visually. Cifuentes and Hsieh (2003) reported that this is purely because the Chinese are used to their style of communication in which they use visual

symbols such as logograms, Chinese graphic characters that represent the entire word Meggs and Purvis (2006).

Visual literacy

Visual literacy also has an effect on the value of dynamic and static visuals. The processing and interpretation of visual meaning is a skill that students absolutely need to learn and which makes *visual literacy* a vital skill. In other words, the viewer who is considered to be visually literate should be able to critically look at an image and interpret the meaning of the image (Bamford 2003). Visual literacy skills can be applied equally to any type of image: photographs, paintings and drawings, graphic art (including everything from political cartoons to comic books to illustrations in children's books), films, maps, and various kinds of charts and graphs. All convey information and ideas, and visual literacy allows the viewer to gather the information and ideas contained in an image, place them in context, and determine whether they are valid.

The type of material to be learned

Some researchers consider external representations to be more powerful in teaching when the subject matter is complex (Leung & Pilgrim 1995; Weiss et al., 2002; Lin, Chen & Dwyer 2006), while others see the value of external representations in cases where students are unfamiliar with the concepts displayed (Mckenzie & Danielson 2003). If, according to Large (1996), students already have a mental image of the material, then its value appears to be of less importance.

Method of instruction used to present information

Method of instruction refers to the way in which the material to be learned is presented to the learner. This includes for example, the use of dynamic and static visuals in support of text, in order to identify have a better understanding of the

advantages and disadvantages of a particular system. Research undertaken by ChanLin (2000) supports the hypothesis that various external representations differ in facilitating different learning procedures. ChanLin carried out an experiment using 357 college students to examine the effectiveness of text, static, and animated graphics. The main objective was to determine how these methods could improve learning of different tasks. It was found that the main effect of visual treatment was significant for procedural learning, but not for descriptive learning, indicating that differences in visual treatment (the use of animation, still graphic, and text) were an important concern in procedural learning. Descriptive knowledge refers to knowledge that can be communicated through a detailed description of objects or events. In the learning and application of scientific concepts, it is essential for providing the basic information to be remembered. In contrast to descriptive knowledge, procedural knowledge refers to learning and development of the problem-solving procedures related to the concepts of a particular subject. Learners need to relate rules and facts to formulate a problem solving procedure. For example, in a mathematics subject, steps could be provided to help students construct a problem-solving concept. Comparisons among different visual treatments reveal that animation is better than text for descriptive learning, while still graphics and animation were both better than text for procedural learning. This, according to ChanLin could be attributed to the limitation of the study which focused on a single lesson.

Cognitive Factors

Most of the papers discussed in the preceding paragraphs (Chandler, 1995, 2004; ChanLin 2000; Rieber 2000; & Lewalter 2003) have also shown that learning with external representations has also been associated with the cognitive tasks, particularly if the external representation is new to learners. For example Ainsworth (2006) state

that when learners are first presented with a new representation, they must understand how it encodes information and its relation to the content it represents. Furthermore, learners may need to select or construct one representation which is suitable to them, which can provide advantages, but also new cognitive tasks. In Mayer's (2001) cognitive learning of multimedia learning, which describes as a learner-centered approach, rather than the technology-centered approach normally associated with the concept of multimedia, the human processing information system is twofold: it comprises of channels for pictorial and verbal processing. The capabilities that each channel has for processing information are limited. According to Mayer (2001), meaningful learning occurs when humans select relevant information, organise the information into sound representational structures, and then integrate it with other existing knowledge. Lastly, this information has to be processed in order to understand the content as whole.

Sweller et al. (1998) classified three types of cognitive load: (a) intrinsic, (b) extraneous, and (c) germane. The first, i.e. intrinsic cognitive load, occurs during the interaction between the type of material to be learned and the prior knowledge of the learner. The second type, extraneous cognitive load, is caused by factors that aren't central to the material to be learned, such as external representation used or activities that split attention between multiple sources of information; these should be minimized to the greatest extent possible because they can impose a high extraneous load which is not relevant to learning. The third type of cognitive load, germane cognitive load, enhances learning and results in task resources being devoted to schema acquisition and automation. The point is that the sum of the three kinds of cognitive load adds up to the total load. If intrinsic load is low, germane load may be improved even if extraneous load is high. On the other hand if intrinsic load is high,

adding a heavy extraneous load may exceed the learner's working memory capacity or interfere with learning, because no capacity is left for germane load. Learning can still occur without germane load, but germane load can further enhance learning. Whether a cognitive load is intrinsic or extraneous depends on the learner's expertise and the educational objectives (Schnotz & Kürschner 2007).

Design principles

In their analysis of learning with multiple representations, Ainsworth and Van Labeke (2004) refer to a structure known as DeFT (Design, Functions, Tasks). The term "multiple representations" refer to various methods used to present a concept, such as using illustrations/animations in lectures. According to Ainsworth and Van Labeke, this system suggests that three basic elements are to be considered in order to understand how multiple representations influence learning: (a) the design factors that are important to learning with more than one representation, (b) the functions that various representations can serve in learning, and (c) the cognitive tasks that must be performed by the learner when working with multiple representations.

Wilson and Dwyer (2001) compared the effectiveness of time and level of visual enhancement in facilitating student achievement of different educational objectives. Four visual treatments, namely still graphics, progressive reveal, animation, and animation and progressive reveal were tested among two hundred students. Although the results from this study do not support the idea that the use of animation facilitates learning, Wilson and Dwyer nonetheless put forth a few feasible reasons for the results: Students may not have been well acquainted with the value of animation and therefore were not able to gain any profitable information provided; equal and fair distribution of information to all the four visual treatments and insufficient appliance

of animation which can lead to it not being able to show the necessary levels of information.

Although there are multiple ways of presenting complex concepts and data to students, some authors urge caution with regard to designing dynamic and static visuals for use in learning. For example, Large (1996) advises that designers must consider the realism and stylisation measures in an animation, the duration of the movie, and whether it will be broken into sequences and if so, whether the user will have access in the execution of each sequence. In addition, Weiss et al., (2002) suggest that designers should ask whether animation has the ability to add value to student learning before advancing to the design process.

From the preceding discussion, it can be seen the design and usage of dynamic and static visualisations requires an appreciation of the cognitive mechanisms that underlie complex thought. Those engaged in the teaching of programming, have not only to consider programming knowledge but have also to research into how learners learn. Having identified the variables in visual processing, it is necessary to look to the interaction among, tasks, texts, and the multimedia-based environment.

2.9   THE PROPOSED MODEL

In view of the above, a model can now been constructed to summarise all the issues discussed in the text (see Figure 1 on page). The model consists of five factors that are crucial for the facilitating effect of external representations: (1) Subject characteristics; (2) cognitive factors; (3) design factors; (4) type of material to be learned and (5) the functions that various external representations can offer in supporting comprehension. All of these factors interact to make a whole or comprehensive facilitative effect.

This model of the facilitating effect of external representations is presented in Figure 1 in the next page
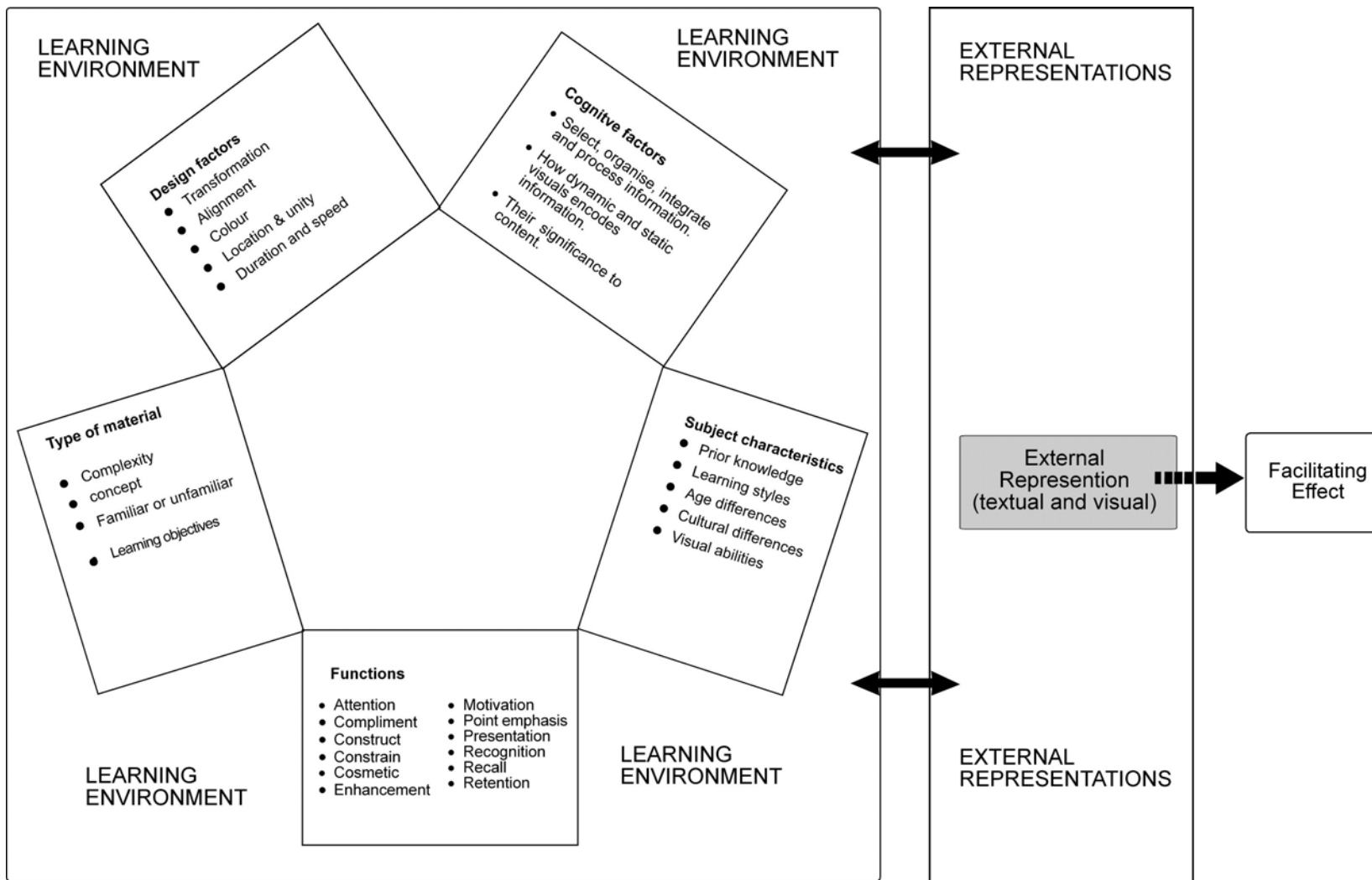
Figure 1. A graphic representation of factors that may influence the facilitating effect of external representations in a learning environment. The 5 squares represent the interdependence of each of these factors. These factors interact with external representations that may or may not produce facilitating effect.

2.10   DISCUSSION

In this paper, some of the findings on the use of dynamic and static visuals in learning have been presented by reference to other studies. The focus was on one specific question within a general framework of learning with dynamic and static visuals. As most of the information currently is presented in the form of text, images or multimedia instructions, the question was about the value of dynamic and static visuals in a learning environment. Some of the research findings identify the principles by which we can combine these representations effectively within instructional materials to their full potential for learning. These principles have been acknowledged and should be regarded as a guideline that can be used to identify the value of dynamic and static graphics in a learning environment. More factors could be identified according to the specific needs and requirements of a particular learning content. For instance, it seems as if the type of visualisation used in a particular content, affects the structure of the internal mental model constructed during learning, which in turn can influence the learning outcomes that individuals show after learning.

It is clear that using dynamic and static visuals to improve understanding, has its advantages and disadvantages. What is clear is that there are conditions in which both can be helpful and also not helpful due to distractibility effects (Mayer 2003) or poorly designed visuals (Pramono 2005). This is also confirmed by research conducted by Rieber (2000) in which he claims that the conditions in which pictures can aid learning need to be considered and are the first principle of instructional learning.

In addition to the above, it can also be seen that, in order to develop our understanding of how dynamic and static visuals can be best used in the educational environment

and how the educational process itself must adapt to the availability of new advances in technology, we need to know, for example, how students with both low and high prior knowledge learn from dynamic and static visuals. More focus must be directed on the material that is to be learned in a given situation and the intellectual abilities, more especially the internal mental models that learners bring to the situation. These are some of the factors that are considered to be impacting on the effectiveness of dynamic and static visuals.

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CHAPTER 3: CAN ANIMATION BE USED TO IMPROVE COMPREHENSION OF INSTRUCTIONAL TEXT?

3.1   INTRODUCTION

The preceding chapter reviewed a number of studies that are concerned with the effects of dynamic and static visuals in various presentation environments were reviewed. Some scholars reported that dynamic information may assist students to comprehend instructional text, specifically if the instructional material is of an explanatory nature (Head 1998; Nowaczyk, Santos & Patton 1998; ChanLin 1998). Other scholars reported that they found no difference in subjects' comprehension of instructional text when different presentation mediums were used (Mayer & Moreno 2001; Tversky, Morrison & Betrancourt 2002; Van Schaik & Ling, 2004). Rieber (2000) summarised some of the research findings from between the early 1970's to the late 1980's which relate to pictures as an aid to learning. His main focus was on the outcomes of static and animated graphics on learning. What is clear from the review of the static visuals is that there has been a shift from early research, which suggested negative effects, such as distractibility on the use of static graphics as an aid to learning, to more recent research which proposes circumstances to be considered in order for static graphics to aid learning. The subjects' prior knowledge, the content of the instructional material and the testing method are but some of the variables that can determine if graphic media can increase a subject's comprehension and if such comprehension can be accurately measured.

Based on the literature review, an experiment was conducted in order to further elaborate on the effect of dynamic and static visuals in relation to learning content. The availability of new software programs makes it comparatively easier to develop

visual learning aids, such as animations. Animation can be used in a variety of ways such as in attention-gaining strategies, emphasising a point and also to assist learners to understand a complex process. For example, Handal, Leiner, Gonzalez and Rogel (1999) examined the benefits of linear multimedia to enhance students' ability to comprehend a complex subject such as physics or chemistry. For the purpose of this discussion, the complexity of a subject can be described in terms of the solution procedures and the tools used to perform the tasks. For example, some calculations in subjects like physics or mathematics could be simple if the learner is provided with a mathematical formula to do the job. However, these calculations may be too complex for a person with little knowledge about how to do them (see Scheiter, Gerjets & Catrambone 2004). The aim of the study by Handal et al. (1994) was to prepare educational material for educators which could be used to improve and promote positive learning in sciences. They found that students appeared to be more attentive to the animated material than the written material. However, some research e.g. that of Mayer & Moreno 2002; Tversky, Morrison & Betrancourt 2002; Van Schaik & Ling 2004; Lai 1998) has found that there are cases in which static visuals can be as effective as dynamic visuals. A study by Lin, Chen and Dwyer (2006) compared the effects of using static visuals against computer-generated animation to improve learners' understanding and retention for learning English as a foreign language (EFL). Their results showed that the understanding of subject matter is dependent on specific and limited conditions. The superiority of animation over static visuals was only realised when the educational objectives were to produce lower level learning outcomes such as factual knowledge. They also found static graphics to be as effective as animation in presenting more complex tasks.

As Lowe (2004) has stated, one thing that might help to improve educational effectiveness of animations is research into how people learn from animations. A key issue is how a learner's information processing load can be kept within the boundaries of available processing capacity while making sure that what is provided remains highly relevant to the learning task (Schnotz & Kürschner 2007).

One of the intentions of this paper was to investigate the effect of prior knowledge in learning with visual representations. In his doctoral thesis, Guan (2002) claims that prior knowledge is the basis from which a learner can develop new information and would therefore be able to process new information without resorting to pictorial aids. Research undertaken by ChanLin (1998) supports the hypothesis that the effectiveness of different presentation techniques is linked to the primary knowledge of students and that these techniques differ in facilitating different learning procedures. The experiment was carried out using 130 college students to examine the effectiveness of non-graphic presentations, stills, and animated graphics. The main objective was to determine what the results would be when using the same visual method to present information to students with different prior knowledge levels (experienced and inexperienced students), and how these methods could improve learning of different tasks. It was found that still and animated graphics were helpful in learning for both experienced and inexperienced learners. It was also concluded that the usefulness of visual design is related to the prior knowledge of the students in learning procedural and descriptive text. Ollerenshaw, Aidman and Kidd (1997) examined the factors prior knowledge and learning styles under different conditions of textual learning. Findings from this research indicate that text learning can be influenced by prior knowledge and learning styles. Multimedia instructions such as animation were found

to be helpful to learners with little prior knowledge and no difference was found for experienced learners.

3.2 THE AIM OF THE PAPER

This paper aims to determine if the animation of a linear process, requiring explanatory text, can assist students to comprehend the process better. Considering some of the advantages of animation, such as the addition of movement to gain attention (ChanLin 1998; Rieber 2000), it was hypothesised that the group who received the animation and text treatment can comprehend the linear process better than the control group (text only) and the other two groups (text and illustration; text and video). The question that was asked to explore this comparison therefore was: "Can animation be used to improve comprehension of instructional text?" The author used a quasi pre-test, post-test experimental design to test the hypothesis.

3.3 METHOD

Subjects

The participants for the study were registered students from the Central University of Technology, Free State. The students were selected from the following programmes: Electrical and Mechanical Engineering, Graphic Design, Information Technology, and Language Practice. The participation was voluntary and was not based on any reward. This is believed to be some of the reasons why some the participants withdrew from the experiment. The other reason could also have been the time allocated to conduct both the pre-test and the post-test. The post-test took place two weeks after the pre-test. Initially there were 122 students who volunteered and participated in the pre-test. Out of the 122 that initially participated in the pre-test, (n = 61) students participated

in a post-test during which they were exposed to 4 treatment variables: text (T), video and text (VT), illustration and text (IT), and animation and text (AT). The participants' ages ranged from 15 – 30. Among them, 37 were male and 24 were female.

<u>Instructional Material</u>

The instructional material for the pre-test and the post-test was developed by the author. With the input of an instructional designer, the material and questionnaires for the experiment were presented via WebCT. The material for the pre-test was composed of text information (365 words) describing the steps in the construction of a pinhole camera. This was also supplemented by a labelled picture of a pinhole camera, demonstrating these steps. The purpose of the pre-test was to determine each participant's knowledge level of the technical process in order to divide the subjects into various groups. For the post-test, the conveyor belt system was chosen as the subject domain, because it is a complex automated linear mechanical process in which items are transported on a conveyer belt, scanned, recognised, sorted and removed from the belt. The author regarded the demonstration of these steps to require a strong visual representation such as animation, because one of the advantages of animation is that it provides a better match between the subject matter and its representation due to its capacity to represent the dynamics explicitly (Lowe 2001). This was also done in line with the recommendations by some of the researchers who found animation to be more helpful in learning when the subject is more complex (Handal et al. 1999; Weiss, Knowlton and Morrison 2002). Subjects also received explanatory text describing the operation of the conveyor belt system. The text content and layout was identical in all 4 treatments. The illustration, the video and the illustrated animation complemented the text and illustrated the process as explained in the text.

A pilot study was also conducted using the instructional material described above in order to subsequently develop the final material for the experiment. The equipment and the outcomes of the pilot study were administered as a test to volunteers who are students at the Central University of Technology, Free State. For the sake of clarity, the purpose of the pilot study was to identify problem areas within the WebCT that participants may experience during the process. The only problem that was identified and rectified, was the process whereby some participants could not log in as they were not registered before the experiment. The participants for the pilot study were recruited from the same subject group as for the formal study, but did not participate in the formal study. Participants were given indefinite time to read over the instructional material and then completed a multiple-choice comprehension test as in the formal study.

Treatments

The pre-test, post-test experimental design was employed to the following treatments:

(a) Text-only group: In this treatment, the content was text alone, describing all the stages in the operation of the conveyor belt system, starting from the beginning where they are placed on the system through to the point where they are removed from the system.

(b) Animation and text: In this treatment, the text was accompanied by a thirty-two second animated picture of the conveyor belt, developed with *3D Studio Max*. This animated picture was intended to promote understanding by demonstrating the flow of all the elements of the system (conveyor belt) as described in the text.
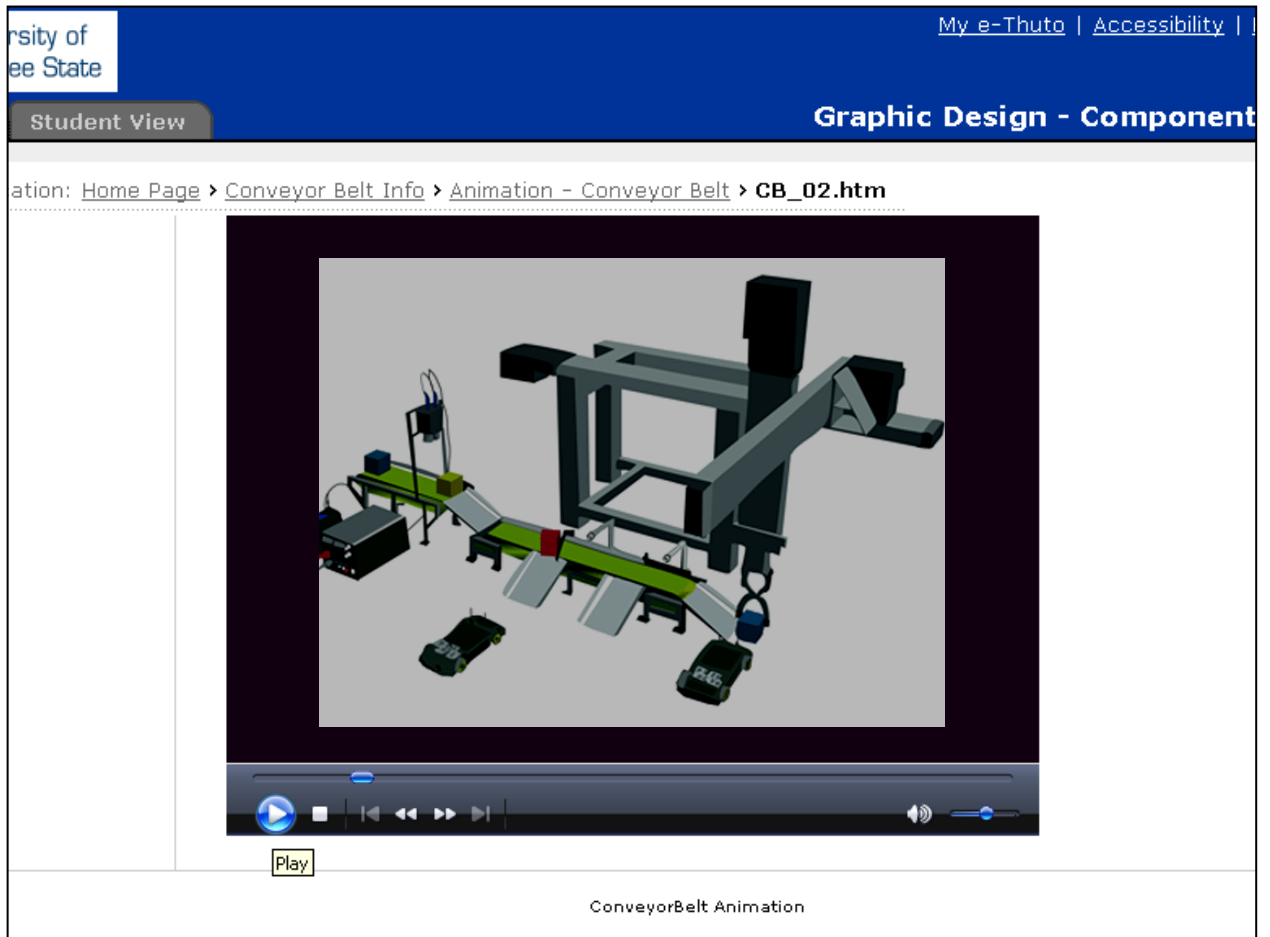
Figure 2.
A sample screen shot of the animation treatment. (Learners were able to see the flow of the elements of the conveyor belt system in this treatment).

(c) Video and text: A thirty-two minute video clip featuring the same item as in the animation group with text. This video clip was captured with a video camera in a studio where the actual conveyor belt was placed. A series of shots were taken, edited and combined into a single video clip.

Figure 3.
A sample screen shot of the static picture of the conveyor belt

(d) Illustration and text: In this treatment, the same picture used in the animation and text group was re-drawn with *Macromedia Freehand* to create a static picture of the conveyor belt. There was no audio for either of the treatments.

Although the animation and video clips were both thirty-two seconds long, the time spent observing the animation, video, text and respective static illustration was equated so that the participant could not move to the next session until the minimum allotted time had passed.

<u>Procedure</u>

The experiment consisted of two sessions: a pre-test and post-test. Both the pre-test and the post-test were conducted in various computer labs. In the pre-test session, subjects were randomly assigned to computer stations, in which all the material for the pre-test was programmed. Using one of the computers together with a projector, the author demonstrated the procedure of this session on the screen to all the participants for 8 minutes, after which they were allowed to carry out the procedure on their own. All students had experience of using the WebCT. As registered senior students, they make use of the WebCT in their respective programmes. The first part of the session was to complete their demographic information (gender and age status) in order to keep the learning process as equal as possible, i.e. equal male and female populations. After this part, participants were instructed to read the text information and view a static picture of a pinhole camera. Each student then clicked the "next" button to continue to the next part where they could do the assessment test based on what they have read in the previous page containing only textual information. Once they were in the assessment page, they could not go back to the previous pages. The whole process took approximately 45 minutes. The results of the pre-test were used to systematically divide the participants into 4 treatment groups for the post-test which took place 2 weeks later. This was done in order to obtain greater equivalence between the groups. The procedure for the post-test was similar to the pre-test, except that students were assigned to one of the four various treatments based on their attainment in the pre-test, i.e. participants with high and low scores respectively in the pre-test were evenly assigned to the four treatments.

Assessment measures

The study measured the following dependant variables: (a) subjects' prior knowledge and (b) subjects' level of comprehension. Two assessment measures were used in this study: Scores attained on the pre-test and the result of the post-test. The questions for the pre-test consisted of 7 multiple-choice questions that were used to measure students' comprehension of the pinhole camera. This text information was developed from a number of sources from the web. The questions for the post-test consisted of 10 multiple-choice questions. The test item measured students' level of comprehension of the operation of the conveyor belt system. Upon completing the test by answering all questions, subjects submitted their answers electronically on the WebCT.

3.4   RESULTS

The means of the different groups ranged from 37% to 48% and were compared with a one-way analysis of variance (ANOVA). No significant difference was found between the mean differences of the 4 groups (p = 0.36; Critical F value = 2.76; level of significance= 0.05). The means are summarised in table 2.

Table 2.
The results of the post-test

Treatment Groups	n	Means
Control	14	3.78
Static	17	3.88
Video	14	4.5
Animation	16	4.8

3.5   DISCUSSION

The question *Can animation be used to improve comprehension of instructional text?* was not satisfactorily answered. The lack of improvement for the animated and text group can possibly be explained in terms of the following attributes:

Distractibility

Rieber's (2000) behavioural and cognitive learning theories suggest that there are times when visuals can aid learning and times when they might interfere with learning. The behavioural theory suggests that a distraction might occur where students are unable to shift their attention from a given graphic to text. In the current study, the distractibility might have occurred, where some students may not have been able to associate the text with the animated video clip that was used. Schaik and Ling (2004) also do not recommend the use of dynamic graphics in web page designs because they claim that users may experience increased distraction by dynamic graphics, as compared to the static graphics.

The type of subject matter used for the study

The apparent difficulty of the material used in the study could also be one of the reasons for lack of improvement concerning the animated and text group. It was hoped that, due to the complexity of the subject domain, animation could assist students to improve their understanding of unfamiliar terms that were used in the text. But instead, this seems to have distracted them or does not seem to have made any difference. This is in contrast with what some of the researchers have found with regard to the advantage that animation has over other visuals. For example, some researchers consider animation to be more powerful in teaching when the subject matter is complex (Handal et al. 1999; Weiss, et al. 2002), while others see the value of animation in cases where students are unfamiliar with the concepts displayed.

According to Large (1996), if students already have a mental image of the material, then the value of animation value appears to be of less significance. In light of Large's results, subsequent research is needed to examine what the outcome would be, if the same visual methods (used in the current study), are presented to students with different prior knowledge levels, i.e. those who are familiar and those unfamiliar with the subject matter presented.

Small number of the subjects

This is relevant to the findings of Nah, Guru and Hain (2000) in which they stated that small statistical power of a particular study may also have effect on the outcome of an experiment. Future research will therefore be carried out with a bigger sample size to assess the effect of animation and text on the proposed dependant variables.

The results also seem to be similar to the existing literature (Tversky and Morrison 2002) that questions the advantage that dynamic visuals may have over static visuals and also on the use of dynamic visuals on the web, particularly because animations are believed to be comparatively expensive and time-consuming to produce (Rieber 2000). For example, Nah, et al. (2002), examined the effect of hypertext and animation in the context of online learning. Their study was based on the following hypotheses: (a) Hypertext reduces the challenges of learning in that it provides the users with solutions to, or clarification on a particular subject, but while the challenges are reduced, the skills, focused attention and flow of learning are increased; (b) animation reduces challenges of learning, since the learning content is made easier through the use of animation. Animation, however, also enhances skills, focused attention, flow and effectiveness of learning. In the study of Nah, et al. (2002), none of their hypotheses are supported by their findings. Nah, et al. (2002) report that hypertext has a negative impact on the dependant variables, while

animation did not show any noteworthy impact on the dependant variables. This implies that static visuals may also be a valuable aid to learning, especially because they are more cost-efficient than dynamic visuals.

The findings of this study have given rise to the following suggestions: The hypothesis that text, together with animated design may improve comprehension of a scientific process more than text alone, or text and video and static illustrations combined with text is not supported by the results of this study. This result can be interpreted as an example of the equality of effectiveness of dynamic and static visuals in supporting instructional text. This means that there are some areas where dynamic visuals can be used and other areas where pictures and other static visuals are more appropriate. Further research examining the students' cultural background, visual literacy of various audiences (including low educated audiences) learning styles and design factors may also be considered when exploring the use of animation in support of text.

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CHAPTER 4

CONCLUSION, RECOMMENDATIONS AND SUMMARY

4.1 CONCLUSION

One of the reasons for using external representations, such as dynamic and static visuals to present educational information, is that external representations are generally thought to improve learning, (Lai 1998; Schnotz 2002; Suwa & Tversky 2002; Hibbing & Rankin-Ericksson 2003; Mayer 2003). The aim of this study was to examine the value of dynamic and static visuals and to explore the conditions under which dynamic and static visuals can be used to achieve meaningful learning. It was also hypothesised that using a dynamic visual to present educational information, could improve comprehension of a scientific linear process. The questions that the study intended to answer were:

To what extent do external representations as developed by graphic software programmes improve or do not improve comprehension?

New information technology offers dynamic and increasingly visual ways of presenting information (Scaife & Rogers 1996; Ainsworth & Van Labeke 2004; Rasch & Schnotz 2009). Problems still exist, however, and not every visual method reaches its intended audience. In this study, the use of external representations is considered from the perspective of the day-to-day practice of academic visualisation research. The study began by reviewing the literature concerning the effects of external representations on students' comprehension. Despite the general assumption concerning the advantage of dynamic over static visualisation (ChanLin 2000; Rieber 2000), the results of the literature review indicated that dynamic visual with text can have essentially the same effect on students' understanding of a particular process as

static visual with text. When looking closely at characteristics of both types of visuals, it seems as if there are some areas where dynamic visuals can be used (ChanLin 2000; Narayanan & Hegarty 2002; Ainsworth & Van Labeke, 2004; Bodemer et al., 2004), and other areas where pictures and other static visuals are more appropriate (Lai 1998; Hibbing & Rankin-Erickson 2003; Mayer 2003; Carney & Levin 2002). Therefore, various types of external representations combined with text have varying functions and can help create a "mental model" (Mayer 2003), rather than simply receiving or absorbing knowledge (Mayer 1989; Suwa & Tversky 2002; Hibbing & Rankin-Erickson 2003). The review found that the subjects' prior knowledge (ChanLin 1998; Guan 2002), the content of the instructional material (Leung & Pilgrim 1995; Weiss et al. 2002; Lin, Chen & Dwyer 2006), and the testing method (Lowe 1999; ChanLin 2000;) are but some of the variables that can determine if an external representation can increase a subject's comprehension and if such comprehension can be accurately measured. Based on these principles, this paper outlined some of the advantages and disadvantages of both kinds of visualisations. These advantages and disadvantages are given in Table 1 on pages 22 - 24.

The results of the review suggest that the following affect comprehensibility of external representations:

1. Learner characteristics? (Prior knowledge, their age, socio-economic background, educational level.)

2. What is the content and difficulty of the material?

3. How much are they learning? Is it long, short, brief, extensive?

4. Why are they reading? To learn, for pleasure or for business?

This study also developed an animation for a specific learning task in order to test the hypothesis that this external representation could improve the comprehension of a linear scientific process. The question that was asked to explore this matter therefore was:

Can animation be used to improve comprehension of instructional text?

The availability of software programs such as *Adobe Flash*, *3-D Studio Max* and *3-D Maya* makes it comparatively easier to develop visual learning aids, such as animations. The aim of the empirical part of this study was to determine if the animation of a linear process, requiring explanatory text, can assist students to comprehend the process better. Tertiary students ($N = 61$) participated in a pre-test, post-test experimental study during which they were exposed to 4 treatment variables: text (T), video and text (VT), illustration and text (IT), and animation and text (AT). It was hypothesized that the group who received the animation and text treatment would comprehend a linear scientific process better than the control group (text only) and the other two groups (text and illustration; text and video). The study did not find sufficient evidence to support the hypothesis. A number of factors might have contributed to the non-significant results. One possible reason is that all methods of successive presentation were not examined. For example, Baggett (1984) found that including speech slightly after corresponding visual sequences, resulted in performance on a recall test that was just as good as performance with simultaneous presentation of speech and visual information. Ozcelik, Karakus, Kursun and Cagiltay (2009) did an investigation on the primary cause of the colour-coding effect by utilising eye movement data. Their results indicate that colour-coding increased retention and transfer performance. Enhancement of learning by colour-coding was due to efficiency of locating corresponding information between illustration and text.

Kozma (1991) reviewed research on learning with different media, e.g. books, video, computers, and multimedia environments. He suggests that various aspects of the learning process are influenced by the cognitively relevant characteristics of media, for example, it is a significant attribute of video that the auditory and visual symbol systems are presented simultaneously. In light of the above results, subsequent research could include colour in pictures or concurrent display of visual, textual and auditory information. There are other aspects that might not have been investigated but whose investigation might stimulate new thoughts and provide new insight. Some of them might have already been mentioned in the discussion, for instance, sample size, cultural factors, selection of the subjects, selection of the variables (choosing dependent variables that are based on a valid measurement).

This study has presented a number of studies that explored the instructional value of external representations in a learning environment. Two key conclusions can be drawn from the observations made in these studies. The proper design of a particular external representation and supporting text, can promote relevant activities that ultimately contribute to fuller understanding of the content. This is in line with Mayer's (2003); Hibbing and Rankin-Erickson's (2003) findings: that pictures are important aids for building internal mental models. Furthermore, this brings up a very interesting issue that care must be taken to design instruction in such a way that it correlates with the type of material as to not overload the mind's capacity for processing information. The focus must be on the concepts to be learned, rather than applying too much cosmetic activities.

Second, external representations must be developed to address the size, complexity, and variety of the content that must be analysed in order to extract knowledge for scientific discovery.

4.2   RECOMMENDATIONS FOR FUTURE RESEARCH

This study reviewed fourty-five studies about learning with dynamic and static visuals. Some of these are about temperature changes in weather map (Lowe, 2003), the function of the human heart (Kleiman & Dwyer 1999), understanding and retention of languages (Lin, et al., 2006), population dynamics (Ainsworth & Van Labeke 2004), how mechanical systems work (Bodemer et al., 2004), and statistical concepts (Bodemer et al., 2004). These papers indicate that both dynamic and static visualisations have much to offer as learning tools. However, it should be noted that badly designed external representations (be it static or dynamic) can interfere with learning. For instance, Rieber's (2000) behavioural theory suggests that this interference might occur where students are unable to shift their attention from a given graphic to text. In addition, some authors have also stated that the use of external representations such as dynamic visuals can impose a high working memory and that they are always not easy to understand (Hegarty 2004; Lowe 2004).

From the study, it can be seen that in order to understand how external representations can effectively be used in learning, extensive research and reflection is required. Understanding of these factors would then guide practice. This study recommended that further research be conducted in the learning environment regarding external representation. This research could be replicated using a larger sample size and should include subjects with varying levels of education, verbal and visual literacy.

The study also highlighted that dynamic and static visuals can interfere with learning and that several factors, apart from the visuals, contribute to a facilitating or and interference effect. Some of the areas that the study did not look at, are the learning styles of the students, the cultural factors, the attentive value, recall, to mention but just a few. The literature review and the results of the empirical research study support the following recommendations for teaching with external representation. Instructional designers and educators using external representations into their programmes should:

1. Consider the relationship between the external representation and how it relates to the content of the learning material.

2. Analyse the students' learning styles and how this affects the potential facilitating effect of an external representation.

3. Consider the effect of graphic cueing tools such as arrows, shading techniques, as an aid to improve comprehension of learning material.

4. Consider visual abilities of the students. External representations can play major roles in addressing some of the factors that characterize disadvantaged context. However, the ability to which students can benefit from these representations is to some extend related to their level of visual abilities.

4.2 SUMMARY OF THE STUDY

This section provides an outline of all the work done in this dissertation. This dissertation was divided into four chapters. A two journal article format was used for the dissertation. The first article, (Chapter 2) was a review of the literature, the theoretical background to the research topic. The second article, (Chapter 3) was accepted for publication by the *South African Journal of Higher Education* (SAJHE)

in 2009 and reported on an experimental study on using dynamic and static visuals. The Bibliographies are also provided at the end each of these two chapters as they were meant to be sent to different journals. The Bibliography at the end of the dissertation is a combination of all the references from these two articles as well as the first chapter.

Chapter 1 presents the introduction, problem, the purpose, the method and defines the terms and concepts. It seems as if there has been considerable interest in developing external representations that enhance learning tasks of students in various courses. One reason for this interest is that using external representations, such as dynamic and static visuals to present educational information, is generally thought to improve learning. However, to take advantage of external representations to improve learning, we need to understand why external representations may help people to learn. In view of understanding how technology can be used to aid the learning process, it seems useful to look at the effects that different external representations, may have on learner performance during the learning process.

Chapter 2, focused on a review of studies regarding learning with text, dynamic and static visuals, and examined the conditions under which external representations facilitate learning. The aim with this review, was to extract specific conditions in which a particular external representation is appropriate or inappropriate, and also if the implementation of several external representations conflict with or cancel out the effects of one another. The question that was used to examine these attributes was: To what extent can external representations such as animation as developed by graphic software programs, improve comprehension of a scientific process?

Five general factors were identified that influence the facilitating effect of external representations in a learning environment. These factors have been acknowledged and should be regarded as a guideline that can be used to identify the value of dynamic and static graphics in a learning environment. More factors could be identified according to the specific needs and requirements of a particular learning content. These factors are: (1) the type of material to be learned, (2) subject characteristics, (3) design factors, (4) cognitive factors, and (5) the functions that various external representations offer in supporting comprehension. All of these factors interact to create a facilitative effect. The factors are fully discussed in section 2.9 and represented by a model (Figure 1, page 40) to suggest how external representations can be used in a learning environment.

Chapter 3 reported on an experiment which was conducted to investigate the effectiveness of dynamic and static visuals in learning. The aim of this experiment was to determine if the animation of a linear process, requiring explanatory text, can assist students to comprehend the process better. The study used a pre-test, post-test experimental design, to test the hypothesis that a group of learners who received a dynamic visual and text treatment will comprehend a linear process better than the control group (text only) and the other two groups (text and illustration; text and video). The question that was asked to explore this comparison therefore was: Can animation be used to improve comprehension of instructional text?

No significant difference was found between the mean differences of the 4 groups ($p = 0.36$; Critical F value = 2.76; level of significance= 0.05). The results are given in section 3.4 in table 2.

These results are similar to the results of other researchers Tversky, Morrison and Betrancourt (2002) that questions the advantage that dynamic visuals has over static visuals and also on the use of dynamic visuals on the web, particularly because animations are believed to be comparatively expensive and time-consuming to generate (Rieber 2000). The findings of this study suggest that there are some areas where dynamic visuals such as animation can be used and other areas where pictures and other static visuals are more appropriate. It is further suggested that the subjects' prior knowledge, cultural background, the content of the instructional material and the testing method should be considered when exploring the use of external representations as they are some of the variables that can determine if graphic medium can increase a subject's comprehension and if such comprehension can be accurately measured.

Chapter 4 presented the conclusion, recommendations and summary of the study. The conclusion was drawn from both the literature review and the empirical work while the summary provided an outline of the dissertation.

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APPENDICES
(Annexure to chapter 3)

Appendix A: *Correspondence with the editor*

Moremoholo Patrick

From:	Pieter duToit [Pieter.duToit@up.ac.za]
Sent:	Monday, March 12, 2007 12:07 PM
To:	Moremoholo Patrick
Subject:	Re: Submission of Proposal
Attachments:	SAARDHE Abstract Form Deadline 17 March.doc; SAARDHE Conference July 2007 Second Call for Papers_1.doc

SAARDHE Abstract   SAARDHE
Form Deadline...   nference July 2007 !

No Problem

We have extended the date till Monday the 19th

Please use the attached format and send it to saardhe@up.ac.za

Looking forward to having you at our campus. Bring your colleagues along.....

>>> "Patrick Moremoholo" <tmoremo@cut.ac.za> 2007/03/09 05:11 PM >>>
Dear Dr. Du Toit

I am a Junior Lecturer at the Central University of Technology, Free State. I am doing a
research (at the level of Masters) where I am investigating the value of various
instructional graphic methods, e.g.
animation, in an educational environment. I was browsing through your website and realized
that I have missed the deadline for submitting my proposals for this year's Conference. Is
there a chance for late submissions? I would very much like to present my paper in this
conference as I have just completed the empirical component of this research. Please let
me know if it is possible so that I can send my proposal immediately.

Looking forward to hearing from you.

Kind Regards

Patrick Moremoholo

Junior Lecturer (Graphic Design Programme, CUT, FS)

This e-mail is subjected to the disclaimer that can be viewed at:
* http://www.cut.ac.za/www/disclaimer/email_disclaimer

85

Appendix A: *Continued*

Moremoholo Patrick

From:	Pieter duToit [Pieter.duToit@up.ac.za]
Sent:	Friday, March 23, 2007 12:04 PM
To:	Moremoholo Patrick
Subject:	Re: FW:

Thanks

I have forwarded it to the office

pieter

>>> "Patrick Moremoholo" <tmoremo@cut.ac.za> 2007/03/23 09:43 AM >>>

From: Moremoholo Patrick
Sent: Friday, March 16, 2007 5:17 PM
To: 'pieter.dutoit@up.ac.za'
Subject:

Dear Dr. Du Toit,

I would like to thank you for giving me the opportunity to submit my proposal for this year's Conference. Please find my documents attached as per the requirements. I am looking for the opportunity to present my paper and hope to see you then.

Thank you

T.P. Moremoholo

This e-mail is subjected to the disclaimer that can be viewed at:
* http://www.cut.ac.za/www/disclaimer/email_disclaimer

Appendix A: *Continued*

that will be fine. I expect that we might do an announcement at the conference in this
regard - extending the final day for submission......

>>> "Patrick Moremoholo" <tmoremo@cut.ac.za> 2007/06/29 10:23 AM >>>
Dear Dr. Du Toit,

I would like to have my paper reviewed for publication in the special conference edition
of SAJHE but my paper is currently submitted for proof reading. Is it possible that I can
email it to you a few days after the conference? Probably Thursday or Friday next week*

Thank you

Patrick Moremoholo

Graphic Design Programme (CUT, FS)

This e-mail is subjected to the disclaimer that can be viewed at:
* http://www.cut.ac.za/www/disclaimer/email_disclaimer

Appendix A: *Continued*

Appendix A: *Continued*

Moremoholo Patrick

From:	Schmidt, Veronica <vs1@sun.ac.za> [VS1@sun.ac.za]
Sent:	Friday, July 11, 2008 2:40 PM
To:	CJ Gerda Bender; emb2@sun.ac.za; Terri Grant; Loots, AGJ, Dr <aloots@sun.ac.za>; mbushney@unisa.ac.za; annemarie.hattingh@up.ac.za; jmotaung@hsrc.ac.za; potterc@umthombo.wits.ac.za; tlhoaelemj@tut.ac.za; vanryneveld@tut.ac.za; cn.vdwesthuizen@gk.up.ac.za
Cc:	Pieter duToit; Waghid, Yusef <yw@sun.ac.za>; Scholtz, Gerda
Subject:	SAARDHE CONFERENCE ARTICLES
Attachments:	ONLINE SUBMITTING OF ARTICLE.doc

Dear authors

1. Will you all please register on the hhtp;//sajhe.org.za website as user. This is necessary for us to do the processing of this special volume.
2. On the website you will find direction how to upload your articles. Please upload the REVISED/CORRECTED article.
3. Very important. After the title of your article please type (SAARDHE). If you do not do so your article will get lost amongst all the others.
4. Please do the above before 21 July. This is the last date that we can forward your articles to the technical editor. If we do not do so another volume will be published before yours.
5. Attached you will also find step by step instructions for uploading.

Regards

Veronica Schmidt
South African Journal of Higher Education
Faculty of Education
Stellenbosch University
Private Bag X1
Matieland 7602
Tel: 021-8082419
Fax: 021-8082283
Email: vs1@sun.ac.za

Appendix A: *Continued*

18 June 2008

Dear Author

CONTRIBUTION TO THE (SAARDHE) SPECIAL ISSUE

Initially it was planned to publish the (SAARDHE) special issue by the end of 2007. However, unforeseen circumstances have crippled the process. I apologise for the delay.

Your paper "Can animation be used to improve comprehension of instructional text?" has been reviewed. It gives me great pleasure to inform you that it has been accepted for publication in the special issue later this year (22(4) or 22(5)). The feedback in general is quite positive.

The minor editorial errors will be taken care of on your behalf.

Some of the comments received:

> *I think that this paper is relatively easier to understand and examines an important dimension in teaching and learning in higher education. It examines the effectiveness of using text and animation as a medium of instruction and concludes that animation may not be the solution as it may result in distraction of attention from the core learning issues of an area. I recommend the article for publication after revision of minor English errors ..... Otherwise the conclusions reached are legitimate on the basis of the experiment that was done.*

You will be expected to pay the page fees that will be due. You will be informed regarding this by the SAJHE administration office and invoiced accordingly.

Dr Pieter H du Toit
Guest Editor

Tel: 012 4202817
Fax: 012 4203003
E mail: pieter.dutoit@up.ac.za

Appendix A: *Continued*

Central University of
Technology, Free State

20 June 2008

Dear Dr. Du Toit

RE-CONTRIBUTION TO THE SAARDHE SPECIAL ISSUE

I acknowledge receipt of your letter (18 June 2008) notifying me for the acceptance of my paper "Can animation be used to improve comprehension of instructional text?" for publication. Thank you very much for your intensive editing work and your comments...your job is highly appreciated. As a young researcher, this to me is an encouragement which I can build from.

Could I also request you to include my Supervisor as the second Author:

Dr. Rudi W. De Lange

Central University of Technology, Free State
School of Design Technology and Visual Art
E-mail: rudi@cut.ac.za

Thank you once again for considering my work and am looking forward to hearing from you soon.

Yours Faithfully

T. P. Moremoholo

Appendix A: *Continued*

From:	Pieter duToit [Pieter.duToit@up.ac.za]
Sent:	Monday, June 23, 2008 1:53 PM
To:	Moremoholo Patrick
Subject:	Re: SAARDHE SPECIAL ISSUE

I need to go back to the SAARDHE programme.....

was your supervisor included as co-author initially?

>>> "Patrick Moremoholo" <tmoremo@cut.ac.za> 2008/06/20 05:02 PM >>>
Dr. Du Toit.

Please see the attached file for your attention.

Regards

Patrick Moremoholo

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* http://www.cut.ac.za/www/disclaimer/email_disclaimer

Appendix B: *SAJHE Vol 22 No. 6 (2008) – Table of Contents*

South African Journal of

Higher Education

Vol 22 No 6 2008

Special Edition (SAARDHE International Conference 2007)

Contents

Appendix B: *Continued*

Appendix C: *First Page of the published paper*

Can animation be used to improve comprehension of instructional text?

T. P. Moremoholo
Central University of Technology, Free State
School of Design Technology and Visual Art
South Africa
e-mail: tmoremo@cut.ac.za

Abstract

The aim of the study was to determine whether the animation of a linear process, requiring explanatory text, can assist students to form a better understanding of the text. Tertiary students ($N = 61$) participated in a pre-test, post-test experimental study during which they were exposed to 4 treatment variables: text (T), video and text (VT), illustration and text (IT), and animation and text (AT) were explored. It was hypothesised that the group who received the animation and text treatment will comprehend the linear process better than the control group (text only) and the other two groups (text and illustration; text and video). The illustration, the video and the illustrated animation complimented the text and illustrated the process during which items were transported, scanned, recognised, sorted and removed from a conveyor belt. The results indicated that no significant differences in achievement existed among the treatment groups.

INTRODUCTION

Several studies have been conducted to investigate the use of dynamic and static visuals in various presentation environments. Some scholars reported that animated information may assist students to comprehend instructional text, specifically if the instructional material is of an explanatory nature (Head 1998; Nowaczyk, Santos and Patton 1998; Chan Lin 1998). Other scholars reported that they found no difference in subjects' comprehension of instructional text when different presentation mediums are used (Mayer and Moreno 2001; Tversky and Morrison 2002; Van Schaik and Ling 2004). Rieber (2000) summarised some of the research findings from between the early 1970s to the late 1980s which relate to pictures as an aid to learning. His main focus was on the outcomes of static and animated graphics on learning. What is clear from the review of the static visuals is that there has been a shift from early research, which suggested negative effects such as distractibility on the use of static graphics as an aid to learning, to more recent research which proposes circumstances to be considered in order for static graphics to aid learning. The subjects' prior knowledge, the content of the instructional material and the testing method are but