Learning Through Multimedia: The roles of Prior Knowledge and Approaches to Learning

by

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The effects of text-supplementing illustrations have been generally well established (Mayer, Bove, Bryman, Mars & Tapangco, 1996). However, these effects are not universal, and are influenced by learner factors including student approaches to learning and prior knowledge (Ollerenshaw, Aidman & Kidd, 1997). The current study extends both Mayer et al. (1996) and Ollerenshaw et al. (1997) studies to examine how learners with different levels of prior knowledge and approaches to learning can learn from an extended set of text supplementation conditions, including animation and full multimedia instruction, manipulated through a repeated measures within-subjects experimental design. A sample of 84 tertiary students completed a prior knowledge measure, the Study Process Questionnaire (Biggs, 1987b) and studied four brief, explanatory biology topics, rotated under four text supplementation conditions, including text-alone, static illustrations, animation and multimedia (text and animation). Retention and problem-solving were measured as dependent variables, following instruction in each of the text supplementation conditions. The results showed that text supplementation had a differential impact on learning outcomes for different learners. Visual instruction tended to produce better learning outcomes, compared to text-only instruction. Prior knowledge did not significantly influence the differential efficiency of the three forms of visual instruction. The direction of non significant trends indicate, however, that novice learners showed their higher retention following static, illustrations-based instruction, while knowledgeable learners showed their highest levels of retention with animation instruction. The effects of text supplementation were not influenced by student approaches to learning. In a post-test survey, surface learners showed greater preferences for visual instruction than all other learners. The trends suggest that visual instruction, particularly static illustrations instruction and multimedia, have varying instructional value for individual learners, depending on their level of prior knowledge. Therefore, tailoring instructional modes of text supplementation to the individual learner profile, may prove beneficial. The significant results combined with the non significant trends indicate that further research in this area is necessary in order to fully understand the role that learner factors have on learning.
Statement of authorship

Except where explicit reference is made in the text of the thesis, this thesis contains no material published elsewhere or extracted in whole or in part from a thesis by which I have qualified for or been awarded another degree or diploma. No other person's work has been relied upon or used without due acknowledgment in the main text and bibliography of the thesis.

Signature: 
Date: 21/3/2000
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Chapter 1: Introduction

1.1 Overview

Many researchers have examined the role of supplementary textual illustrations in learning (e.g., Balluerka, 1995; Kliese & Over, 1993; Mayer, Bove, Bryman, Mars & Tapangco, 1996; Mayer & Gallini, 1990; Mayer, Steinhoff, Bower & Mars, 1995). To date, a large number of studies have supported the premise that illustrations provide an effective source of supplementary instruction, resulting in increased levels of retention (e.g., Mayer, 1989; Mayer & Gallini, 1990; Peeke & Jans, 1987). The instructional benefits of these illustrations are, however, contingent on the coordinated visual-verbal features incorporated within the illustration, such as labels and annotations. Recently, Mayer et al. (1996) extended these findings by showing that a series of explanatory illustrations, depicting and labelling the essential features of the instructional material, produces the same or greater levels of conceptual understanding for novice learners, as when accompanied by text.

The Mayer et al. (1996) findings have significant implications, not only for conventional textbook instruction, which frequently intersperses illustrations throughout the text, but also for other presentational media, such as instructional multimedia, as is available on CD-ROM. To date, much of the research conducted in the area of text supplementation - including the Mayer et al. study - has not considered factors such as (a) the different types of instructional learning media (the Mayer et al. study used conventional illustrations, not multimedia animation), or (b) individual differences in students' approaches to learning, such as deep, achieving or surface approaches to learning.

Research conducted by Ollerenshaw, Aidman and Kidd (1997) indicated that learning outcomes using supplementary textual aids are influenced by these two factors. Firstly, learning appears to be influenced by the presentational form of the instructional material. Specifically, multimedia animation was noticeably more helpful to some learners more than others. Secondly, surface approach learners showed considerable improvements in their learning following multimedia instruction. Despite these findings, the incremental value of instructional multimedia animation, in comparison to static illustrations, when matched for completeness of visual content and information, as modelled on Mayer et al. (1996) findings, remains relatively unknown. Therefore, the aim of this study was to bring together research on two fronts, (a) the impact of the method for presenting the instructional material, while (b) examining the added influence of "learner factors" including prior
knowledge, and students' approaches to learning on learning outcomes such as memorising and understanding the material.

1.2  **Text instruction accompanied by illustrations**

Early research (e.g., Donald, 1979; Hayes & Henk, 1986; Peeck & Jans, 1987) supported the assertion that text or verbal instruction accompanied by pictures illustrating the material described in the text or verbal passage can improve certain cognitive processes. Pictures consistently improved recall of the textual material in contrast to text without pictures. It was, therefore, suggested that these visual "accompaniments" provide a complementary source of information to the written/verbal text. Furthering these assumptions, Wetzel, Radke and Stern (1994, p. 62) proposed that visual-spatial presentations accompanying text provided support by (a) helping the learner focus on relevant information within the text, (b) assisting the learner in organising the material in a meaningful manner, and (c) supporting novice learners, by visually representing concepts which may otherwise be difficult to understand.

These earlier studies provided evidence justifying the use of textual illustrations. However, they did not address other questions which arise as a direct consequence of these findings, such as what features of an illustration improve understanding of the text, and for which learners? In this context, the term understanding is defined as "the ability to transfer the material to new situations...to generate solutions to problems that are based on the presented explanation of the system" (Mayer & Sims, 1994, p. 389). Balluerka (1995) and Mayer (1989) responded to these questions by suggesting that explanatory text incorporating labelled illustrations (as opposed to unlabelled illustrations) enhances both retention and problem-solving, for novice learners. The labelled illustrations support the essential material described in the text, helping guide the learners attention towards the relevant passages within the text (Mayer, 1989). In this study (Mayer, 1989), and the subsequent Mayer studies (Mayer & Gallini, 1990; Mayer & Anderson, 1991, 1992; Mayer et al., 1995; Mayer et al., 1996) the instructional focus was explanatory material which provides a cause-and-effect explanation, because the material is "potentially meaningful" (Mayer, 1989, p. 244). This is because it increases the likelihood that "a coherent mental model from the material" (Mayer, 1989, p. 240) is constructed.

More recently, the features comprising "dynamic illustrations" were shown to be more beneficial for increasing conceptual understanding of the instructional text amongst novice learners - those with little or no prior knowledge of the material
under instruction (Mayer & Gallini, 1990). Dynamic illustrations are illustrations that depict and label both the parts and operating stages of the device/material under instruction, thereby, fully integrating all explanatory information (for example, see Mayer & Gallini, 1990). The explanatory material presented in these illustrations produced greater levels of conceptual understanding because the combined visual and verbal components helped the novice learner develop a comprehensive visual image of the device. This, consequently, focused their attention on the explanatory information within the text, further complementing their understanding of the material (Mayer & Gallini, 1990). Learners with prior knowledge of the material under study will henceforth be referred to as knowledgeable learners. They are unlikely to benefit from dynamic illustrations because they - unlike novice learners - have a knowledge basis which includes their own mental image of the device which they invoke when reading the text, rather than using the textual illustration supplied (Mayer & Gallini, 1990).

In addition to the features of the dynamic illustration, subsequent research findings (Mayer & Anderson, 1991, 1992; Mayer & Sims, 1994; Mayer et al., 1995) indicate that the incorporation of the following elements further increase the value of illustrations:

1. multiframed illustrations, incorporating brief, explanatory, sentence length, annotations beneath the labelled illustrations, and

2. placing these illustrations adjacent to the relevant, explanatory passage of text that describes the changes depicted in the illustration (as opposed to placing the illustrations beneath the appropriate paragraph).

The comprehensive presentation of visual-verbal information contained within the illustration, and the physical proximity between it and the textual passage, ensures that relevant connections between the two disparate sources of information (visual and verbal material) are made. This encourages the novice learner to build concise, informative visual and verbal mental representations of the text and the illustration (Mayer & Anderson, 1992).

In summary, illustrations have been shown to be a useful supplement to written text (particularly when the text is explanatory, i.e., describing the cause-and-effect relationships of events/devices). The incorporation of certain features within the illustrations and their proximity to the text, influences their instructional efficacy. Furthermore, these features provide a meaningful basis for learning, and, it is this meaningful context for instruction which is of most benefit to novice learners (Mayer, 1989; Snow & Lohman, cited in Mayer, 1989).
Considering the comprehensive nature of these dynamic, annotated illustrations, the significance of the textual explanation has been called into question. Mayer et al. (1996) set out to extend earlier research (e.g., Mayer & Gallini, 1990; Mayer & Anderson, 1990; Mayer et al., 1995) to examine whether these illustrations-alone (unaccompanied by an explanatory text) provided a sufficiently informative model of introductory instruction for novices. Five sequential illustrations, each including labels and brief explanatory annotations of the major events being depicted were presented to individuals with low prior knowledge of the information depicted within the illustrations. This visual-verbal illustrative summary without text, produced the same or greater levels of conceptual understanding than when accompanied by either an extended, or summarised, passage of text. These illustrations were less effective when either the labels or annotations were removed (Mayer et al., 1996). For the purposes of the current study these illustrations will henceforth be referred to as "dynamic-plus" illustrations (for example, see Mayer et al., 1996).

Consequently, Mayer et al. (1996) claimed that the "concise, coherent and coordinated features" (p.72) of these dynamic-plus illustrations made it easier for the learner to build a thorough visual and verbal mental representation, without competition from the text. They proposed that these features enhance cognitive processing because the learner is able to assimilate the explanatory material more efficiently by reaching all five stages that are associated with multimedia learning. This five stage process involves selecting, organising and integrating the visual and verbal material presented in the illustrations. It is this process which is most likely to produce a "meaningful" basis for introductory learning (Mayer et al., 1996).

To further support these findings, Mayer (1997) recently reviewed a series of studies examining the instructional effectiveness of coordinated visual and verbal explanatory material. Comparisons were made between groups of students who received coordinated visual and verbal explanatory instruction, and those that received (a) verbal explanations-only, or (b) uncoordinated visual and verbal instructions. The presentation of coordinated visual and verbal instruction consistently improved students' abilities to problem-solve. This prompted Mayer (1997) to propose that coordinated visual and verbal instructional material encourages learners, particularly those with low prior knowledge and/or high spatial abilities, to select, organise and integrate the visual and verbal material.

The one apparent weakness in the Mayer studies (e.g., Mayer & Gallini, 1990; Mayer & Anderson, 1991; Mayer et al., 1996) relates to the manner in which students were categorised into "high prior knowledge" and/or "low prior knowledge"
(Mayer & Gallini, 1990). The measure used to ascertain students' prior knowledge was based on self-appraisal questions. Specifically, students were asked to rate their prior knowledge and experience, rather than answer questions about the different topics so as to validate and quantify their "true" level of prior knowledge. This is not so much a limitation but more of a misrepresentation of the concept "prior knowledge". Although Mayer and his colleagues did not label the pre-test as a measure of "prior knowledge", it is implied in so far as the information gauged from these questions was used to categorise students into high and low prior knowledge groups. Therefore, while the current study will continue the tradition set in the Mayer studies by using a similar pre-test measure to categorise students into prior knowledge categories, the term "prior knowledge" will be used to refer to students' prior experience and self-competence, rather than as a quantifiable measure of prior knowledge.

The results of the Mayer et al. (1996) study are consistent with earlier theoretical proposals (Larkin & Simon, 1987; Sweller, 1990) that divergent forms of instruction should be coordinated to maximise understanding. In an overview of the processes of cognition associated with different instructional techniques, Sweller (1990) maintained that dual sources of instruction, such as a diagram accompanying an extended passage of text, can harm cognitive functioning because information is divided between two presentation forms, each requiring separate processing. Thus, greater effort is exerted by the learner to assimilate these divergent forms of information. To maximise the efficiency of processing these two presentational formats, Sweller (1990) suggested that written information should be integrated within the diagram to reduce cognitive overload and improve cognitive processing.

Similarly, Larkin and Simon (1987) assert that diagrams can provide greater instructional impetus than written instructions, provided the following criteria are met: (a) all information is confined within the diagram, thereby reducing the need to search the text for relevant material, (b) diagrams are representative of their physical form, and (c) they encourage the learner to make "perceptual inferences" about the information (p. 98). It is these features, which, enhance the learners ability to solve problems and the dynamic illustrative summaries used in the Mayer et al. (1996) study fits each of these criteria (Larkin & Simon, 1987).

To summarise, visual stimuli have been used effectively to enhance certain cognitive processes associated with learning. Initial research supported the use of labelled diagrams accompanying explanatory text, but recent studies indicate that sequential illustrations alone, comprising concise labels and annotations, can pre-empt the need for accompanied written text. With reference to the learner, these
findings are contingent on only one factor - lack of prior knowledge. However, it is possible that other characteristics of the learner, such as their approach to learning, could influence this outcome. This view was proffered by Kliese and Over (1993) whose results did not support the theory that dynamic illustrations are an effective supplement to textual learning, despite repeating Mayer and Gallini's study (1990) in a "real" college setting with apprentice mechanics, rather than a laboratory setting with tertiary students recruited through a subject pool. In consolidating their findings, Kliese and Over (1993) proposed that the composition of learner orientations in each of the two studies differed sufficiently to alter post-test performance, measuring problem-solving transfer. Considering these findings, it is necessary to keep in mind that these learner factors may come into play when the role of learning is examined in this experiment, and will be discussed in further detail, later.

In spite of the most recent findings, the method for presenting the material in the Mayer et al. (1996) study, has so far been restricted to static illustrations. However, the emergence of animated instruction within computer software programmes raises the question of whether the instructional components inherent in the dynamic-plus illustrations produce the same, or greater levels of conceptual understanding, when incorporated within an animated sequence. So far, the instructional benefits of animation have produced mixed results, with one group of researchers supporting animated instruction (e.g., Park & Gittelman, 1992; Williamson & Abraham, 1995) and others not supporting it (e.g., Kinzer et al., 1989; Mayer & Anderson, 1992). However, some of these studies lack the theoretical rationale and methodological strength (cf. Reiber, 1991) which have been, for the most part, a feature of the Mayer studies.

1.3 A theoretical framework for the cognitive processing of text and illustrations

Prior to examining the role of animated instruction, it is necessary to review the rationale underlying the cognitive processes used to assimilate the visual and verbal features of the Mayer et al. (1996) dynamic-plus illustrations. This cognitive model of processing has direct implications for learning with animated and/or multimedia instruction, as it offers the type of visual and verbal material which is comparable to the Mayer et al. (1996) dynamic-plus illustrations.

incoming visual and verbal material, this model which has been developed by Mayer et al. (1996), suggests that "meaningful learning" is contingent on five stages of cognitive processing. These five stages require that the learner becomes "actively" involved in assimilating the visual and verbal material by (a) selecting the visual material, (b) selecting the verbal material, (c) organising the visual material, (d) organising the verbal material, and (e) integrating the visual and verbal material - a process which is made easier when dynamic-plus illustrative summaries are used (Mayer et al., 1996). These stages appear rather mechanistic and superficial, with very little evidence regarding their temporal succession or simultaneous interaction. Thus, they should be treated as a crude metaphor.

Paivio's (1971, 1986) dual coding theory originally proposed that all incoming information is assimilated in working memory by one of two specialised subsystems, namely the verbal and visual subsystems, providing "associated networks of verbal and imagery mental representations" (Clark & Paivio, 1991, p. 151). The verbal subsystem manages all incoming verbal/linguistic material, such as speech and writing, and builds verbal representations (Hodes, 1994, p. 37). On the other hand, the visual subsystem deals with all non-verbal, image based information, such as pictures and illustrations, building "imaginal" representations (Hodes, 1994, p. 37; Paivio, 1986). These two subsystems ensure that all information passing into long term memory are encoded in a manner which is analogous to its original presentation (Clark & Paivio, 1991). While working independently of each other, the two subsystems (which construct visual or verbal mental representations of the material) are linked by the "referential connection", ensuring all corresponding verbal and non-verbal mental representations are coordinated. The referential connection is a process of linking relevant stimuli between the two subsystems, while the associative stage ensures that connections are made between other relevant encoded information within the same subsystem (Paivio, 1986).

According to the latest findings (Mayer et al., 1996) dynamic-plus illustrative summaries increase the likelihood that novices will engage in all of the stages comprising meaningful, multimedia learning. This is because the visual and verbal illustrative material is presented in a concise, coherent and coordinated manner that facilitates selecting, organising and integrating both its visual and verbal components. The conciseness of the visual and verbal material supposedly encourages the learner to select both the appropriate, explanatory images and words, which are then assimilated in the respective subsystems, building thorough internal visual and verbal mental representations. Secondly, the coherent nature of these illustrations impels the learner to organise both the visual and verbal material
succinctly, with reference to the changing events and properties being described. The final stage in this cognitive process pertains to the coordinated manner in which the visual and verbal information is represented. The combined presentation enhances the integration of the material so that referential connections between the visual and verbal mental representations are made (Mayer et al., 1996). Once all stages are achieved, conceptual understanding, as measured by problem-solving transfer, is more likely to occur (Mayer & Sims, 1994).

What has come to be referred to as the cognitive model of multimedia learning (Mayer et al., 1996) has been chosen as the primary theoretical rationale for the current study because of its conceptual and methodological convenience. Apart from its general simplifications, the model has its limitations. In particular, the model assumes that all incoming information is processed either in the visual or verbal subsystems. It does not, however, describe how other material, which is not of a visual or verbal nature, is processed within these dual coding modalities. For instance, it does not explain how information assumed from other sensory modalities, such as touch or smell, is processed. Do the dual coding subsystems accommodate other sensory input, or are there multiple coding systems for retaining this material? Thus, while it is acknowledged that there are limitations with this model, it is a convenient theoretical exemplar from which to operationalise the constructs and examine the qualitative learning outcomes from the different text supplementation conditions since, essentially, they comprise verbal and/or visual material.

The studies to date have focused predominantly on "static" illustrations accompanied by written labels and annotations (e.g., Mayer, 1989, Mayer & Gallini, 1990). However, other studies have used animated visual depictions and narration (Mayer & Anderson, 1991, 1992; Mayer & Sims, 1994). Despite this, only passing references have been made regarding the dynamic visual qualities of animation. As there is some debate surrounding animated instruction as an effective instructional adjunct, one of the aims of this study is to examine dynamic-plus illustrations using animation to see if there is a difference in the mode of visual processing. Further, learning outcomes will be examined with reference to this theoretical model.

1.4 Measuring learning outcomes

Learning outcomes play an important role in the Mayer (e.g., Mayer & Gallini, 1990, Mayer et al., 1996) studies because they provide quantifiable information about the cognitive processes which underpin learning with visual and verbal material. Researchers in the Mayer and Gallini (1990) study and the follow up studies (Mayer & Anderson, 1991, 1992; Mayer & Sims, 1994; Mayer et al., 1996)
have chosen to use recall/retention and problem-solving learning outcome measures because they are (a) "sensitive to the specific goals of instruction" (Mayer & Gallini, 1990, p. 725), and (b) they represent the learning "products" that result when stages in the theoretical model of cognitive processing are met. For example, retention measures are used to gauge how well a "learner acquires the presented information" (Mayer & Anderson, 1992, p.445) and is used as an indicator of whether the first stages of learning in this cognitive processing model have been met. If visual and verbal mental representations have been built a high score on retention will likely be observed. This is because the learner is able to draw on the information stored in one or both of the subsystems to answers questions which require a remembrance of the information.

On the other hand, problem-solving measures are used to gauge levels of conceptual understanding of the information (Mayer & Anderson, 1992). According to the cognitive processing model, the two separate visual and verbal mental representations are linked to form a representational connection which will result in an understanding of the material, increasing the learner's capacity to solve problems. This is because the two subsystems are now linked and, therefore, produce complementary sources of information which build "a visual mental model of the system along with verbal interpretations of the cause-and-effect chain in the running of the model" (Mayer & Anderson, 1992, p. 446). According to Mayer and Anderson (1992), a high score on retention but not on problem-solving indicates that representational connections have been made, but that the referential connections which require a more complex step in this model, have not been achieved. Therefore, conceptual understanding, as measured by scores on problem-solving, will be weaker.

In light of this theoretical rationale, both retention and problem-solving measures will be incorporated in the current study to gauge post-test learning outcomes, following different instructional presentations. These two learning outcome measures will be compared, and examined with reference to Mayer et al. (1996) cognitive model of multimedia learning. Higher scores on problem-solving and retention outcomes will be expected following the text-supplementation conditions that comprise dynamic-plus illustrations. However, due to fewer cognitive processes involved in memorising than in understanding, the effects on retention are likely to be stronger than on problem-solving.

1.5 Representing information visually and verbally in multimedia

The dynamic-plus illustrations featured in the Mayer et al. (1996) study, show
the importance of obtaining the right balance of visual and verbal information when using instructional illustrations. These findings have direct, transferable implications for illustrative text-book design, because the medium of instruction used in the experiment was static illustrations, presented on paper. Illustrations are examples of static media because they have no "time dimension" and, therefore, do not alter over time, unlike dynamic media, such as animation, which is a moving display contingent on time for its full exposure (Sutton, 1995). The criteria pertaining to the dynamic-plus illustrative summary should not, however, be restricted to static presentations. The extensive use of dynamic, visual displays, such as animation, as a means of imparting procedural-explanatory material within educational multimedia programmes, are likely to involve the visual and verbal criteria proposed by Mayer et al. (1996).

For instructional purposes, computer animation can be expanded to static illustrations as a supplementary, visual adjunct to the written text or narrative, and is frequently incorporated within CD-ROM instructional programmes and databases. As is the case with these animated sequences, there is often very little consistency in the presentation of the visual and verbal information, either between software products, or even between different entries within the same programme. For example, animation may or may not be accompanied by labels, or even narration. While previous research has examined the instructional capabilities of animation and narration (Mayer & Anderson, 1991, 1992; Mayer & Sims, 1994), seemingly no prototype has been developed, such as that proposed by Mayer et al. (1996), for the presentation of visual and verbal information for animation, in their "dynamic-plus" format. Considering the similarity of the visual and verbal features contained in illustrations and animation, the prototypic illustrative summary presented by Mayer et al. (1996) could be incorporated in explanatory multimedia animation.

In the present study, animated instruction will be examined in the multimedia computer environment and, in this context, the term multimedia refers to the combination of computerised animation and sound effects - including narrative - as is available on compact disc-read only memory (CD-ROM). The CD-ROM is the unit for storing most multimedia information and, as such, the computer becomes the instrument through which the CD-ROM directs the multimedia information (Sutton, 1995). Typically, the computer appears as one media unit, however, other media are often integrated within the computer, such as a CD-ROM, working in combination with the computer, rather than independent of it, thus "the term computers is actually a synecdoche where a part stands for a whole" (Veltman, 1993, p. 47). Like conventional computers, multimedia computer systems offer the same features such
as graphics, sound, and text. However, it is the incorporation of motion video and high quality sound emission, including articulated speech, which characterises its multimedia status (Hapeshi & Jones, 1992; Phillips & Pead, 1994).

Computers have the capacity to store and manipulate information. They can also "transform" input/output information, and alter its presentation from one format into another (Kozma, 1991, p. 195). It can provide - alone, or in combination - aural, visual and tactile stimuli (Saloman, cited in Gavora & Hannafin, 1995). The advantages in providing a more elaborate transformational utility ensure that information represented by these different symbol systems increases the congruence between the real-world properties, and their representation within the media (Kozma, 1991; Pea, 1994).

The televised medium, which predates the PC, has also been used for instructional purposes, within education. The two media, the PC and television, contain some comparable features, however unlike computers the televised medium was not as widely accepted within education because of certain limitations. One criticism of televised education pertains to the ephemeral nature of the visual and verbal information which is unable to accommodate learners with little or no prior domain knowledge (Kozma, 1991). Thus, for high prior knowledge learners, the rapid succession of televised information can help build complete mental representations because their prior knowledge helps them encode the information presented at the televised pace, thus supplementing their knowledge base (Kozma, 1991). However, low prior knowledge learners are disadvantaged by the transience of the material because the encoding of new information usually takes longer than the time for which it is exposed on the television. Consequently, learning from the television is likely to result in a lessening of comprehension (Kozma, 1991).

Passive learning has been an issue concerning televised instruction. Other instructional presentations such as text and dynamic-plus illustrations require the learner to actively participate in understanding and obtaining the information by reading the material and selecting, organising and integrating the information (Mayer et al., 1996). Instructional television is designed for presentation within large groups and can often inhibit these active learning processes because very little effort is needed, on behalf of the learner, to respond to the televised message (Miller, 1994). The ephemeral nature of televised information requires that the visual and verbal contents are presented in a clear and immediately understandable manner so that the viewer does not have to actively seek out the message, as is necessary when reading a passage of text. Thus, the televised medium may be equated as an "easier" instructional medium for learning than text, because of its realistic qualities, and
immediate understanding of the message. However, comparable post-test performances following instruction in both these mediums, indicates that text enhances learning (as measured by inferences and recognition), because the learner is required to exert greater mental effort in both acquiring and assimilating the message (Saloman, 1984).

1.6 Interactive versus primary multimedia instruction

The computer programme provides an opportunity for the user to interact with the computer, which encourages higher levels of participation which in turn, helps develop the learners' skills and knowledge (Barker & Tucker, 1990). Interactive multimedia, in-part, assumes that the potential for learning and developing skills is the responsibility of the learner, for it is he/she who controls and manipulates the presented information (Barker & Tucker, 1990). In support of interactive multimedia, Simpson (1994) suggests that the neurophysiological processes inherent in learning can be enhanced using the interactive features of multimedia, resulting in an increased level of understanding and retention. Theoretically, the brain is stimulated by material which requires learner interaction, thus, learning is likely to be facilitated when the brain is "actively engaged", rather than when it is passive (Simpson, 1994).

Levels of computer interaction vary considerably depending on the computer programme. Barker and Tucker (1990), however, state that the medium itself is a poor indicator of the level of interactivity, because computer software packages impose the level of interaction. Thus, levels can vary greatly from minimal interaction, where the learner simply clicks on a button to obtain another screen of information (analogous to turning the pages of a book), through to higher levels of interaction where the learner controls all aspects of incoming data (Barker & Tucker, 1990).

Deciding upon an appropriate level of interactive freedom has become a contentious issue. Begeman and Conklin (cited in Hapeshi & Jones, 1992) suggest that problems arise when material, such as that presented in the hypertext environment, is unstructured. Subsequently, the learner is burdened with the task of extracting "appropriate" information from the large amounts available. Research undertaken by Psotka, Kerst, Westerman and Davison (1994) and Schnotz, Boeckheler, Grzondziel, Gaertner and Waechter (1998) exemplify this point. In the Psotka et al. (1994) study, learning outcomes were greatest following restricted interaction within hypertext, in comparison to complete interactive freedom. Psotka et al. (1994) posits, therefore, that learners become confused by unrestricted access to large amounts of information because it disrupts their usual strategy for learning,
and produces an overall lowering in post-test scores compared to the "guided" navigational group, where interactive freedom was limited by the predetermined boundaries set by the experimenters.

Similarly, Schnotz et al. (1998) compared students' learning outcomes following interactive and non interactive exploratory, animated instruction. They observed that learning with interactive animation increased a learners encoding of information detail. This finding prompted Schnotz et al. (1998) to conclude that interactive animation has an extraneous effect on cognitive load.

For these reasons, therefore, interactivity between the learner and the computer interface will be kept to a minimum, in this study. Given that the focus of this study is on the mode of instructional presentation within the multimedia computer environment, confounding variables such as unrestricted learner interaction may adversely affect learning outcomes. Furthermore, instructional multimedia software that incorporates text, illustrations and animation offer minimal levels of interaction. These programmes provide a similar format and amount of information as that which is contained within the learning conditions under examination in this experiment, thus, interaction levels will be comparable. Computer interaction will be restricted to a basic - "primary" - level, whereby the learner will control the pacing of the computerised information. Pacing refers to the flow or progression of the instructional material as controlled by the individuals' responses, or the computer program designers (Gavora & Hannafin, 1994, p. 446). Use of the keyboard or mouse to repeat the animated sequence, or scroll the text up and down are examples of primary interaction.

1.7 Features of the CD-ROM

High quality sound, including speech, and dynamic visual images, such as motion video and animation, were referred to earlier as being the components that determine whether the computer offers multimedia facilities (Hapeshi & Jones, 1992; Phillips & Pead, 1994). Both are commonly available on CD-ROM which relays this information to the computer. CD-ROM equipment has the capacity to store information which would otherwise be difficult to store within the hard-drive of the computer because moving graphics and sound require large amounts of disc space for storage (Sutton, 1995). It is, therefore, understandable that CD-ROM equipment accommodates much of the information which is deemed to be multimedia in nature.

CD-ROMs have the potential to play an important role in education. Not only can they offer a range of presentational formats in conjunction with the software
program and computer hardware, but it is also capable of offering interactivity between the user and the software program. In the earlier days, when CD-ROM systems were in their infancy, they were limited in their slowness to access information and inability to provide animated illustrations, due to the amount of memory needed to perform such functions (Barker & Tucker, 1990). Nowadays, these "problems" have been addressed and the CD-ROM offers the functions and conveniences that assume the title of multimedia. CD-ROM software, while being relatively inexpensive, offers a range of facilities, including the delivery of current databases, and interactive, instructional tutorials. Some of the encyclopaedias available on CD-ROM are a fitting example of the sophisticated visual, auditory and interactive features available. However, there are a many subject-specific educational compact discs available which provide the same benefits for all levels of learning. Understandably then, the allure of the CD-ROM is likely to lead to its inclusion within the education environment, as a supplementary source of reference.

It is within this context, that the availability of animated visual images has come into its own. With reference to the "output of information", Barker and Manji (1989, p. 326) describe "visualisation" as the "computational processes that analyse data and information and then present it in a pictorial format that is easily, rapidly and, hopefully, unambiguously interpreted" (p.326). As previously discussed, many studies have been conducted which support the benefits pictures and illustrations have on various "learner" processes. Therefore, visual-spatial instruction "can constitute the only channel of communication between the computer and its user or they can form part of a multi-media integrated message that also includes sound and text" (Barker & Manji, 1989, p. 326). The sophisticated visual presentations available via the computer have the capacity to enhance the cognitive processes associated with learning. Thus, the development of unique visual presentations could increase a learner's understanding of difficult material and abstract theories while helping develop strategies - through the use of visualisation - to increase their power to solve problems (Rieber, 1995).

This is the likely reason behind the increased prominence and availability of dynamic visual images within instructional compact discs. Software developers, such as Microsoft, the producers of the Encarta CD Encyclopaedia, are capitalising on the inclusion of sophisticated graphical presentations (Erwitt, 1997). Yet, despite the advances, there is still some doubt as to whether these dynamic presentations - such as multimedia animation (the subject of the present study) - are (a) beneficial modes of instruction, and if so, (b) whether they are being utilised to their full instructional potential.
1.8 Computer animation and its impact on cognitive processes

Despite the increasing popularity of animated graphics within computer-based instruction, educational researchers are undecided as to its efficacy as an instructional tool (see Rieber & Kini, 1991). The reasons for this include:

(1) the "serious concern for its true instructional purpose or impact" (Rieber, 1991, p. 318), and

(2) of those studies conducted, a proportion lack the theoretical strength and methodology to support their findings (Rieber, Boyce & Assad, 1990).

Furthermore, the research that has addressed these limitations has provided inconsistent results that have caused divergent theories to arise. One group of researchers (e.g., Ollerenshaw et al., 1997; Rieber, 1990; Rieber & Kini, 1991; Williamson & Abraham, 1995) supports the use of animation as a visual aid to learning, suggesting that it is preferable to conventional methods of instruction (i.e., text and/or illustrations). This is because it contains qualities that are capable of representing the essential, dynamic properties of objects that would otherwise be unrepresented by illustrations (Park & Gittelman, 1992; Williamson & Abraham, 1995). Conversely, other researchers have been unable to find evidence of this, and have therefore questioned whether animation is a more satisfactory method of instruction (Kinzer, Sherwood & Loofbourrow, 1989; Rieber et al., 1990).

In education, instructional animation is the incorporation of dynamic visual images used to facilitate learning within a media-based environment, such as computer based instruction (Park & Gittelman, 1992). In this context, animation fulfils two roles. Firstly it is used as a presentational display, similar to that of illustrations, and secondly, as an activities based simulation (Rieber & Kini, 1991). It is the role of animation in the former setting, which is of most interest because comparisons can be made with static - explanatory - illustrations.

In their overview, Rieber and Kini (1991, p. 85) proposed that animation is most likely to enhance cognitive processing by developing visual representations, when the following requirements are met. Firstly, the animated sequence must depict information in a highly imaginative manner to increase the probability of it being committed to memory. Secondly, animation is best suited to representing procedural concepts that change, and evolve, over time. This is because apparent motion presents a clear, visual depiction of such changes which are likely to be better understood, and remembered than either words or static illustrations (Rieber & Kini, 1991). Further, animation is ideal for representing directional changes of objects - such as the concept of velocity - which is difficult to depict using conventional instructional techniques (Rieber & Kini, 1991).
Kozma (1991) also offers support for graphical computer representations, and suggests that they are most effective when they (a) depict abstract concepts, such as using symbols and arrows to represent velocity (p. 198), and (b) are presented to novice learners. He clarifies this by suggesting that accurate mental models are formed when links are made between the concept itself, and its physical appearance, particularly when an object changes over time. These claims are confirmed by research findings implying that computer animation, used to depict explanatory, evolutionary information, is a more effective presentation display than other conventional forms of instruction, such as text and/or illustrations (e.g., Hays, 1996; Park & Gittelman, 1992; Rieber, 1990; Rieber, 1991; Williamson & Abraham, 1995).

Thus, the studies conducted by Park and Gittelman (1992) and Williamson and Abraham (1995) both examined the role of computer animation in adult learning. Each study focused on a procedural topic that physically changed over time either by moving or transforming, such as an electric circuitry display. In both studies, animation was compared to different instructional conditions. The Park and Gittelman (1992) study compared animation to static illustrations as visual adjuncts accompanying tutorial lessons, but including only those learners with little prior domain knowledge. Williamson and Abraham (1995), on the other hand, drew comparisons between groups exposed to animated visual displays (both as an adjunct to science lectures, and as a one-on-one tutorial display/activity) and those who were given instructions which were essentially the same as in the lecture but excluded visual adjuncts. In both cases, instruction which incorporated animation produced higher levels of conceptual understanding (Williamson & Abraham, 1995) and problem-solving (Park & Gittelman, 1992), than the other methods of instruction.

Consequently, both research teams proposed that the dynamic qualities of the computer animation, provided a comprehensive model for instruction because they are able to represent the component behaviours of the item, including the procedural functions and structural features, over a time continuum. Further, they suggest that animation can visually represent those items which are normally invisible or unrepresented by static illustrations. This visual display supposedly aids the novice learner in developing a superior understanding of the material, because the comprehensive nature of the material produces a more detailed and "expertlike" mental representation of the information (Williamson & Abraham, 1995, p. 532).

Further support for these findings is provided by Hays (1996). In this study, however, levels of visual-spatial ability were examined in relation to instructional learning with either text, illustrations or animation. Although Hays' results are
limited by the population from which the sample was drawn (early secondary school students), the research examines what effect animation has on learning for learners with different, "predisposed" characteristics. Exemplifying this, the research found students with low visual-spatial abilities, ie: those students who were unable to build visual images, appeared to benefit from visually based instruction, and especially animation, when instruction involved difficult to learn topics and concepts, which often involved time change and movement. Hays (1996) therefore suggests that "spatial representations are the more appropriate form of memory representation for concepts involving time and motion, such as diffusion" (p. 150). Thus, animation would aid low spatial ability learners because the animation is both an effective form of instruction and can be readily stored in memory (Hays, 1996).

The studies cited so far provide empirical support for animated instruction, whether compared directly to static illustrations, or instruction containing no visual adjuncts. However, as indicated in these studies, animation is not preferable to all other modes of visual instruction, or in every learning condition. The role of animation as an efficient visual model for learning is contingent on certain criteria, including the following:

1. the material under instruction must be explanatory and maintains a high level of conceptual information;
2. the animated sequence should depict movement or change over time, as in the case of scientific constructs of technical devices;
3. learners with little prior domain knowledge will be the main beneficiaries of animation.
4. an emerging stream of research indicates that learners with low spatial abilities may also benefit.

In contrast to these findings, other researchers (e.g., Kinzer et al., 1989; Palmiter & Elkerton, cited in Najjar, 1996; Rieber et al., 1990) have found no evidence that animation facilitates learning any more than other forms of instruction. Rieber et al. (1990) found that when animation accompanied by narration was compared with (a) text interspersed with illustrations, or (b) highly imaginative textual explanations, no significant differences were observed between the three conditions. Only one advantage was evident following animation - responses to the post-test questions were faster. Thus, they speculated that although understanding was not affected, animation helped in the processing of the visual information in the initial stages, which resulted in faster retrieval of information from memory.

In light of their findings, Rieber et al. (1991) proposed that text, which is carefully developed to include highly imaginative explanations, and examples to
describe the instructional material, is of equal benefit in developing a mental image of the material, as are dynamic visual representations. Indeed, Clark and Paivio (1991, p. 155) attest the benefits of concrete rather than abstract verbal material, in relation to their theory of dual coding. Concrete words relate to what is tangible, and therefore can bring to mind a corresponding image of the word, thus increasing the possibility that the material will be assimilated in both the verbal subsystem - because of its linguistic basis - as well as the non-verbal subsystem, because of its imagery arousing capabilities. Abstract information and words are less likely to be processed in both subsystems because they are not tangible, therefore a mental image of the word is unavailable, and will likely only be retained in the verbal subsystem (Clark & Paivio, 1991). Sadoski, Goetz and Fritz (1993) provide experimental evidence to support this, finding instructional text containing concrete words enhanced mental imagery, resulting in increased recall and comprehension, in contrast to text containing abstract words.

Other reasons have been offered in response to the lack of support for animated instruction. An alternative theory proposed by Palmiter and Elkerton (cited in Najjar, 1996), which was also identified by Miller (1994) and Saloman (1984) in relation to televised instruction, is that animation, as opposed to reading, is a passive medium which, therefore, does not offer a good instructional model for long term memory storage. They found that response times were faster and more accurate immediately following animated instruction, than textual explanations. However, on retest a week after instruction, the findings were reversed and favoured textual instruction. It was therefore postulated that reading the information required participants to attend more closely to it, thereby facilitating long term storage, suggesting that the reverse is the case when viewing animation.

The extent to which these findings could be generalised were limited by shortcomings with the methodology, which may have favoured the non-animated instruction, in the before mentioned study. For instance, the lack of one on one interaction with the computer may have favoured the non-illustrative condition. All participants in the Palmiter and Elkerton study (1991) viewed the simulation without interacting with the material, even by way of pacing the material presentation, which may have contributed to the lack of long-term processing. Had these participants been given more control over the information presentation, different results may have been obtained. This is supported by Simpson (1994), who suggested that understanding of computerised information is likely to be enhanced by interaction because the learner is actively engaged in the rate and exposure of the material being presented.
In their review, Park and Hopkins (1993, p.435) proposed that the limitations in methodology, apparent in some of the research, and the inconsistency in research findings, have occurred because there are too few specifications regarding the componential features of animation. Too often, general assumptions are made about animation in the context of learning, with little reference being made to what components, including accompanying narration or text, facilitate these learning processes.

These issues have been partially redressed by Mayer and Anderson (1991, 1992) and Carpenter and Just (1992). They each conducted an examination of explanatory animation, focusing primarily on the verbal descriptions accompanying the graphical sequences. In these studies, componential and conceptual understanding of an explanatory technical device - for novice/low prior knowledge (LPK) learners - was greatest following the concurrent presentation of narration and animation. The animation fulfilled two instructional purposes by describing, and depicting the structural features and changing components of the device. Further, Mayer and Anderson (1991) found animation without any verbal prompts was as ineffective as no instruction.

Carpenter and Just's (1992) findings are evidence that effective animation is contingent on accompanying verbal explanations for low prior knowledge learners. Mayer and Anderson (1991, 1992) elaborate further by relating their findings to the "contiguity principle", which originates from Pavio's (1971, 1986) dual coding theory. According to this principle, the visual and verbal sub-systems (assumed to encode visual and verbal information, respectively) are enhanced by the simultaneous presentation of visual and verbal stimuli. This, supposedly, produces more complete visual and verbal mental representations, which aid understanding and subsequently the retrieval of the information from long term memory.

Mayer and Anderson's (1992) results suggest that animation, alone, does not enhance the understanding of the material under instruction, but rather, it is the presentation of dual sources of information which produce thorough visual and verbal mental representations. These principles were referred to earlier in the other studies conducted by Mayer and colleagues where they were used to explain the benefits of "dynamic" and "dynamic-plus" illustrative summaries. In a similar vein, Mayer and Anderson's (1992) animated sequence and narration is analogous to Mayer and Gallini's (1990) study where illustrations were presented in conjunction with labels and explanatory text.

Interestingly, Mayer and Anderson (1991, 1992) did not mention the possibility that the instructional medium - the computer - could have affected the
way in which students' perceived and/or approached the instructional task. While the format and visual/verbal content of the animated instruction is essential to the encoding of information, the medium of instructional presentation, and its effect on the learner, could have influenced post-test results. A post-test measure asking participants about their attitude towards computerised instruction would have identified whether computer-based presentations impelled them to learn. Likewise, asking them to subjectively rank order each of the features of the animated simulation - visual and verbal - would have provided further understanding of its impact on learning.

Furthermore, the Mayer and Anderson studies (1991, 1992) examined computer animation - alone or in conjunction with successive or concurrent narration - but made no comparisons with static illustrations. While they assume that the completeness of the visual and verbal content of the animation/narration facilitate understanding, they do not acknowledge that the dynamic properties of the animation could have contributed to this result. Considering that other researchers (e.g., Park & Gittelmann, 1992; Williamson & Abraham, 1995) propose that it is the dynamic qualities of animation which facilitate learning, it might have been worth Mayer and Anderson attempting to validate their theoretical position further, by comparing static illustrations to animation, controlling for the completeness of visual and verbal content in both conditions.

1.9 Learner characteristics influencing the effects of text supplementation: Prior knowledge and approaches to learning

The learner characteristics of prior knowledge have had an impact on learning, following different text supplementation conditions. To summarise the findings of Mayer and his colleagues (e.g., Mayer & Gallini, 1990; Mayer et al., 1995; Mayer et al., 1996) participants' prior knowledge of the material under instruction influenced learning outcomes. In particular, those learners with little or no prior knowledge showed their greatest improvements in learning from text supplemented illustrations (e.g., Mayer & Gallini, 1990; Mayer et al., 1995) and, more recently, from dynamic-plus illustrations (Mayer et al., 1996). On the other hand, knowledgeable learners showed fewer improvements in learning following text supplemented instruction (e.g., Mayer & Gallini, 1990; Mayer et al., 1995).

Until now, however, learner characteristics other than prior domain knowledge, have been largely ignored in most of the preceding research. Many studies examining illustrative and animated explanatory instruction have not considered the possibility that individual differences exist in the manner in which
students approach their studies. Considering many of the studies mentioned have used tertiary students, it would seem logical to measure students' approaches to learning in order to establish whether or not learning outcomes are influenced by certain approaches to study.

Learner factors such as intellectual ability (see Ackerman & Woltz, 1994), learning ability (Ayresman & von Minden, 1995) and learner motivation (Kinzie, 1990) have been identified as having an impact on learning outcomes. To counteract some of these factors, Ollerenshaw et al. (1997) measured students' approaches to learning, focusing on those learners with tendencies towards a surface approach (Biggs, 1987a), to examine the influences they may have on learning in each of the four text supplementation conditions. The study was modelled on that of Mayer and Gallini's (1990), however, the combined computer animation and text condition was used instead, to represent (in animated form) the features of the "dynamic illustrations" of the procedural, technical device. Levels of prior knowledge (high and low) were also gauged.

According to Biggs' (1987b) model of student approaches to learning which was used in the Ollerenshaw et al. (1997) study, the deep, achieving and surface approaches comprise a combined measure of students' (a) motives for learning, and (b) the strategies they use when learning. Surface learners, for example, are externally motivated by tangible goals, such as gaining employment, and thus, their study intentions are purely pragmatic - to pass the formal academic requirements without exerting too much effort (Biggs, 1991). To meet such goals, they often use strategies which are easy to embrace but are often only temporarily effective, such as rote learning (Biggs, 1987a, 1988). Therefore, Ollerenshaw et al. (1997) hypothesised that surface learners would underachieve across all learning conditions, but would show improved comprehension following instruction involving text and animation.

They found that computer animation comprising the properties of "dynamic illustrations" (i.e., comprehensive visual model depicting and labelling the parts and operating stages of the device) accompanied by text proved most beneficial to low prior knowledge learners. Additionally, surface learners, who "underperformed" across all learning conditions showed significant improvement in the multimedia animated condition (Ollerenshaw et al., 1997, p. 227). Their level of conceptual understanding was highest following instruction in this condition, and was equal to those students' in the comparable group of learners comprising all other learning approaches (Ollerenshaw et al.,1997). Ollerenshaw et al. (1997) offer two reasons why surface learners performed best under animation and text. Firstly, the computer
simulation may have provided a medium which accommodates the motives and strategies of these learners because it "provides a means of learning the material without exerting too much effort" (Ollerenshaw et al., 1997, p. 236). Alternatively, it was suggested that the animated instruction "may have encouraged surface learners to become intrinsically motivated and curious about the material" (Ollerenshaw et al., 1997, p. 236), thus, temporarily relinquishing their surface approach and adopting a deeper one.

There are limitations in the Ollerenshaw et al. (1997) study that reduce the extent to which these findings can be generalised into the broader educational context. Firstly, the small number of surface learners requires caution in interpreting these findings (Ollerenshaw et al, 1997), as does the inter-group comparisons (between subjects design). Secondly, while the researchers' themselves acknowledge the importance of addressing the remaining, predominant approaches to learning, as categorised by Biggs' (1987b), it may also be beneficial to examine each of the motive and strategy scores comprising the three learning approaches (deep, achieving and surface), since they, too, may produce different learner effects on the results of animated instruction. Furthermore, theoretical questions are left unanswered regarding the "beneficial" elements of the multimedia condition. Thus, it is unclear whether the dynamic and novel qualities of the computer animation contributed to a fuller understanding of the material for surface learners and low prior knowledge learners, or whether, as postulated by Mayer and Anderson (1991, 1992), the visual and verbal thoroughness of the animated presentation helped build a better visual and verbal mental representation of the device. These questions could have been answered had the static illustrations not been "incomplete" in comparison to the computer animation - they included only some of the elements of the dynamic illustration.

The earlier suggestion about a subjective measure to gauge learners' attitudes and preferences for animated instruction, made in relation to the Mayer and Anderson (1991, 1992) studies is also pertinent to the Ollerenshaw et al. (1997) study. Not only would such a measure provide some insight into how these four instructional presentations are perceived by the learners, but it would indicate whether instructional preferences are associated with students' approaches to learning. Specifically, surface learners, who, in the Ollerenshaw et al. (1997) study showed their best learning performance with animated instruction, may also prefer visual instruction because it accommodates their motives and strategies for learning. Animations and illustrations present information in a manner which is immediately recognisable though visual representation - it does not require the learner to exert any
effort to obtain meaning, as is the case when reading text. Further, it is more visually pleasing, and novel, all of which may complement the motives and strategies of the surface learner, as proposed by Ollerenshaw et al. (1997).

In summary, there appears to be some confusion surrounding the use of instructional animation as an explanatory visual display. Consequently, various theories have emerged. On the one hand, some researchers attest the benefits of animation suggesting that the dynamic qualities make it a more comprehensive model for instruction. Conversely, others dispute these findings arguing that animation provides no greater advantages than text or illustrations. Yet other authorities elaborate further and propose that when animation is found to facilitate understanding, it is not because of its dynamic features, but rather the visual and verbal qualities contained in the animated sequence which produces improved mental representations. A recent study suggested that a learners orientation towards study significantly influenced learning outcomes following computer animated instruction.

It would seem therefore, that the illustrative and animated instruction could benefit from further elucidation. Closer attention needs to be paid to all learning approaches and not just to surface learning. This would be most effectively carried out by increasing the experimental power by using a repeated measures design and allowing for within-subjects comparisons, as will be developed in the current study. Additionally, the models by which Ollerenshaw et al. (1997) and Mayer and Anderson (1991, 1992) developed the visual and verbal components of animation were obtained from the Mayer and Gallini (1990) study pertaining to "dynamic illustrations". However, in light of recent findings by Mayer et al. (1996) indicating that illustrative summaries comprising "dynamic-plus" illustrations are more effective for novice learners (even than when accompanied by text), this criterion needs to replace that of the "dynamic illustration". This would fulfil two purposes by (a) re-evaluating the Mayer et al. (1996) findings, and (b) examining whether this criterion could be a useful aspect of animated instruction.

1.10 Individual learning styles and approaches to learning

Perceptions, personality type, motivation, and other determinants influence how an individual approaches, and conceptualises information, not only in the formal academic setting, but in all learning situations. The combination of the learning style characteristics often directs how the individual learner will embrace and internalise instructional material (Nelson et al., 1993). If the findings of Ollerenshaw et al. (1997) are any indication of the effect an individuals' orientation to study has over
learning, its role, particularly in the current multimedia age, should not be overlooked.

Ollerenshaw et al. (1997) refer to the possible advantages of developing instructional multimedia to accommodate students' approaches to learning. Previously, students have successfully been taught how to accommodate and utilise their own individual approaches to learning (Nelson et al., 1993). In this instance, students' themselves were the focus for accommodating their own particular style of learning, but it is conceivable that instructional computerised programmes have the capacity to accommodate each approach and level of learning. Nowadays, computer technology, including computer interaction, offers a range functions that could be tailored to an individuals own educational needs, learning experiences, and in this instance, an individuals' own approach to learning (Kinzie, 1990). Further reiterating this proposal, Hartley (1998) suggests that hardware and software technologies have the potential to be customised to the individual learner. However, he stresses that despite the potential for new technologies in learning, it is still necessary to examine how these technologies can be used effectively, to facilitate learning.

Research examining the impact of instruction on learning recognises that individuals respond differently to the learning environment, because of differences in abilities (Hegarty & Just, 1993), prior domain knowledge (Mayer, 1989) age, reading ability, comprehension skill (Peeck, 1993, p. 231), motivation (Kinzie, 1990) and so on. While acknowledging that these influences are important, the individual's approaches to learning is at best referred to as an avenue for future research (cf. Kliese & Over, 1993). However, these factors should not be ignored. The idea that learners regulate their own study and learning behaviour, embraces the theoretical proposition that all learners act according to their own individual goals and strategies (Purdie, Hattie & Douglas, 1996).

From a holistic perspective, each learner exercises control over their learning and, as such, become self-initiators, regulating their beliefs and behaviours in the learning context (Purdie et al., 1996). According to this theory, students evaluate and then regulate their own behaviour in reference to their own belief system and goals, rather than the "external controls" imposed upon them by the educational institution, such as assessment expectations (Purdie et al., 1996, p. 87). The individual differences are believed to comprise various "personal" attributes such as personality, learning experience and psychological differences, which act separately - or in combination - to control how the learner modulates their learning (Ayersman & von Minden, 1995; Purdie et al., 1996). It is within this framework that terms such as "learning style" and approaches to learning arise, as a means of identifying and
quantifying the manner in which individuals interpose their individual characteristics upon the context of learning (Ayersman & von Minden, 1995).

Researchers have developed different models describing 'how' and 'why' individuals influence the processes over which they learn (e.g., Biggs, 1987; Kolb, 1984; Ramsden & Entwistle, 1983). These models are derived from different theoretical perspectives. For example, Kolb (1984) developed a model of learning which is based on cognitive theory, social psychology and philosophy by incorporating these elements into a cyclical model. With reference to the experiential learning theory, which proposes that an individual experience plays a significant role in the process of learning (Kolb, 1984, p. 20), Kolb offers a "a holistic integrative perspective on learning that combines experience, perception, cognition, and behavior" (1984, p. 20).

Kolb's (1984) model, thus, comprises four distinct, but integrated modes of learning, each representing the polar extremes of cognitive growth and understanding (Hayes & Allinson, 1993). Two of these modes - concrete experience, and abstract conceptualisation - refer to the opposing dimensions of attaining information from the external, physical environment, categorised under the broader term "prehension". Prehension is attained through either (a) comprehension, which regulates learning on an abstract plateau, and relies on the individual's capabilities to conceptualise information and develop symbolic relations, or (b) apprehension, which is the practical and unsophisticated awareness of the physical environment and the sensations associated with it (Kolb, 1984).

The remaining two stages comprising Kolb's (1984) model of learning are known as active experimentation, and reflective observation, which are categorised under the broad term "transformation". Transformation thus refers to the cognitive processes that create a personally meaningful understanding of the events occurring in the learner's environment. The bi-polar processes involved in transformation are (a) intention, which encapsulates all learning behaviours which deliberately attend to experiential information, and (b) extension, which expands upon these conscious thoughts and feelings linking them with previous knowledge. Earlier, learned experiences are thus built upon.

Essential to Kolb's (1984) model is the understanding that learning is a "process whereby knowledge is created through the transformation of experience" (Kolb, 1984, p. 41). Usually, an individual uses one of the polarised dimensions from prehension and transformation to achieve an awareness of experience, and then convert this into a meaningful - internal - learned experience. The individual
variations for learning is the consequence of embracing one or two of these modes, regulating the manner to which they learn.

In contrast, Biggs (1987a) and Ramsden and Entwistle (1983) developed inventories for measuring the approach a student applies when studying. These learning inventories are different from the learning style inventory, developed by Kolb (1984). The latter seeks to classify the overall manner in which an individual perceives information from their environment and subsequently learns from this information in a personally meaningful manner. The inventories measuring study approaches, however, are more context specific. They measure an individual's orientation towards study in the formal - secondary and tertiary - education setting (Newstead, 1992). While comparisons can be drawn between learning approaches and learning styles, the latter adopts a more holistic approach, whereby all human learning is under consideration. Biggs' (1987b) examination into learning however is more specific: learning behaviour in the education setting is the focus of his research.

Biggs' (1987a) inventory for measuring students' study approaches derives from a theoretical model of learning which comprises information processing and learner factors, that include "personality and academic performance" (Biggs, 1993, p. 4). Thus, Biggs (1987a) has established a model of student learning which represents learning as a cycle comprising three distinct stages. Known as 'Presage', the first stage represents all factors that exist within the learner, prior to entering the learning setting, including personal factors such as intelligence, personality, work/study ethic and situational factors, such as course content, disciplines of study and so on (Biggs, 1987a). These factors remain fairly constant over time, however, they can influence learning behaviour in the formal educational environment. The second stage in this cycle is known as 'Process', and it is the primary focus of Biggs' Study Process Questionnaire because it identifies how students orientate themselves towards learning. According to Biggs (1987b, 1988), the process by which students' approach their learning is regulated by their (a) motives and reasons for learning and (b) the strategies utilised to fulfil these motives. There are three identifiable approaches to learning - deep, achieving and surface - each being represented by a distinct learning motive and strategy (Biggs, 1987b).

The surface and deep approaches represent the two extremes of learning, with reference to students' motives and strategies. On the one hand, individuals with a surface approach to learning conduct their studies on a superficial level because they are extrinsically motivated. As described earlier in this paper, surface learners desire to pass the formal educational requirements of the course by expending minimal effort, to achieve the tangible goal of, for example, having a tertiary qualification
(Biggs, 1988, p. 198). Therefore, these learners are very much bound by situational factors such as assessment, learning topics and the like. The strategies often embraced by these learners are in essence "reproductive", and include memorisation techniques, such as rote learning (Biggs, 1987b, p.11). Alternatively, the deep approach refers to a more referential, and qualitative approach to study. Students' exhibiting this approach are often interested in the material under instruction, and are motivated to learn more about it. They are therefore influenced more by the person factors such as interest in the material or their own control mechanisms over their learning than by with situational factors (Biggs, 1987b). Consequently, their learning strategies include extending this knowledge by reading widely and gaining a broader understanding of the material under study (Biggs, 1987b, p.11).

Marton and Säljö (1976a, 1976b) investigated student learning from a different theoretical perspective to Biggs (1987b) but they, too, identified similar constructs that characterise student learning, also defined as the deep and surface approach (Christensen, Massey & Isaacs, 1991, p.290). Marton and Säljö examined students learning from a phenomenographical approach, which is defined as "the qualitatively different ways in which people experience and conceptualise various phenomena in the would around them" (Marton, Dall'Alba & Beaty, 1993, p. 278). They sought to examine the ways in which students learnt information - "how students grasped or comprehended ideas and principles, which were presented in their set books or in texts of a similar kind" (Marton & Säljö, 1976a, p. 4) - rather than measuring the amount of learning which has taken place (Marton & Säljö, 1976a). This qualitative analysis of how students undertake their learning differentiates Marton and Säljö's research from that of Biggs (1987a), who uses quantitative measures to examine learning motivation and strategies (Christensen et al., 1991, p.290).

From their investigations, Marton and Säljö (1976a) defined surface learning as a "reproductive" process (p. 7). Thus, students who adopt this approach tend to focus solely of the words comprising the instructional material (in their study, the instruction comprised a passage of text) to attain learning, rather than the meaning of the material. These learners, therefore rely heavily on memorisation techniques to assimilate the information. In contrast, students with deep learning processes focus on the significance of the content of the instructional material in order to gain an understanding of it (Christensen et al., 1991, p.290). This is a more "active approach to learning" (Christensen et al., 1991, p.290) because the deep learner tries to comprehend the meaning and message which is being disseminated through the instructional medium (Marton & Säljö, 1976a).
Parallels can be made between Marton and Säljö (1976a, 1976b) and Biggs (1987) deep and surface learning approaches, however, Biggs has also conceptualised a third, distinctive approach called the achieving approach. This achieving approach is derived from a different perspective than the previous two approaches, and acknowledges that some students pursue their studies with a predetermined desire to achieve highly and obtain optimal grades. Hence, their motivation for learning is the personal satisfaction which arises from gaining good grades, by thus, using a range of strategies. These may include self-disciplinary behaviour incorporating rigid study schedules, adherence to all scholarly activity and the like (Biggs, 1991).

The final stage in Biggs cyclical model of learning is referred to as 'Product'. This stage is an evaluation of the learning outcomes that eventuate when utilising a specific approach to learning (Biggs, 1991). Thus, the level of understanding, the academic grade obtained in the course, or the satisfaction derived from learning all fall within this domain of performance outcomes (Biggs, 1991).

From this theoretical model, Biggs (1987a) developed the Study Process Questionnaire (SPQ) to measure tertiary students' approaches to learning. It is used to identify the strategies and motives comprising a student's predominant approach to study. Importantly, Biggs considers an individual's approach to learning is relatively consistent over time, and is resistant to change: a students' motives - which determines the learning strategies adopted - for study, usually remain fairly constant (Biggs, 1988, p. 198). Thus, under exceptional learning situations, some pressures may force students to adopt a surface approach to learning, despite normally possessing a different approach (Biggs, 1988). Biggs (1988) identifies heavy assessment and time restraints as two examples which often force a student towards temporarily adopting the surface approach.

Biggs (1987a, 1987b) contends that the three approaches to learning create different performance outcomes in the formal educational setting, whereby the characteristic strategies used by deep, achieving and surface learners guides their study behaviour and techniques, directly influencing their academic grades. Thus, surface approach learners are, frequently, poor academic performers (Biggs, 1987a, p. 70). While using memorisation to recall factual, concrete information, their understanding of the structural relationships contained within the information is often overlooked (Biggs, 1987b, p. 3). However, students displaying an achieving approach to learning, combined with elements from the deep approach often produce the best performance outcomes. Biggs' (1987b) proposed that this deep-achieving approach is one of the more "powerful" learning orientations, leading "to good
performance in examinations, a good academic self-concept, and to feelings of satisfaction" (p. 4).

In the before mentioned study, Ollerenshaw et al. (1997) provided some support for Biggs' (1987a) assertion that students' motives and strategies for learning produce different learning outcomes. The current study will examine the influence of the text supplementation conditions, including multimedia instruction, on learning by taking the three groups of learners, surface, deep and achieving, through a number of text supplemented conditions and examining their performance through within subjects comparisons. To summarise the findings of Ollerenshaw et al. (1997), surface learners achieved their highest level of comprehension - equal to that of all other learning approaches - with text instruction which was supplemented by animation, despite consistently underachieving in all other text-supplementation conditions, in comparison to their deep and achieving peers.

These results suggest that the motives and strategies of the surface learner are fostered both by the medium and format (computer/animation) of presenting this information, and the comprehensive content of the information (depicting and labelling the features and stages of the operational device). Considering surface learners employ memorisation techniques when learning, the sensory appeal, realistic features and the presentation of factual information contained within the animation may foster their learning strategies and motives as well as their preferences for these different instructional conditions. Indeed, these outcomes could represent a ceiling effect whereby the comprehensive multimedia information offers surface learners a plateau from which to attain a maximum level of knowledge, using their superficial learning strategies. Cowie-Scott (1994) offers support for this view. She examined the attitudes students with different approaches to learning have towards computer aided instruction and found low achievers - who were typically surface learners - rated computer instruction more favourably than higher achievers. Cowie-Scott (1994), therefore, suggests that computer instruction is favoured more by low achievers because it is perceived as a concrete - rather than abstract - mode of presenting information, thus contributing to its appeal.

A discrepancy, however, is apparent between performance outcomes following computerised instruction in the Cowie-Scott (1994) and Ollerenshaw et al. (1997) studies. In the former study, surface learners favoured computerised instruction, however their level of achievement was low. With regards to performance however, the opposite was true in the Ollerenshaw et al. (1997) study which indicates that the manner (animation) and content (visual; elaborative) of the
information in this study contributes to better levels of understanding and performance outcomes using the surface strategies.

Conversely, deep and achieving learners, some of whom comprised the composite group in the Ollerenshaw et al. (1997) study, showed less variation in learning outcomes following combined text and animation instruction. This suggests that this instruction was no more beneficial to these learners than text alone instruction. These findings imply that deep learners and achieving learners are endorsing the learning strategies consistent with their approach to learning, as theorised by Biggs (1987a, 1987b). Deep learners, who show an intrinsic interest in their studies may have found information in the text-alone condition, equally, if not more conducive to their strategies to attain a deeper level of knowledge, than text accompanied by visual adjuncts, which, although novel, are considerably less detailed than text.

Predictions can also be made about achieving learners, following the Ollerenshaw et al. (1997) study. Since these learners seek academic success and closely attend to all prescribed work, they would be unlikely to change their study strategies to accommodate novel, visual adjuncts (such as animation or illustrations). Thus, because of their desire for academic success, they probably used the same - frequently used - rigid strategies in all four learning conditions, irrespective of the visual adjuncts.

In light of Cowie-Scott's (1994) findings, students' preferences for the "visual" presentation conditions will be examined, to ascertain whether learner factors, such as student approaches to learning, and prior knowledge, influence their subjective preferences. Since surface learners in Cowie-Scott's research preferred computerised instruction, it is expected that they will also prefer the novelty of the animated and illustrated images presented via the computer. Surface learners have been described by Biggs (1987b) as being influenced by the situational events that surround learning, therefore if the visual - animated - instruction, as in the Ollerenshaw et al. (1996) study, appears more helpful to these learner, it is expected that more positive feedback for these conditions will be observed. In contrast, students with other approaches to learning will likely show less variation in their preferences, following the different text supplementation conditions. This is because (a) deep learners are more interested in the instructional content of the material, and (b) achieving learners aim to perform well in all learning situations, thus suggesting that both these groups of learners will be less swayed by the presentation of the material and as such will show fewer preferences for these instructional presentations.
Furthermore, students' prior knowledge, which will also be examined in this study, may also be associated with preferences for the visual instruction. For example, if novice learners show better performance outcomes following the visual instruction, they may perceive the instructional presentations as beneficial to their learning and thus show stronger preferences for it. On the other hand, knowledgeable learners may be less swayed by their preferences for the presentation styles because they are not relying on the material to gain their knowledge but rely on their past knowledge and experiences.

1.11 Interactions between mode of instruction and learner factors

The theoretical foundations underlying these "learning" inventories can provide valuable information to educators when developing learning programs, and assessment criteria. This is no more apparent than in the Cowie-Scott (1994), and Ollerenshaw et al. (1997) studies, whereby students' approaches to learning were found to influence attitudes and performance outcomes following different methods of instructional presentation via the computer. Kaplan and Kies (1995) suggest educators need to be aware, and presumably flexible, in their teaching methods, considering students exhibit an individual preference for learning, in style. Indeed, Fernandez, Johnston, Peat and Nearhos (1997) discuss this in their review of educational technology by referring to the importance of student learning orientations, suggesting that "technology must cater for different learning styles and support the processes students use when they learn" (p. 32).

Gow and Kember (1993) conducted research examining the relationship between teaching style and learner approaches and found that there was a relatively strong correlation between the two. This research identified two main approaches to teaching - 'learning facilitation' and 'knowledge transmission' - which positively or negatively impacted upon students learning approaches, as measured by the SPQ. 'Learning facilitation' was associated with teaching qualities which help, guide and motivate students to learn, and encourages them to embrace positive and meaningful (deep or achieving) approaches to learning, rather than a reproducing approach. Alternatively, 'knowledge transmission' refers to the teaching orientation whereby the dissemination of knowledge and information - rather than the individual learner - is of paramount importance to the teacher. Consequently, when this orientation was embraced, surface learners out numbered those students with meaningful learning approaches.

In part, the Kaplan and Kies (1995) study supports Biggs (1988) claim that approaches to learning are affected by situational events or occurrences. In this study,
however, teaching styles greatly influence the learners strategies and motives. While Biggs (1988) acknowledges that some learning situations can cause students to adopt a reproductive approach to study when normally they would not, the Kaplan and Kies research implies that the reverse is also true. Namely, teaching orientations which foster meaningful learning can cultivate students' intrinsic understanding, thus reducing the need to adopt shallow learning strategies, such as those used by surface learners. This finding confirms that the role of instruction and learner mediation needs to be closely examined in conjunction with students' approaches to learning.

If Kaplan and Kies (1995) are correct in their assumption that students - particularly surface learners - alter their approaches in accordance with the mode of instruction, the Ollerenshaw et al. (1997) findings can be interpreted from a different perspective. For example, computer animated instruction may encourage surface learners to use different study strategies, which are normally associated with deep or achieving learners (Ollerenshaw et al., 1997). Thus, the information presented in the animation may incite surface learners to use a different study approach because learning the information satisfied their interest, and was thus, intrinsically motivating. While not offering this scenario, Biggs (1988) does posit that students change their learning strategies under exceptional circumstances, and applies this to deep or achieving learners who may opt for surface strategies. However, if this situation is permissible, why not the reverse? The computer animated presentation - an unusual method for wholly presenting explanatory information at a tertiary level - may constitute that rare circumstance whereby surface learners forsake their usual superficial study motives and strategies and opt, instead, for a strategy which will encourage a richer level of information processing.

Sein and Robey (1991) examined learning styles and their relationship to different modes of instruction - abstract or analogical - when learning about computer mailing systems, and found a link between the two. While accepting that learning style influences an individuals' performance on the experimental task - irrespective of the instructional method and medium - Sein and Robey suggest that for some learner types, performance was enhanced because the mode of instruction was analogous to their learning orientation. This result partially supports Kaplan and Kies (1993) findings, however, as in each of these cases, different learning inventories were used, which measured different aspects of individual learning.

These studies indicate that method of instruction does play a potentially significant role in learning outcomes. While it is important to address learner factors when teaching, or developing instructional aids, Ayersman and von Minden (1995) suggest that until now, this has been a difficult objective. In the conventional
classroom situation either the teacher or the student has had to readjust - and thus compromise - their styles to suit the mode of instruction (Ayersman & von Minden, 1995). However, with the increasing sophistication of computer technology, computer programmes could be developed to "accommodate individual differences in learning style" (Sein and Robey, 1991, p. 246) and presumably, approaches to learning.

Various researchers acknowledge that features and/or the instructional medium of the computer has the potential to accommodate purposeful instruction which complies with an individuals style and approach to learning (e.g., Ayersman & von Minden, 1995; Geisert, Dunn & Sinatra, 1990; Ollerenshaw et al., 1997; Sein & Robey, 1991; Stoney & Wild, 1998). Computer technology offers multiple methods of instruction which is unavailable in the conventional classroom. Thus, the features of a computer programme could allow the learner to adopt a preferred mode of instruction, conducive to their learning style (Geisert et al., 1990). Documented evidence of this has been sparse. While Ollerenshaw et al. (1997) offer support for computer instruction using text and animation, the benefits appear contingent on the individuals predominant approach to learning. The methodology limitations and constraints of this study means, however, that many questions are left unanswered.

1.12 Summary of the theoretical rationale and hypotheses of the study

The theoretical rationale underlying the Ollerenshaw et al. (1997) study was largely derived from the earlier studies by Mayer (1989; Mayer & Gallini, 1990) which examined the instructional benefits of text supplemented illustrations. Mayer and his colleagues (Mayer et al., 1996; Mayer & Sims, 1994; Mayer et al., 1995) have since extended these findings, and more recently suggested that dynamic-plus illustrations containing complementary visual and verbal instruction are a more effective means of introductory instruction for novice learners, than when illustrations are accompanied by text (Mayer et al., 1996). Despite the significant implications of these findings, they are, however, limited to text supplemented illustrations. For example, with the emergence of computer generated animation in instructional multimedia software programmes, the Mayer et al. (1996) findings could also be used to maximise the instructional impetus of dynamic visual animations.

The intention of this study was to re-examine the relationships discovered in the Ollerenshaw et al. (1997) study between mode of instruction - computer/animation - and learning (which will be gauged using post-test measures of recall and problem-solving). Again, level of prior knowledge and students'
approaches to learning - deep, achieving and surface - needed to be measured to further examine their impact on these "learning" outcomes. In light of the Mayer et al. (1996) findings, the criteria pertaining to dynamic-plus illustrations will be incorporated in all the visual adjuncts contained in the study, including illustrations and multimedia animation. Four learning conditions will, therefore, be included in this study - namely (a) text alone, which will be used as a base-line measure, (b) static, dynamic-plus illustrations, as developed in the Mayer et al. study, (c) dynamic-plus animation, which will help ascertain whether dynamic visual displays provide a better model for learning explanatory material, than their static counterparts, and finally, (d) text accompanied by dynamic-plus animation. This condition proved to be most beneficial to surface learners in the Ollerenshaw et al. (1997) study. Thus, comparing these conditions will determine whether greater levels of learning are attributed to the computerised technology, or the contiguous manner in which the visual and verbal material is presented. Learning outcomes - retention and problem-solving - will be examined in light of the Mayer et al. (1996) cognitive model of multimedia learning. Further, students' subjective preferences for the different text supplementation conditions will also be gauged.

It was therefore anticipated that a learner's mastery of the learning segments will be affected by the form and/or medium in which the segments are presented. Animation and multimedia sequences were expected to be more effective, than static-illustrations, even after matching for completeness of the visual content and information. This pattern of relative efficiency will, however, be influenced by certain characteristics of the learner, including prior knowledge and approaches to learning, and also the quantifiable measures used to gauge learning outcomes. Preferences for the different visual learning conditions were expected to be associated with student learner factors, such as prior knowledge and student approaches to learning. It was hypothesised as follows:

**Hypothesis 1.** When studying brief, explanatory learning segments under different text supplementation learning conditions, including text only (text), dynamic-plus illustrations (illustrations), dynamic-plus animation (animation) and a combination of animation and text (multimedia), these learning conditions will have a significant, overall effect on how well students learn the material. This effect will, however, depend on the students' approaches to learning, their level of prior knowledge and the learning outcomes measure, as outlined in hypothesis two to six.

**Hypothesis 2.** Levels of prior knowledge will interact with the learning conditions in influencing learning performance. In particular, learners with low prior knowledge will show greater increases in learning through "visual instruction", a
term that will henceforth describe all three instructional conditions which contain visual instructional aids (illustrations, animation and multimedia), than learners with high prior knowledge.

**Hypothesis 3.** Students' approaches to learning will influence the effect of the learning conditions on the learning outcomes. Specifically, surface learners will perform better in the two animated conditions (animation and multimedia) followed by the illustrations condition, and will perform worst with text only instruction. This effect of visual instruction will be less pronounced for deep and achieving learners.

**Hypothesis 4.** The interaction between approaches to learning and prior knowledge will influence the effect of learning conditions on learning outcomes. In particular, adding text to animation will have a differential effect on learners' performance, depending on their approach to learning and prior knowledge. Deep learners with high prior knowledge will perform better under multimedia instruction, than under the animation condition. For surface learners with low prior knowledge this pattern is likely to be reversed.

**Hypothesis 5.** All factors presented in hypotheses one to four (learning condition, prior knowledge and approaches to learning) will have differential effects on the two direct learning outcomes measured in this study. Overall, the impact of these factors on retention of the learned material will be stronger than on performance in problem-solving tasks related to the learned material.

**Hypothesis 6.** Learner preferences for different text supplementation conditions will be associated with their approaches to learning and prior knowledge. In particular, surface learners and learners with low prior knowledge will report greater preference for visual instruction, than for text. For deep and achieving learners and high prior knowledge learners this pattern of response is unlikely to be observed.
Chapter 2: Method

2.1 Participants

Eighty-four past and present university students (51 women and 33 men) aged between 17 and 50 years (mean age of 26.2 years) volunteered to participate in this study. Of these participants, 81 were enrolled in a tertiary course at the time of testing. The remaining three participants were recent tertiary graduates. In total, 79 participants were drawn from the population of students at a regional Victorian University. Participant experience with computer controls including the mouse, was a prerequisite for participation in the study. This was because anxiety with computers has been identified by researchers (e.g., Hayward, 1994; Lens, 1994; Leutner & Weinsier, 1992) as a common problem, which needs to be addressed when examining the role computers play on individual learning outcomes. Therefore, students were excluded from participating in the current study if they had no previous computer experience, in order to avoid any possibility that confounding effects or novelty events may occur.

Participation in the study was voluntary. An incentive plan was developed in lieu of course credit to encourage a greater rate of participation, and a wider range of students from different schools across the university. The incentives included a number of $50 book vouchers and computer software packages (Microsoft Encarta CD-ROM Encyclopedia, 1998). Participation in the study ensured entry into the draw. Upon completion of all testing, thirteen entries were randomly drawn and matched to one of the incentive items.

Prior to testing students were fully briefed about the study. In particular, participants were given a disclosure form explaining the study. Written consent was then sought from all students prior to the commencement of testing. Full ethical approval for this study was obtained from the University's Human Ethics Research Committee. The materials including forms, tests and questionnaires were fully approved by the committee, and all volunteers were treated according to the requirements of the ethical guidelines.

2.2 Materials

The materials included an A4 "question booklet" containing - in order of presentation from front to back - the knowledge pre-test; the Study Process Questionnaire (SPQ) question pamphlet and answer sheet; four sets of knowledge post-instruction questions; the post-test Learner Feedback Survey. The requirements for the computer equipment included an IBM compatible pentium computer with

2.2.1 Pre-test. The knowledge pre-test contained eleven questions (refer to Appendix A). The format and structural content of these questions were the same as those employed in the Mayer studies (e.g., Mayer & Gallini, 1990; Mayer & Anderson, 1991; Mayer et al., 1996) and gauged prior domain experience and appraisal of the learner's confidence in the topics presented in the four learning conditions. The topics chosen for instruction were different from those in the Mayer et al. (1996) study, and therefore, the questions in the pre-test reflected this difference.

The first five questions presented in the pre-test solicited information about prior experience/understanding of the different biological concepts, including the anatomy and physiology of the ear and eye, and the processes of photosynthesis and the stages of mitotic cell division. A Likert, five-point rating scale ranging from 1 = "none" to 5 = "substantial" knowledge and/or understanding was used to answer questions such as "How much knowledge/understanding do you have of the anatomy and physiology of the human eye?". The remaining six questions on the pre-test solicited further information about previous study and/or experience with scientific instruments, to gauge their experience with science, such as "Did you study any biology after 1996?", and "Do you know what a chromosome is?". To answer these questions, "Yes/No" responses were required.

2.2.2 Study Process Questionnaire. The Study Process Questionnaire (SPQ), a 42 item self-report measure identifies tertiary students' motivation and strategies comprising their approaches to learning. The SPQ comprises (a) question pamphlet listing all questions, and (b) separate answer sheet with a response key for answering each of the questions (refer to Appendix B). Each item in the question pamphlet is presented as a statement which reflects a motive or strategy for each of the three orientations to learning, namely deep, achieving and surface. Students respond to statements such as - "I summarise suggested readings and include these as my notes on a topic" - using a five-point Likert rating scale which is provided on the answer sheet. The scale ranges from 5 = "always or almost always true of me", to 1 = "never, or only rarely true of me".

Acceptable reliability and validity have been reported for the SPQ. Biggs (1987a) provided a measure of reliability for the deep, achieving and surface motives, strategies and approaches. "Satisfactory" levels of internal consistency were reported (1987a, p. 23), however, alpha levels indicate variation between the subscales. The alpha levels for the composite scores for the three learning approaches showed higher
levels of reliability than the motive and strategy scales from which they were derived (Biggs, 1987a, p. 22). The achieving approach scale showed the strongest alpha level ($\alpha = .78$) followed by the deep approach ($\alpha = .76$). The surface approach ($\alpha = .64$) showed the weakest measure of internal consistency across all approaches. A similar pattern of internal consistency was apparent for the motive and strategy scales. The achieving motive ($\alpha = .72$) and strategy ($\alpha = .73$) subscales showed the strongest levels of internal consistency, followed by the deep motive ($\alpha = .64$) and strategy ($\alpha = .65$), and the surface motive ($\alpha = .55$) and strategy ($\alpha = .56$).

Biggs (1987a) offered additional measures of internal consistency for the SPQ, from independent studies. O'Neil and Child (cited in Biggs, 1987a, p. 22) showed stronger levels of reliability for the SPQ. The weakest alpha coefficient was for the surface motive ($\alpha = .60$) and the strongest for the achieving strategy ($\alpha = .74$). Each of the three approach measures provided consistently reliable alpha levels (deep, $\alpha = .79$; surface, $\alpha = .75$; achieving, $\alpha = .77$).

Test-retest reliability for the SPQ was unavailable in the test manual, however, correlations provided by an independent researcher (Murray-Harvey, 1994) showed a reasonable levels of stability following a 12 months interval. The test-retest reliability coefficients ranged from 0.42 to 0.66. Validity of the SPQ was demonstrated by its correlations with students' subjective reports of their study performance and satisfaction. These correlations ranged between -0.15 and 0.3 (Biggs, 1987a). Concurrent validity was confirmed when the deep, achieving and surface scales of the SPQ correlated with the Approaches to Study Inventory constructs (Wilson, Smart & Watson, 1996). The predictive validity of the SPQ have also been confirmed (Hall, Bolen, Gumpton & Juhl, 1995). The SPQ, coupled with the Scholastic Aptitude Test have been used successfully to predict Grade Point Averages, with the achieving approach scores providing the strongest prediction for GPA (Hall et al., 1995).

2.2.3 Post-instruction. The post-instruction comprised four sets of questions - one set for each of the four topics of instruction, namely mitosis, photosynthesis, ear and eye (refer to Appendix C). Each set contained either (a) eight multiple choice questions (each question contained four statements - one of which was the correct answer, and the remaining three incorrect) or (b) seven multiple choice questions (the same format as above) and one statement requiring a "True/False" answer. Each set of questions were displayed on two pages.

The first four questions in each set of post-instruction measured retention/recall of the test material. The questions and answers were extracted from the material presented in the respective instructional learning segments. The remaining
four questions in each set examined conceptual understanding of the test material. These questions posed problematic scenarios which were related to the material provided in the instructional passage. Both the retention and problem-solving test questions were developed with the help of individuals with science backgrounds.

The structure of the post-instruction - the retention/recall, and problem-solving transfer questions - was analogous to that used in the Mayer and Gallini (1990), study and more recently in the Mayer et al. (1996) study. In the present study however, the post-instruction format comprised a series of multiple choice questions, rather than the short answer format which was adopted in the other studies. Multiple choice questions were more appropriate in this research context because (a) of the length of time required to conduct the within-subjects design and (b) they provided a more objective scoring system from which the correct answers could be immediately identified.

2.2.4 Learner Feedback Survey. The Learner Feedback Survey contained a series of questions which required a subjective rating of (a) the different methods of instructional presentation - text; illustrations; animation, and multimedia - (b) the supplemental features of the visual adjuncts and (c) the comparative motivational qualities of illustrations and animation (refer to Appendix D). The first ten questions were answered using a Likert scale ranging from 1 = "not at all"/"not helpful"/"no use"/"detrimental" to 5 = "very helpful"/"very useful"/"essential". Questions included "How did the text add to your understanding of the animation?". Other questions were more specific, asking how one feature added to the overall understanding of the information, for example, "How much do you think the annotations added to the illustrations?". Other questions gauged the contribution specific instructional features had on learning motives, such as "To what extent did the illustrations motivate you to learn?". The final two questions provided an opportunity for participants to comment upon the instructional material and make suggestions for improvements. In addition, the Preference for Visual Instruction Scale, an eight item subscale comprising questions from the Learner Feedback Survey (listed in Table 1), provide a rating of visual instruction - animation; combined animation and text; illustrations - accompanied with/without text.
Table 1

Items Comprising the Preference for Visual Instruction Scale on the Learner Feedback Survey (LFS)

<table>
<thead>
<tr>
<th>LFS Question No.</th>
<th>Item Content</th>
</tr>
</thead>
<tbody>
<tr>
<td>3a</td>
<td>Labelled illustrations accompanying text</td>
</tr>
<tr>
<td>3b</td>
<td>Animation and narration accompanying text</td>
</tr>
<tr>
<td>4d</td>
<td>Animation and narration contributing to understanding</td>
</tr>
<tr>
<td>4e</td>
<td>Illustrations contributing to understanding</td>
</tr>
<tr>
<td>4f</td>
<td>Combined animation &amp; text contributing to understanding</td>
</tr>
<tr>
<td>7</td>
<td>Labels accompanying illustrations</td>
</tr>
<tr>
<td>8</td>
<td>Animation contributes to learning motivation</td>
</tr>
<tr>
<td>9</td>
<td>Narration accompanying animation</td>
</tr>
</tbody>
</table>

2.2.5 Instructional materials and details of text supplementation conditions. The learning conditions for computer presentation consisted of an animated "Media Entry" from the Encarta '98 Interactive Multimedia Encyclopedia on CD-ROM; an explanatory passage of text; six sequential dynamic-plus illustrations for each of the following four instructional topics:

1. The ear (structure and function).
2. The eye (structure and function).
3. Mitosis (mitotic cell structure and stages of cell division).
4. Photosynthesis (leaf structure and the process of photosynthesis).

These four animated entries were selected for use within this research for two reasons. Firstly, each animation was similar in structural content, features (narration, labels, annotations) and quality, allowing it to closely resemble the instructional content of the dynamic-plus illustrations featured in the Mayer et al. (1996) study. Secondly, the material within the animation was explanatory, providing information about the structure of each topic, as well as describing the changing features inherent within the topic. Explanatory instruction, with cause and effect style descriptions, have been used in all Mayer's research when examining the instruction/learning capacity of illustrations, illustrative summaries and animation (e.g., Mayer & Gallini,
1990; Mayer & Anderson, 1991; Mayer et al., 1996), and this approach has become a standard for the field.

The four animations contained comparable multimedia features. These included an animated sequence depicting the features and processes involved in the four chosen biology topics. The animations were accompanied by a recorded, explanatory narrative which played concurrently with the animation. Other sounds were also evident in the animation and were used in conjunction with the narration and animation to further explain the topics. For example, high and low pitch sounds were used in the "ear" multimedia entry to accompany the animated changes occurring in the inner ear. Supplementary labels were another feature of the animations. In addition, the structural components or features inherent in each of the entries were labelled. The animations ranged from 80 to 108 seconds, with a mean duration of 94 seconds.

In the text instructional condition, four passages of explanatory text - one for each of the four instructional topics - were stored in separate Microsoft Word documents (a copy of each is available in Appendix E). The information contained in each textual passage was analogous in content to the animation and narration, however, it was written with more detail to clarify points that were only apparent when accompanied by the animation. Additional resources were required when developing the text (these resources have been included in the reference list). The word count for each of the four textual passages ranged from 350 to 380.

Coloured illustrations were developed for each of the four instructional topics. For each topic, a series of six sequential "static" images were developed from the Encarta multimedia animations, used in the animated conditions. From the animated sequence, the selected images were "Paused", the image was captured using the "print screen" function. The image was then imported into an image editing program where it was edited so that all annotations within the box were removed and, if necessary, additional labels were included. This edited image was then incorporated in a Word document. Annotations, comprising key words and a brief sentence or two which was adapted from the narration accompanying the animation were placed underneath each of the illustrations. A word processing file for each of the four instructional topics was used. The six illustrations in each file were positioned in the centre of the screen and each illustration was numbered in sequence. A copy (printed in black and white) of the illustrations is available in Appendix F.
2.3 Procedure

Test administration took approximately one hour, and was conducted in groups comprising between one and four students, so close individual supervision was assured. Students were first instructed to complete the knowledge pre-test by circling the responses that pertained to their knowledge and understanding of the topics listed. After completing this, the Study Process Questionnaire was administered. Instructions for answering the questions were provided on the front page of the question booklet. Students were asked to answer the forty-two items listed in the question pamphlet by marking one of the five answer boxes (representing the five point Likert scale) for each item, using the answer sheet.

Students were randomly assigned to four learning sequences comprising the four different instructional topics (ear; eye; mitosis; photosynthesis) and presented in the four text supplementation conditions (text; illustrations; animation; multimedia). The instructional topics were rotated across the four learning conditions in an attempt to avoid any (a) sequencing effects, and (b) confounding differences on the post-test measure which may occur as a result of varying levels of difficulty for each of the four information topics. Thus, rotation resulted in equal frequency, whereby each of the 4 instructional topics was presented in each of the four conditions. The rotation resulted in 16 sequences.

Students were seated at a computer terminal, facing a covered computer screen and were given instructions on how to use the computer to view/read the topic information. Once the students were ready, the computers were uncovered and students were timed for five minutes while they viewed the information on the computer screen. Students were asked to re-read the text or illustrations, or restart the animation again until the end of the five minutes. Students in the multimedia condition were instructed to read the text, then view the animation. With any remaining time, students were given the choice of re-reading the text, or restarting the computer animation. The overall procedure was similar to that employed in the Mayer and Gallini (1992) study, and the subsequent Mayer et al. (1995, 1996) studies.

Participants were given 5 minutes to study the on-screen material, after which they were asked to answer a set of post-instruction multiple-choice questions in the test booklet. There was no time limit for answering the questions.

In the remaining three conditions, testing was conducted in the same manner, with students viewing the material for 5 minutes, then answering the post-instruction questions. After answering the questions in the final condition, participants completed the Learner Feedback Survey.
2.4 Scoring

2.4.1 Pre-test. Consistent with the procedure used in the Ollerenshaw et al. (1997) study and similar to that used by Mayer and Gallini (1990), levels of prior knowledge were calculated by totalling all the responses on the pre-test. The first five questions were calculated by adding the circled responses on the five point rating scale. Each of the yes/no answers for the remaining six questions were scored as 1 or 0, respectively. In theory therefore, the total pre-test score could range from a minimum of 5 to a maximum score of 31. The pre-test composite measure yields reliability with a standardised alpha of .82 on the eleven items. Therefore, the composite score was used to determine contrasting groups of low, medium and high prior knowledge, for all four subject areas together. On the basis of their pre-test score, students were divided into one of the three categories of "low prior knowledge", "medium prior knowledge" and "high prior knowledge".

2.4.2 Study Process Questionnaire. Two sets of scores were derived from the SPQ. Firstly, students were classified into their predominant approach to learning according to the Study Process Questionnaire Manual (Biggs, 1987). Students' predominant approaches to learning were identified by combining the motive and strategy scores for each of the three learning approaches (deep, achieving and surface) thus resulting in composite scores for the deep approach (comprising the deep motive and deep strategy), the achieving approach (comprising the achieving motive and achieving strategy) and the surface approach (comprising the surface motive and surface strategy). The composite scores were then converted into deciles using the normative tables for male or female University students in the following disciplines - "Arts", "Education" and "Science" - as provided in the Manual (Biggs, 1987b). Norms were not available for students in other disciplines, therefore, participants from other disciplines were allocated to one of the three disciplines most similar to their area of study. The SPQ Manual (Biggs, 1987b) broadly labels decile scores into categories labelled "below average" (decile scores ranging from 1 to 3), "average" (comprising decile scores ranging from 5 to 7), and "above average" (consisting of decile scores ranging from 8 to 10).

Decile scores for each of the three approaches classified students into one of the six learning approach groups, comprising (a) the "pure" approaches ("deep" learners; "achieving" learners; "surface" learners), (b) the "mixed" approaches ("deep-achieving" learners and "surface-achieving" learners), and (c) learners with no predominant approach. Students were classified as having one of the "pure" approaches to learning if they obtained either (1) an above average decile score on the designated composite approach (i.e., the deep approach for deep learners) and an
average or below average decile score on the remaining two composite approaches, or (2) obtained an average score on the designated composite approaches, and below average scores on the other two approaches.

Student's exhibiting a mixed approach to learning obtained either (1) an above average decile scores on the two designated approaches, and an average or below average decile score on the third approach, or (2) obtained average deciles on the two designated approaches and a below average score on the third approach. Conversely, participants with no predominant approach to learning obtained an equal decile score on each of the three approaches.

The second set of scores derived from the SPQ calculates learners' scores for each of the motives and strategies. All students were classified into high and low groups for each of the six motive and strategy scales, following median splits for each of the SPQ motive and strategy raw scores.

2.4.3 Post-instruction. Each question was scored as 0 when the answer was incorrect, or 1 for a correctly identified answer. For each subtest a maximum total score of eight (a score of four for the retention questions, and a score of four for the problem-solving questions was possible).

A measure of instrument reliability for items measuring retention and problem-solving across each of the four topic conditions was conducted. Consequently, the alpha levels for each item helped determine whether items were included, removed (because of insignificance), or in some cases reclassified as retention questions.

Due to the uneven number of items in the measures, and differences in instructional difficulty between the four biology topics (repeated measures MANOVA, with an alpha level of .05), showed a significant main effect of instructional topic on post-test measures, both through averaged multivariate estimation, (Pillais Trace, $F(6, 498) = 5.06, p = .00$) and averaged univariate estimation; retention scores, $F(3, 249) = 3.45, p = .02$; problem-solving scores, $F(3, 249) = 7.44, p = .00$), the composite totals for retention and problem-solving were converted to $z$-scores, for each of the instructional topics. The items comprising the retention and problem-solving composite groups for each topic, and the standardised reliability alpha coefficients, are presented in Table 2.
Table 2
Item Composition and Alpha Coefficients for Retention and Problem-solving Tests for the Instructional Topics

<table>
<thead>
<tr>
<th>Topic of instruction</th>
<th>Items</th>
<th>Standardised Alpha</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ear</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Retention</td>
<td>1, 2, 3, 4, 7</td>
<td>.50</td>
</tr>
<tr>
<td>Problem-solving</td>
<td>6, 7, 8</td>
<td>.21</td>
</tr>
<tr>
<td>Eye</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Retention</td>
<td>1, 2, 3, 5</td>
<td>.53</td>
</tr>
<tr>
<td>Problem-solving</td>
<td>6, 7, 8</td>
<td>.47</td>
</tr>
<tr>
<td>Mitosis</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Retention</td>
<td>2, 3, 4</td>
<td>.35</td>
</tr>
<tr>
<td>Problem-solving</td>
<td>6, 7, 8</td>
<td>.28</td>
</tr>
<tr>
<td>Photosynthesis</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Retention</td>
<td>1, 3, 5</td>
<td>.54</td>
</tr>
<tr>
<td>Problem-solving</td>
<td>6, 7, 8</td>
<td>.35</td>
</tr>
</tbody>
</table>

2.4.4 Learner Feedback Survey. All responses were examined both at the raw score level, and as a composite scale measuring preferences for mode or form of instruction, features and motivational influence of the learning conditions. Scores on the Learner Feedback Survey ranged from 17 to 85, with high ratings on each of these items indicating a stronger preference for the instructional aid, while the opposite is true for low scores. Reliability of this 17 item measure was strong: the standardised alpha of the Satisfaction Rating Scale was .83. Scores on the Preference for Visual Instruction Scale (PVIS) ranged from 8 to 40, with a high score on the scale indicating stronger preference for visual instruction. In contrast, a low score on the scale indicated negative or non preference for visual instruction. Reliability of this eight-item Preference for Visual Instruction Scale was .77.
Chapter 3: Results

3.1 Preliminary analysis: Order effects and associations between variables

With the repeated measures design, all participants went through all four text supplementation conditions studying the four distinct instructional topics in varying sequences. It was therefore important to examine the order effects of this variation. A repeated measures MANOVA (the alpha level was set at .05 for this and all other analyses, unless otherwise stated) showed that rotating the sequence of instructional topics across the learning conditions did not significantly affect the post-instruction scores, neither through multivariate estimation (Pillai's Trace, $F(18, 480) = .63, p = .82$) nor averaged univariate estimation on retention scores, ($F(9, 240) = .70, p = .71$) and problem-solving scores ($F(9, 240) = .67, p = .74$).

As mentioned in the Method section, differences in difficulty between the four biology topics were observed. To counterbalance these differences and to compensate for the uneven numbers of items in the post-instruction retention and problem-solving measures, all retention and problem-solving scores were converted to $z$-scores.

Correlations between the SPQ measures (motive and strategy scales, and normalised classification of students' predominant approaches to learning), post-instruction outcomes, and other participant information (age, gender, university level) are presented in Appendix G. The SPQ motive and strategy scales, and student approaches to learning tended to correlate with post-instruction scores following the four text supplementation conditions. Students' predominant approaches to learning (categorised as 1 being the most "effective" learning approach - deep-achieving, to 6 - students with no predominant learning approach) significantly correlated with problem-solving, following text instruction ($r = -.26, p = .01$). The direction of this association indicates that the more "effective" learning approaches correlated with better problem-solving, following text instruction. Further, the SPQ surface motive score showed a weak correlation with problem-solving following text instruction ($r = -.17, p = .10$). In comparison, the deep motive score significantly correlated with problem-solving in the text-only condition ($r = .23, p = .03$). The achieving strategy showed a weak correlation with retention following instruction with (a) text ($r = -.17, p = .10$) and (b) multimedia ($r = -.18, p = .09$).

3.2 Effects of text-supplementation conditions on retention and problem-solving

To examine the effects of the text supplementation conditions on the dynamics of participants' retention and problem-solving outcomes, two repeated
measures ANOVAs were conducted. The retention and problem-solving post-instruction z-scores were the dependent variables, and the independent variable was text supplementation. The results showed that the text supplementation conditions produced a significant main effect on retention scores ($F (3, 198) = 3.40, \ p = .02; \ \text{observed power} = .76$). Planned contrasts showed that the effect of text supplementation on retention scores were strongest between (a) the text and illustration conditions ($F (1, 66) = 7.29, \ p = .01$), (b) the illustrations and multimedia conditions ($F (1, 66) = 4.29, \ p = .04$) and (c) the text and animation conditions ($F (1, 66) = 4.20, \ p = .04$). However, the text supplementation conditions produced no significant effect on problem-solving scores ($F (3, 198) = .86, \ p = .46; \ \text{observed power} = .24$).

Specifically, as presented in Table 3, text instruction resulted in the weakest learning outcomes, both on retention and problem-solving measures. The highest mean retention scores were observed with illustrations instruction, followed by animation, then by multimedia instruction. By comparison, the highest mean problem-solving scores were observed under the multimedia condition, followed by illustrations instruction, and then animation.

Table 3
Retention and Problem-solving Results (z-scores) for the Four Text Supplementation Conditions

<table>
<thead>
<tr>
<th>Learning condition</th>
<th>Retention</th>
<th>Problem-solving</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>M</td>
<td>SD</td>
</tr>
<tr>
<td>Text</td>
<td>-.26</td>
<td>1.18</td>
</tr>
<tr>
<td>Illustrations</td>
<td>.19</td>
<td>.78</td>
</tr>
<tr>
<td>Animation</td>
<td>.09</td>
<td>1.01</td>
</tr>
<tr>
<td>Multimedia</td>
<td>-.01</td>
<td>.97</td>
</tr>
</tbody>
</table>

Note. Higher z-scores correspond to greater levels of retention and problem-solving.
3.3 Effects of prior knowledge on learning outcomes

The same repeated measures ANOVAs were examined for the differential effects of participants' prior knowledge on the pattern of retention and problem-solving through the four text-supplementation conditions. The results showed that students' prior knowledge levels, categorised as high, medium and low, influenced retention scores ($F (6, 198) = 1.95, p = .07$; observed power = .71) but this effect was not significant. Planned contrasts showed that this trend (the term “trend” and “non significant trends” will only be applied to those statistics where the p value falls between .05 and .10. P values greater than .11 will be deemed “insignificant”) was strongest between the animation and multimedia conditions ($F (2, 66) = 3.92, p = .02$). Prior knowledge did not affect problem-solving scores ($F (6, 198) = .64, p = .70$; observed power = .25).

Specifically, as shown in Table 4, the mean retention scores for high prior knowledge (HPK) learners was consistently higher than for both low (LPK) and medium prior knowledge learners (MPK). LPK learners showed their highest retention scores with illustrations instruction, followed by multimedia instruction. LPK learners however, showed their lowest retention scores with text instruction, followed by animation instruction. On the other hand, HPK and MPK learners achieved their highest retention scores with animation instruction, but performed considerably worse with the multimedia.
Table 4
Retention and Problem-solving Results (z-scores) for Low, Medium and High Prior Knowledge Learners, for the Four Text Supplementation Conditions

<table>
<thead>
<tr>
<th>Learning condition</th>
<th>Retention M</th>
<th>Retention SD</th>
<th>Problem-solving M</th>
<th>Problem-solving SD</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Low Prior Knowledge Learners (n = 30)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Text</td>
<td>-.57</td>
<td>1.39</td>
<td>-.28</td>
<td>1.10</td>
</tr>
<tr>
<td>Illustrations</td>
<td>.18</td>
<td>.78</td>
<td>.18</td>
<td>1.03</td>
</tr>
<tr>
<td>Animation</td>
<td>-.38</td>
<td>1.31</td>
<td>-.08</td>
<td>1.03</td>
</tr>
<tr>
<td>Multimedia</td>
<td>.03</td>
<td>.84</td>
<td>.13</td>
<td>.87</td>
</tr>
<tr>
<td><strong>Medium Prior Knowledge Learners (n = 28)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Text</td>
<td>-.24</td>
<td>1.07</td>
<td>-.38</td>
<td>1.00</td>
</tr>
<tr>
<td>Illustrations</td>
<td>.04</td>
<td>.69</td>
<td>-.03</td>
<td>1.07</td>
</tr>
<tr>
<td>Animation</td>
<td>.18</td>
<td>.78</td>
<td>.03</td>
<td>1.01</td>
</tr>
<tr>
<td>Multimedia</td>
<td>-.32</td>
<td>1.21</td>
<td>-.14</td>
<td>1.05</td>
</tr>
<tr>
<td><strong>High Prior Knowledge Learners (n = 26)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Text</td>
<td>-.09</td>
<td>.91</td>
<td>.09</td>
<td>.97</td>
</tr>
<tr>
<td>Illustrations</td>
<td>.36</td>
<td>.84</td>
<td>.02</td>
<td>.88</td>
</tr>
<tr>
<td>Animation</td>
<td>.54</td>
<td>.48</td>
<td>.25</td>
<td>.77</td>
</tr>
<tr>
<td>Multimedia</td>
<td>.28</td>
<td>.72</td>
<td>.41</td>
<td>.90</td>
</tr>
</tbody>
</table>

Note. Higher z-scores correspond to greater levels of retention and problem-solving.

3.4 Effects of student approaches to learning on learning outcomes

The same repeated measures ANOVAs were examined for the differential effects of students' approaches to learning on the pattern of retention and problem-solving, following text supplementation. The results showed that student approaches to learning did not affect post-instruction retention ($F (15, 198) = .52, p = .93$; observed power = .33) or problem-solving outcomes ($F (15, 198) = .70, p = .78$; observed power = .45). Student approaches to learning were categorised as suggested by Biggs (1987a) into deep, achieving, surface, deep-achieving, surface-achieving, and included a category for students with no predominant approach to learning. However, inspection of the raw data indicates that some SPQ scales (separate
measures of motives and strategies associated with deep, achieving and surface learning) were likely to be associated with learning outcomes.

Repeated measures ANOVAs examined the effects of learning motives and strategies (categorised as "high" and "low" scoring groups, following median splits on SPQ motive and strategy scales) on the dynamics of retention and problem-solving through the four text supplementation conditions. The results showed that there were no significant effects. However, a repeated measures factorial ANOVA showed a significant interaction effect between the achieving motive and achieving strategy scales to influence retention scores ($F (3, 216) = 3.96, p = .01$; observed power = .83), with planned contrasts showing the strongest differences between the text and multimedia conditions ($F (1, 72) = 4.10, p = .05$). These results are presented by the mean retention scores in Table 5. High scorers on the achieving motive and high scores on the achieving strategy, and low scorers on the achieving motive and low scores on the achieving strategy produced considerably better retention following the multimedia instruction, than with text instruction. In contrast, high scorers on the achieving motive and low scores on the achieving strategy, and low scorers on the achieving motive and high scores on the achieving strategy showed less variation on the retention scores in both the text and multimedia conditions.

Table 5
Retention Results (z-scores) for Interactions between High and Low scores on the Achieving Motive and Achieving Strategy (Achy Strat) for Text, and Multimedia Instruction

<table>
<thead>
<tr>
<th></th>
<th>Text</th>
<th>Multimedia</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>M</td>
<td>SD</td>
</tr>
<tr>
<td>High Achieving Motive</td>
<td></td>
<td></td>
</tr>
<tr>
<td>High Achv Strat (n = 24)</td>
<td>-.70</td>
<td>1.23</td>
</tr>
<tr>
<td>Low Achv Strat (n = 18)</td>
<td>.31</td>
<td>.59</td>
</tr>
<tr>
<td>Low Achieving Motive</td>
<td></td>
<td></td>
</tr>
<tr>
<td>High Achv Strat (n = 18)</td>
<td>.10</td>
<td>1.05</td>
</tr>
<tr>
<td>Low Achv Strat (n = 24)</td>
<td>-.51</td>
<td>1.32</td>
</tr>
</tbody>
</table>

Note. Higher z-scores correspond to greater levels of retention and problem-solving.
3.5 The influence of the interactions between approaches to learning and prior knowledge on learning outcomes

Again, the same repeated measures ANOVA was examined for the influence of interaction effects between students' prior knowledge levels and categories of student approaches to learning on the dynamics of learning outcomes in different text supplementation conditions. The results showed no influence of interactions between prior knowledge groups and categories of student approaches to learning on retention and problem-solving outcomes. Furthermore, inspection of the separate SPQ scales (motives and strategies comprising the deep, achieving and surface approaches to learning) showed no significant influence of interactions between prior knowledge and the SPQ motive and strategy scales (categorised into "high" and "low" groups following a median split) on retention and problem-solving.

3.6 Comparing the effects on retention and problem-solving

The results from the previously conducted ANOVAs were reviewed to examine the differential effects of the text supplementation conditions on the dynamics of retention and problem-solving outcomes. This comparison revealed stronger differences between the learning conditions in retention scores ($F (3, 198) = 3.40, p = .02$) than in problem-solving scores ($F (3, 198) = .86, p = .46$). Similar trends were also observed for the differential effects of prior knowledge - categorised as high, medium and low - on the two learning outcomes. The repeated measures factorial ANOVAs indicated that prior knowledge categories influenced retention scores ($F (6, 198) = 1.95, p = .07$), however, this effect was not significant. Prior knowledge did not influence problem-solving scores ($F (6, 198) = .64, p = .70$).

Furthermore, repeated measures factorial ANOVAs showed that student approaches to learning, categorised as deep, achieving, surface, deep-achieving, surface-achieving, and students with no predominant learning approaches did not affect the pattern of retention scores ($F (15, 198) = .52, p = .93$) nor problem-solving scores ($F (15, 198) = .70, p = .78$). The SPQ motive and strategy scales did not influence post-test outcomes. However, the interaction between the achieving motive and achieving strategy significantly influenced retention ($F (3, 216) = 3.96, p = .01$), but did not influence problem-solving ($F (3, 216) = 1.38, p = .26$).
3.7 Associations between prior knowledge, student approaches to learning and learner preferences for visual instruction

One-way ANOVAs were conducted to examine the effects of prior knowledge and student approaches to learning on the Preference for Visual Instruction (PVIS), ascertained through the Learner Feedback Survey. Prior knowledge did not affect PVIS scores ($F(2, 83) = .14, \ p = .87$). However students' approaches to learning showed a significant association with preferences for visual instruction ($F(5, 83) = 2.57, \ p = .03$). A Tukey test (based on alpha = .05) revealed that these differences lie between surface learners and all others, with mean differences indicating that surface approach learners reported a greater preference for visual instruction.

Significant differences were also observed between high and low scorers on the surface motive ($F(1, 83) = 10.55, \ p = .00$) and the surface strategy scales ($F(1, 83) = 14.99, \ p = .00$) on preferences for visual instruction, as measured with the PVIS. An examination of the mean scores in Table 6 indicate that learners with high scores on both the surface motive and surface strategy showed stronger preferences for visual instruction than learners with low scores on the surface motive and surface strategy.

Table 6
PVIS Scores for High and Low Surface Motive and Surface Strategy learners

<table>
<thead>
<tr>
<th>Learners</th>
<th>n</th>
<th>M</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>High Surface Motive</td>
<td>41</td>
<td>34.5</td>
<td>2.93</td>
</tr>
<tr>
<td>Low Surface Motive</td>
<td>43</td>
<td>31.8</td>
<td>4.42</td>
</tr>
<tr>
<td>High Surface Strategy</td>
<td>40</td>
<td>34.8</td>
<td>2.65</td>
</tr>
<tr>
<td>Low Surface Strategy</td>
<td>44</td>
<td>31.6</td>
<td>4.41</td>
</tr>
</tbody>
</table>

Note. Higher scores correspond to greater levels of preference for visual instruction.
3.8 **Summary of statistical results**

Text supplementation conditions influenced learning outcomes on retention but not problem-solving. Closer examination of this result revealed that retention scores were strongest following illustrations instruction, followed by animation.

Prior knowledge levels influenced post-test retention, however, the effect was not significant. Problem-solving outcomes were not influenced by prior knowledge levels.

Students' approaches to learning did not influence post-test retention and problem-solving outcomes. However, interactions between the achieving motive and achieving strategy (comprising the SPQ motive and strategy scales) influenced retention outcomes.

Interactions between students' approaches to learning and prior knowledge did not reach significance.

Results from the Preference for Visual Instruction on the Learner Feedback Survey indicate that prior knowledge did not influence learner preferences for visual instruction. However, students' approaches to learning did influence learner preferences for visual instruction. Specifically, surface learners and high scorers on the surface motive and surface strategy scales showed stronger preferences for visual instruction.
Chapter 4: Discussion

4.1 Overview

The instructional supremacy of visual text supplementation has been well documented in the literature (e.g., Balluerka, 1995; Hayes & Henk, 1986; Mayer & Gallini, 1990). Recently, however, Mayer et al. (1996) found "dynamic-plus" illustrations, comprising a series of illustrations complemented by brief verbal instructions, including labels and annotations, were more effective when introducing explanatory material to novice learners, than illustrations supplemented by a passage of text. However, Mayer et al. (1996) did not examine the role that learner factors other than prior knowledge have on learning, or whether learning is enhanced if the features comprising dynamic-plus illustrations were incorporated within animation. Ollerenshaw et al. (1997) for example, found surface learners, as well as novices, produced better problem-solving when studying explanatory material with a combination of animation and text. The limitations of that study meant, however, that animation was not compared with dynamic-plus illustrations, and the between-subjects design reduced the extent to which the findings could be generalised.

The present study has extended both the Mayer et al. (1996) and Ollerenshaw et al. (1997) research by using a within-subjects experimental design, and comparing animation and illustrations when matching them for completeness of visual and verbal content, as modeled on the Mayer et al. (1996) dynamic-plus illustrations. Learning outcomes were found to be influenced by different text supplementation conditions. Specifically, non significant trends indicate that students' prior knowledge had some influence over this effect. Overall, "visual instruction", namely the illustrations, animation and multimedia conditions, tended to be more beneficial to learning than text instruction. The direction of non significant trends indicate that learners with low prior knowledge of the instructional material showed their greatest improvements in retention with the illustrations instruction. These dynamic-plus illustrations appeared to provide a more effective method of introducing explanatory information to novices. In contrast, the animation condition, which contained comparable visual and verbal information to that of dynamic-plus illustrations, was not as helpful for novice learners as the illustrations instruction. For knowledgeable learners, however, both animation and multimedia appeared to be the most effective methods of instruction. Thus, animated instruction may be more beneficial when revising explanatory material, rather than as a means of introducing new material to learners. Discussion of these findings is, however, speculative because the findings
are based on trends which indicate the direction the results may have taken had they reached statistical significance.

Students' approaches to learning did not influence learning outcomes with the different text supplementation conditions. However, an interaction between the achieving motive and achieving strategy scales comprising the achieving approach to learning did influence retention outcomes following text supplementation. Surface learners showed strong subjective preferences for visual instruction than students with other predominant approaches to learning. These results will be discussed in further detail below.

4.2 The text supplementation conditions and their influence on learning

Consistent with the first hypothesis, studying explanatory material with the four text supplementation conditions did affect students' learning. This was irrespective of the effects that "learner factors", such as prior knowledge and student approaches to learning have on this result. Specifically, better retention of the material was observed for most students when studying with illustrations, followed by animation, as shown by the post-instruction responses in Table 3. Scoring trends for post-instruction problem-solving showed that for most learners, higher problem-solving levels were observed when learning with multimedia instruction. In contrast, trends indicate that the lowest levels of retention and problem-solving outcomes were observed following text instruction.

By virtue of the repeated measures design, the results provide support for inferences about causal relations between the different text supplementation conditions, and their influence on learning outcomes. As such, the findings indicate that visual instruction improves learners' retention and problem-solving outcomes. This offers strong support for the proposal (e.g., Hayes & Henk, 1986; Peeck & Jans, 1987; Wetzel et al, 1994) that instruction, containing visual-spatial adjuncts, improves different learning outcomes. The content and features unique to all three visual instructional conditions and which were modeled on the visual and verbal content of the Mayer et al. (1996) dynamic-plus illustrations, improved students' memory and understanding of the material more so than text instruction. These findings contradict previous research proposing that visual instructional adjuncts, such as illustrations (e.g., Mayer & Anderson, 1992), and animation (e.g., Kozma, 1991) are only helpful when introducing explanatory material to novices. Instead, the present findings suggest that the complement of visual and verbal material contained in the three visual instructional conditions was more effective in conveying
information to all learners, irrespective of their learner characteristics, than text-only instruction.

Some text supplementation conditions, however, produced better learning outcomes than others. In particular, the highest overall retention levels were achieved under the illustrations condition indicating its superiority as a means of memorising the material, for the majority of learners. On the other hand, the highest levels of problem-solving were observed under the multimedia condition, suggesting that a combination of the dynamic features of the animation, with an extended complement of text, was particularly conducive to the deeper understanding of the material, for the majority of learners. That illustrations appeared to offer a stronger basis from which learners could retain information, and multimedia enhanced their understanding of the material, suggests that the different methods of presenting material, the static or dynamic presentations, appear to affect different cognitive processes. However, it is difficult to make further generalisations about this result without looking at the effect different learner factors, such as prior knowledge and student approaches to learning, have on learning outcomes which will be discussed below. The findings, however, support the premise that the content, features and method of presenting instruction influence students' learning.

4.3 The influence of students' prior knowledge on learning

The second hypothesis, that students' prior knowledge of the instructional topics will influence learning outcomes following the different text supplementation conditions was unsupported. Despite this, the direction of non significant trends show that visual instruction improved retention outcomes over the text-only condition for low, medium and high prior knowledge learners (who will henceforth be described as novice, intermediate or experienced/knowledgeable learners), as indicated by the pattern of post-instruction scores, shown in Table 4. Each of the prior knowledge groups, however, showed different learning outcomes following visual instruction. Specifically, novices retained more explanatory information under the illustrations condition, closely followed by the multimedia condition. In contrast, knowledgeable learners, unexpectedly, showed their highest levels of retention following animation.

In general, the direction of the non significant post-instruction scores for novice learners offers cautious support for the well documented findings (e.g., Balluerka, 1995; Mayer, 1989; Mayer & Gallini, 1990) that illustrations improve learning, such as retention, because they facilitate the cognitive processes that are associated with these learning outcomes. The "dynamic-plus" illustrations (Mayer et
al., 1996) comprising a series of sequential illustrations containing complementary verbal instructions such as labels and annotations, produced better memory and understanding than the three remaining text supplementation conditions. These illustrations appeared to offer a better instructional framework from which novices could build complete visual and verbal mental representations, therefore helping them retain the material under instruction. In accordance with the proposals of Mayer et al. (1996, p.65), the concise and coherent manner of presenting the visual material (the pictorial depiction) and the verbal material (the labels and annotations) in these illustrations may have helped students build complete visual and verbal mental representations of this material, which they called upon when answering the retention questions.

Apart from re-examining the Mayer et al. (1996) findings, the current research extended the instructional boundaries of their study to examine whether the dynamic features of animation, which were matched for completeness of visual and verbal material and modeled on the dynamic-plus illustrations, would improve learning outcomes over the illustrations-only condition. Based on the direction of the post-test trends, animation appeared to be the least effective method of visual instruction for novices. They retained less explanatory information than with dynamic-plus illustrations, or multimedia. Although this result did not reach statistical significance, these trends are important because they indicate that the features differentiating animated instruction from illustrations instruction, namely apparent motion and sound, appear to produce no greater improvements to memory or understanding for novices.

The trends do not support the large body of research (e.g., Kozma, 1991; Rieber & Kini, 1991; Williamson & Abraham, 1995) advocating that the dynamic and realistic properties of animation provide a more comprehensive and superior model of visual instruction, than static depictions. Instead, the direction of the trends provide cautious support for Mayer and Anderson's (1992) claims that it is the manner in which the visual and verbal instruction is incorporated within the animation, rather than its dynamic properties per se, that increases a learners' retention and understanding. Thus, while animation appears to offer a more effective method of instruction than text-alone, the results indicate that animation does not appear to be a better method for presenting explanatory information to novices than well constructed dynamic-plus illustrations.

Contrary to expectation, the direction of trends indicate that better learning outcomes were observed for knowledgeable learners following visual instruction. In particular, higher retention levels were observed under the animated instruction,
suggesting that this may be a better instructional method from which most knowledgeable learners can memorise the material. This finding conflicts with previous research (e.g., Mayer, 1989; Mayer & Gallini, 1990; Mayer & Anderson, 1992) proposing that visual instruction does not improve learning for knowledgeable learners because they recall their own mental image of this information, which they built at an earlier time. Consequently, the recent Mayer studies (e.g., Mayer et al., 1996) have chosen solely to examine the influence that novice learners have on learning outcomes, following different instructional presentations.

The direction of the present trends suggests, however, that this explanation may be incorrect, at least with reference to animated instruction. Specifically, the "complete" visual and verbal complement of instruction contained in the animation may have provided knowledgeable learners with a comprehensive "reintroduction" of the information which not only refreshed, but also enhanced their visual and verbal memory of the material. This in turn increased the chances that comprehensive visual mental representations of the material were constructed. However, the dynamic properties of animation must also play a significant role in learning for knowledgeable learners, otherwise post-test retention scores within the animation and illustrations conditions would have been comparable. The features which are unique to animation, namely the dynamic qualities and sound/narration, seem to offer additional benefits to knowledgeable learners other than just the comprehensive presentation of the visual and verbal instruction. One likely explanation for this is that the pace at which the instruction unfolds is beneficial to the learning processes of knowledgeable learners. This proposal has been offered by Kozma (1991) in response to television instruction, which shares many similarities with animated presentations. Kozma suggests that the rapidity of the televised material facilitates learning for knowledgeable learners because they can encode the material at a pace which is supplemented by their prior knowledge.

Although the results did not support this second hypothesis, the post-test trends for retention indicate the direction the results are likely to have taken had they reached statistical significance. The limitations of this study, namely poor measures and weak manipulation of the variables, have limited the power of the present results. Firstly, prior knowledge may have been more accurately measured using a pre-test which evaluated students' prior knowledge and understanding of the instructional topic, rather than relying on a self-appraisal of their knowledge. In this study, the questions comprising the pre-test measure were similar to those employed in the Mayer studies (e.g., Mayer & Gallini, 1990; Mayer & Sims, 1992; Mayer et al., 1996), however the one weakness with this measure was that there was no means of
validating students' responses to these questions to ascertain how accurate and comprehensive their understanding of the topics was. Therefore, developing a measure that evaluates prior knowledge levels would not only improve the accuracy and precision in determining students' prior knowledge, but would provide a comparable measure from which to examine the advances made in post-instruction learning, following each text supplementation condition.

Secondly, the validity of the pre-test measure may have been reduced because a single composite score was used to measure students' prior knowledge of all four Biology topics. Although the pre-test was found to be a reliable measure, the test itself was not capable of detecting differences in knowledge levels between the four different topics. Furthermore, because the pre-test measure gauged students' prior knowledge for four topics rather than just one, as in the Ollerenshaw et al. (1997) study, instrument reliability data for this measure could not be obtained. To avoid this problem in future research, it is essential that a different set of pre-tests, each comprising a battery of topic specific questions, are developed to ensure that prior knowledge is measured for each topic of instruction.

Furthermore, the post-instruction measures of retention and problem-solving may have reduced the power of the present results. Firstly, the reliability of these measures, particularly for problem-solving, was relatively poor, as indicated by the alpha levels presented in Table 2. Secondly, the structure of the post-test questions relied on a different memory tasks to that used in earlier studies, thus reducing the extent to which comparisons could be made between post-test results in this and other studies. In this study, post-instruction comprised multiple-choice questions which measure recognition memory. However, short answer responses measuring memory recall were employed in the Mayer et al. (1995; 1996) and Ollerenshaw et al. (1997) studies. Thirdly, converting all post-test raw scores into z-scores may have further limited the variance. To address these problems in future research, it is recommended that (a) the structure of the current post-instruction measure is refined in order that the reliability and validity of this measure is improved, and (b) raw scores are not converted to z-scores.

In summary, the data provide further insight into the association between prior knowledge and the instructional efficacy of the different text supplementation conditions. In particular, the direction of non significant trends indicate that presenting the same visual and verbal material through static illustrations or animated sequences may produce different learning outcomes. In spite of the growing interest and development of educational multimedia often comprising animation, the direction of the present trends suggest that animation may not benefit all learners.
However, given that these trends only show the likely direction that the results would have taken had the findings been statistically significant, further research is necessary in order to qualify these trends.

4.4 Student approaches to learning and the influence of these approaches on learning

The third hypothesis predicted that student approaches to learning will influence learning outcomes following the different text supplementation conditions. This was not supported by the present results. The variables comprising the construct of student approaches to learning, as well as the aggregate measure of students' approaches, as suggested by Biggs (1987a, 1987b), did not influence learning outcomes.

Bearing in mind that no significant results were elicited to support this hypothesis, no further insight was gained into how students' approaches to learning will influence learning outcomes. However, because of the limitations in the current study, which will be discussed in more detail later, the lack of significant findings does not imply that either Biggs' (1987a, 1991) conceptualisation - that student approaches to learning are associated with performance outcomes - or the Ollerenshaw et al. (1997) research findings are any less valid. Instead, a stronger design removing many of the limitations of the present study is likely to offer a better insight into the influence of student approaches to learning over learning outcomes.

As expected, however, different methods of instruction did not show any differential impact on deep learners and achieving learners. However, an interaction between the achieving motive and achieving strategy scales - both of which comprise the achieving approach to learning - in affecting retention outcomes, was observed. The interaction between these two scales influenced retention outcomes for text, and multimedia instruction. Specifically, learners with strong achieving motives and strong achieving strategies, and learners with weak achieving motives and weak achieving strategies showed better retention scores when learning with multimedia instruction. This result offers tentative support for the proposal that students motives and strategies comprising the learning approaches are associated with learning outcomes. The present interactions suggest that multimedia instruction is a more comprehensive method of instruction for some student approaches to learning, than others.

Limitations with the current study design may have prevented some significant results from being obtained. Firstly, certain shortcomings were identified in the interpretation of the Study Process Questionnaire. For example, the number of
students representing each of the five predominant learning approaches (deep; achieving; surface; surface-achieving and deep-achieving) was relatively small. Thus, the sample may not have been large enough to represent the true effect that these learning approaches had on learning outcomes. While it was essential that all other categories comprising Biggs' (1987) student approaches were examined in addition to the three "main" approaches - deep, achieving, surface - this may have been made at the expense of reducing the statistical power of the results. Thus, in future studies where all five approaches to learning (deep, achieving, surface, deep-achieving, surface-achieving) are to be examined, the sample size needs to be increased, with near equal numbers of students in each group.

Another limitation with the present findings relates to the restrictive nature of the Study Process Questionnaire norms which may have been too narrow for this study. SPQ norms were developed for only three tertiary disciplines, namely Arts, Education and Science. Therefore, categorising students from outside these disciplines sometimes proved difficult, and may have resulted in some students being incorrectly categorised. Although Biggs (1987b, p.21) himself agrees that norms from other discipline areas across the university need to be developed, this proposal was made over ten years ago, and still no new normative data has been provided. With newer technology-based disciplines growing in the tertiary arena, the call for more diverse normative sampling is not only necessary, but integral if the SPQ is to be incorporated in research and educational settings in future.

Further, the limitations discussed in the previous hypothesis pertaining to the post-instruction measures are likely to have reduced the power of results. The post-instruction measures, therefore, need refining in order to improve its reliability and validity.

Finally, the lack of results to support this hypothesis reinforces the need for caution when interpreting the SPQ scores, particularly the combined scores that comprise Biggs' (1987) approaches to learning. As mentioned earlier, this study has suggested a refined mechanism for measuring student approaches to learning by separately analysing the motive and strategy scores on the SPQ. Combining the motive and strategy scores to gauge student approaches to learning appears to reduce the true effects of these different variables in representing the constructs of student approaches to learning. On the basis of these findings it is recommended that future research examines the SPQ scores for the combined approaches to learning, as well as separate scores for each motive and strategy.
4.5 **Prior knowledge and approaches to learning: Interaction effects**

The fourth hypothesis predicted that the two independent variables examined in the earlier hypotheses, prior knowledge and student approaches to learning, would interact to influence learning outcomes. Despite this, interactions between student approaches to learning and prior knowledge did not influence the effect of learning conditions on learning outcomes.

Some of the limitations discussed for the previous two hypotheses help to explain why significant results supporting this hypothesis were not obtained. Specifically, the pre-test measure of prior knowledge relied on students' subjective rating of their prior knowledge, rather than gauging prior knowledge using a quantifiable and objective measure. In addition, the SPQ norms were too narrow to accommodate the diverse range of subject disciplines from which the students were drawn. Furthermore, weak reliability and validity of the post-instruction measures was observed, while the use of z-scores was likely to have resulted in limited variance. These limitations help explain why statistically significant results were not observed. To examine the extent to which prior knowledge and student learning approaches interact, future research needs to address the previously mentioned limitations. Further, changes to the present research methodology would increase the chances of detecting interactions between these two learner factors. This may include extending the present within-subjects design so that each student is exposed to the four instructional conditions twice - once with unfamiliar information, and then with familiar information. Results would, therefore, be gauged for each student as novice and expert learner. This would improve the statistical power so that more general conclusions can be made about the results.

4.6 **Differences between the learning outcomes: Retention and problem-solving**

To date, text supplementation conditions, students' prior knowledge and students' approaches to learning have each had a varying influence on learning outcomes, measured for retention and problem-solving. Indeed, the pattern of retention and problem-solving scores offers weak support for the fifth hypothesis, that retention of the instructional material will be stronger than on problem-solving. Specifically, learning with the different text supplementation conditions, and post-instruction response trends for prior knowledge groups, and interactions between constructs measuring motive and strategy scales for student approaches to learning showed stronger differences in retention outcomes, than in comparison to problem-solving.

One possible explanation for the observed differences between retention and
problem-solving outcomes is that the text supplementation conditions facilitated students' memory for the instructional material, more than their understanding. With reference to the cognitive model of multimedia learning (Mayer et al., 1996), stronger retention outcomes indicate that visual and verbal mental representations were facilitated by some text supplementation conditions, particularly illustrations instruction. Specifically, the visually rich content of the visual presentations accompanied by the verbal explanations, may have facilitated the building of comprehensive visual and verbal mental representations, thus fostering students' memory of this material. However, cognitive processes associated with the other three stages of "multimedia learning", which is measured by their ability to problem-solve, appear to be less affected by these same text supplementation conditions. Thus, according to one aspect of the Mayer et al. (1996) cognitive model of multimedia learning, the referential connection that links the verbal mental representations with the visual mental representations which complement learning, and facilitate understanding, appears not to have occurred.

The strength of this explanation is, however, undermined because of limitations in the methodology of the current study. These limitations reduce the extent to which comparisons can be made about differences between post-instruction retention and problem-solving. Firstly, the observed differences between retention and problem-solving scores may have occurred because of differences in difficulty between the retention questions and the problem-solving questions. The reliability of the problem-solving measure was also weaker than the reliability of the retention measure, further exaggerating the observed differences between the two post-instruction measures. Secondly, differences in magnitude between retention and problem-solving outcomes is confounded by the pre-test measure. This is because the pre-test measure only gauged students' self appraisal of their prior knowledge, rather than measuring their level of retention and understanding of the instructional material, prior to testing. Had such a pre-test measure been used, more direct comparisons between post-instruction retention and problem-solving following text supplementation could have been made.

In light of these methodological flaws, it is highly recommended that in future research, a pre-test measure is developed that quantifies students' initial memory and understanding of the instructional material. This would enable researchers to more accurately compare advances in learning following text supplementation.

Finally, the multiple choice format for answering all post-instruction questions, may have reduced the power of the present findings. Although the content
of each of the post-instruction questions was comparable to those asked in the Mayer studies (e.g., Mayer & Gallini, 1990; Mayer & Anderson, 1992; Mayer et al., 1996), multiple choice questions, rather than short answer formats, were adopted. The present format was chosen as the most appropriate method for gauging learning outcomes because of the length of time to test all students for this within-subjects experimental design, and the time constraints of the students. In particular, the retention post-instruction questions may have been better presented as a series of short answer questions in an attempt to reduce any shortcomings that may be associated with multiple choice answer formats, such as word recognition, or guessing the correct answer (Kaplan & Saccuzzo, 1993). Although these are general issues relating to these learning outcome measures, they are none the less important and need to be addressed in future research to further increase the likelihood of obtaining reliable and valid measures of retention and problem-solving.

4.7 Text supplementation condition preferences

The sixth hypothesis, that student approaches to learning would influence students' preferences for visual instruction, was supported by the results. Specifically, surface learners responded differently to the PVIS questions on the Learner Feedback Survey, rating visual instruction and their features, such as narration and labeled diagrams, more highly than other learners. In contrast, students' prior knowledge levels showed no association with their preference for visual instruction. For example, novices showed no greater preference for visual instruction than their more knowledgeable peers.

Given that surface learners showed stronger preferences for visual instruction than learners with other approaches to learning, suggests that these three text supplementation conditions had a positive influence over their motives and strategies for studying. Biggs (1987a, 1987b, 1991) proposed that surface learners are externally motivated to complete their studies and as such are influenced by situational factors, including the nature of the learning task, the teaching method and so on. Typically, these students do not want to study too hard, but at the same time try to pass the set requirements of the course. They often do this by embracing the essential message of the instructional material by relying on their memory. Surface learners may perceive animation and illustrations instruction as simpler to understand, and therefore "easier" methods from which to learn. For example, the information comprising the visual instructional conditions was presented in a "concrete" manner, and the instructional topic were immediately recognisable by the visual image contained in the animation and illustrations. Further, these depictions
were not accompanied by excessive or insignificant verbal material. Instead, verbal
instructions were succinct, and complemented the visual instruction, which may also
be conducive to the learning motives and strategies of surface learners.
Consequently, the conditions may have been viewed more favourably by these
learners, as reflected by their strong preferences for the visual instruction.

This explanation is consistent with Cowie-Scott's (1994) findings that "weak
achieving" students - who were identified in Cowie-Scott's research as surface
learners - held computerised instruction in high regard. Although attitudes towards
computer instruction per se, were not gauged in this study, students' preferences for
these instructional presentations could be interpreted as a measure of their acceptance
of computerised instruction. For instance, it would be unlikely that students would
prefer multimedia, animation or illustrations if they did not perceive the computer as
a beneficial medium for presenting this instruction. This offers yet another plausible
explanation why students rated the instructional conditions as highly as they did.

In addition to these results, students with strong surface motives and strong
surface strategies also rated the visual instruction highly. For these learners,
preferences for visual instruction may be a reflection of their intrinsic interest, and
thus, satisfaction with the visual instruction. This is because visual instruction may
have altered their learning motivation which had a positive affect on their learning
experience, and thus their preferences for these instructional conditions.

In contrast, students with other learning approaches did not share the same
preferences for visual instruction. As predicted, deep and achieving learners did not
show strong preferences for the visual instruction. Because deep learners are
intrinsically interested in their studies they may have been unaffected by the
presentation of the information. This may be because their interest and attention was
focused on the content of the information contained in these presentations, rather
than the physical presentation of the material. This explanation is consistent with
Biggs (1987b), who proposed that deep learners are affected by personal factors
associated with learning such as experience, interest in the material and so on, rather
than situational factors such as the "instructional set" or the teaching approach (p. 5-
6). Similarly, achieving learners showed no preferences for visual instruction.
Because these learners pursue their studies for the personal satisfaction which are
achieved through good grades, they may not prefer one visual instructional condition
over another because they strive to achieve a high level of success with all learning
situations, regardless of the form in which this information appears.

Similarly, students' prior knowledge did not influence preferences for visual
instruction. Contrary to expectation, novices did not prefer visual-based instruction
more than their knowledgeable peers. It was expected that inexperienced learners would perceive the value of the visual and verbal material contained in the animation and illustrations as helpful to their learning, and rate it accordingly. One explanation why this did not occur was that novice learners were restricted only by their knowledge of information, and not their characteristic learning behaviour, as was the case with student approaches to learning. Because of this they may be less influenced by their preferences for the instructional presentations than they were for the content and quality of the instruction.

Overall, the PVIS offered a meaningful measure of learner preferences for visual instruction, relevant to this study's experimental setting. However, an obvious shortcoming with this measure was that it offered only an aggregate score of learner preferences for visual instruction. It did not obtain specific scores for each method of presentation, and students' perceptions of the instructional medium through which the information was presented. Developing the PVIS further, to incorporate a richer, more specific measure of learner preferences for the different text supplementation conditions would be an advantage in future studies.

4.8 Implications of the findings

The implication of the significant results combined with the non significant trends is that learners study better with different instructional presentations. Specifically, all learners showed an overall improvement in learning outcomes following visual instruction. Furthermore, some technological instructional presentations, for example multimedia and animation, failed to improve students' learning. Non significant trends suggest that while experienced learners showed stronger learning outcomes with these two presentations, novices tended to do better with illustrations instruction. While confirmation of these trends is required in future research, implications for the development and application of multimedia software programmes can be offered.

Despite the sophisticated features, such as sound, narration and motion, animation does not offer a panacea for presenting instruction for all learners. The direction of the non significant trends suggest that short, animated learning sequences should only be offered to those students who are "equipped" to deal with the material, such as knowledgeable learners, or those who may benefit from the animated instruction. This proposal relates to the findings that not all students showed improvements in their learning following the two text supplementation conditions that contained animation. Some students showed no benefits when learning with these presentations, for example, non significant trends suggest that
novices tended to show better learning with illustrations. Thus, not all learners should be expected to ingest more information with animation simply because it contains a greater number of features.

Secondly, in order that animated instruction is utilised to its full potential, these short animated segments containing explanatory instruction need to incorporate a minimum level of visual and verbal content. Frequently, educational software programs offer so called "instructional animation", but verbal instruction complementing the animation, such as labels or accompanying narration, is not available or incorporated within these presentations. Thus, animation needs to contain comparable visual and verbal instruction whereby the narration and labels are coordinated with the animation to facilitate dual-coding.

4.9 Recommendations for future research

On the basis of the present findings, various recommendations for future research can be offered in order to qualify the non significant trends, and extend the potential of this research. The results suggest that the presentation of instruction needs to be further examined, as do the learner factors, particularly student approaches to learning, in this context. The research has drawn attention towards limitations with the present study design and measures, and has outlined suggestions for future research in this area.

In summary, the limitations that have been identified for each hypothesis, need to be addressed in future research. Firstly, a quantifiable pre-test measure should be developed, to assess students' prior knowledge for each instructional topic. The test of prior knowledge was developed in accordance with the pre-test measures adopted in the Mayer studies (e.g., Mayer & Gallini, 1990; Mayer et al., 1996), but it offers a less than accurate measure of prior knowledge because it relies solely on students' self-assessment of their prior domain knowledge. Furthermore, making comparisons between retention and problem-solving following text supplementation was limited because the pre-test could not quantify students' advances in learning. It was therefore strongly recommended that a quantifiable measure of prior knowledge be developed. Also, acquiring a separate measure of prior knowledge for each topic of instruction rather than a composite score - even where the topic comprises various sub-categories - would be helpful in categorising students according to their true level of prior knowledge. It is strongly recommended that the pre-test is altered to accommodate the previously mentioned recommendations to improve the reliability and validity of the measure.
Secondly, refinement of the post-instruction measures is critical if the multiple-choice format of questions is to be employed in future research. Limitations with the current post-instruction format including weak reliability and validity, and changes in post-instruction format between this study and that of Mayer et al. (1996) and Ollerenshaw et al. (1997) are likely to have contributed to a reduction in power. Improving the reliability of the post-test items will likely result in fewer items being removed before conducting the analyses, thus reducing the likelihood that scores will need to be converted to z-scores, which limits the variance of scores.

If used in future research, care also needs to be taken when interpreting the scales and norms comprising the SPQ. For instance, the SPQ norms may have been too narrow in the context of this study. It was suggested, therefore, that developers of the SPQ expand and upgrade the norms so that a broader range of study disciplines are available. In light of the interactive tendencies between motive and strategy scores measuring student approaches, a larger sample of students is required in future research.

Alterations to the present research methodology may also be necessary in order to accommodate the future research directives that are to be discussed as follows. Specifically, the present findings pave the way for future research in this area. One question arising from the current research is whether similar learning outcomes would produce more significant findings if each of the four text supplementation conditions were incorporated within a tertiary class or tutorial, as a supplementary aid to the tutor's instruction. To refer to a remark made by Mayer et al. (1996, p. 73), learning with short instructional summaries may be quite different from learning from instructional summaries which are incorporated within a lesson/tutorial. Learning outcomes may be further affected if studying from a learning sequence of longer than a few minutes duration.

Many of these suggestions would be effectively addressed within a longitudinal study where the different text supplementation conditions could be incorporated and rotated at intervals within the tutorial setting, over a period of one or two semesters. This would extend the present findings and provide a stronger basis from which to compare gains in learning. Thus, the need to examine whether transference of results occurs in a more realistic, rather than experimenter controlled setting, is essential. It has also been suggested that learner interaction with the material may have both a positive (e.g., Simpson, 1994) and negative (e.g., Barker & Tucker, 1990) influence over learning outcomes. Thus, it is important to examine the impact learner control has on the present findings by including an additional text
supplementation condition where the learner can interact freely with the animated sequence to control the amount and type of information they view.

In summary, therefore, the present study has discovered some non significant trends but there is still some question as to whether the different text supplementation conditions will play a more prominent role within the classroom environment, over a longer period of time. Will the results yielded after 5 minutes of testing be similar after fifteen minutes instruction, for instance? Future papers needs to address these questions if research in this area is to progress.

4.10 Summary and conclusion

The results of this study have extended our understanding of the contribution "learner factors" have on learning short segments of explanatory material with different text supplementation conditions. Overall, the results support the well documented supremacy of visual instructional presentations. Specifically, animation, illustrations and multimedia - for which the content of the animation (contained in both the animation and multimedia conditions) and illustrations were modeled on the Mayer et al. (1996) "dynamic-plus" illustrations - tended to produce better learning outcomes than text-alone instruction. However, no single method of visual instruction produced consistently superior learning outcomes.

Despite the enthusiasm surrounding animation instruction and multimedia instruction, the present non significant trends suggest that it is not as helpful to novice learners as more conventional text supplementation methods. As shown by the trends in post-instruction scores for novice learners, instruction with illustrations comprising the properties of the Mayer et al. (1996) dynamic-plus illustrations consistently improved their retention and problem-solving than with both multimedia and animation instruction. Despite closely matching the instructional content of the illustrations and animations, it appears that the novel and dynamic qualities of animation offer few instructional advantages for novices. Thus, constructing coordinated and complementary visual/verbal illustrations which allow the learner to view the material at their own learning pace is important when introducing novices to unfamiliar, explanatory information segments.

The post-instruction outcomes show that student approaches to learning did not appear to play a role in learning outcomes. It was proposed, therefore, that the limitations with the current study design may have prevented the results from reaching a significant level of effect.

In conclusion, the findings suggest that considerable care needs to be taken by educators and researchers alike when using multimedia instruction within education.
Firstly, short segments of instructional animation need to contain a minimum level of visual and verbal information, comparable to that of the Mayer et al. (1996) dynamic-plus illustrative summaries. Secondly, for knowledgeable learners and high surface motive learners, animation needs to be accompanied by an extended passage of text. Finally, animation should not be given to novice learners, since they are better able to learn with the static illustrations instruction. Future research is necessary in order to qualify these findings and the direction of non significant trends, and extend this area of research so as to fully understand the impact of the learner factors, particularly student approaches to learning, when studying with different text supplementation conditions.
References


Appendix A
Knowledge pre-test questionnaire

Please rate you **experience and/or knowledge** in performing the following activities:

1 = none   2 = a little   3 = average   4 = above average   5 = substantial

1. How much knowledge/understanding do you have of the anatomy and physiology of the human eye? 1 2 3 4 5
2. How much knowledge/understanding do you have of the anatomy and physiology of the human ear? 1 2 3 4 5
3. How much knowledge/understanding do you have of the processes of photosynthesis? 1 2 3 4 5
4. How much knowledge/understanding do you have of cell division (eg: meiosis; mitosis)? 1 2 3 4 5
5. How much knowledge/understanding do you have of genetics? 1 2 3 4 5

Please respond to the following activities by circling the appropriate response:

1. Did you study any biology after 1996? yes / no
2. Do you understand the workings of a microscope? yes / no
3. Do you know who Gregor Mendel is? yes / no
4. Have you ever spent time in a science laboratory? yes / no
5. Do you know how a DNA strand replicates? yes / no
6. Do you know what a chromosome is? yes / no
Appendix B
Study Process Questionnaire (SPQ); question booklet and answer sheet
What the SPQ is About

On the following pages are a number of questions about your attitudes towards your studies and your usual ways of studying.

There is no right way of studying. It all depends on what suits your own style and the courses you are studying. The following questions have been carefully selected to cover the more important aspects of studying. It is accordingly important that you answer each question as honestly as you can. If you think that your answer to a question would depend on the subject being studied, give the answer that would apply to the subject(s) most important to you.

How to Answer

For each item there is a row of boxes for a five-point scale on the Answer Sheet:

A response is shown by marking one of the five boxes for an item.

This underlines the desired number.

The numbers stand for the following responses:

5 — this item is always or almost always true of me
4 — this item is frequently true of me
3 — this item is true of me about half the time
2 — this item is sometimes true of me
1 — this item is never or only rarely true of me.

Example

I study best with the radio on.

If this was almost always true of you, you would underline 5 thus:

5 4 3 2 1

If you only sometimes studied well with the radio on, you would underline 2, thus:

5 4 3 2 1

Underline the number on the Answer Sheet that best fits your immediate reaction. Do not spend a long time on each item: your first reaction is probably the best one. Please answer each item.

Do not worry about projecting a good image. Your answers are CONFIDENTIAL.

Thank you for your co-operation.
Study Process Questionnaire

Underline one number for each item.

1  I chose my present courses largely with a view to the job situation when I graduate rather than out of their intrinsic interest to me.

2  I find that at times studying gives me a feeling of deep personal satisfaction.

3  I want top grades in most or all of my courses so that I will be able to select from among the best positions available when I graduate.

4  I think browsing around is a waste of time, so I only study seriously what’s given out in class or in the course outlines.

5  While I am studying, I often think of real life situations to which the material that I am learning would be useful.

6  I summarize suggested readings and include these as part of my notes on a topic.

7  I am discouraged by a poor mark on a test and worry about how I will do on the next test.

8  While I realize that truth is forever changing as knowledge is increasing, I feel compelled to discover what appears to me to be the truth at this time.

9  I have a strong desire to excel in all my studies.

10 I learn some things by rote, going over and over them until I know them by heart.

11 In reading new material I often find that I'm continually reminded of material I already know and see the latter in a new light.

12 I try to work consistently throughout the term and review regularly when the exams are close.

13 Whether I like it or not, I can see that further education is for me a good way to get a well-paid or secure job.

14 I feel that virtually any topic can be highly interesting once I get into it.

15 I would see myself basically as an ambitious person and want to get to the top, whatever I do.

16 I tend to choose subjects with a lot of factual content rather than theoretical kinds of subjects.
17 I find that I have to do enough work on a topic so that I can form my own point of view before I am satisfied.

18 I try to do all of my assignments as soon as possible after they are given out.

19 Even when I have studied hard for a test, I worry that I may not be able to do well in it.

20 I find that studying academic topics can at times be as exciting as a good novel or movie.

21 If it came to the point, I would be prepared to sacrifice immediate popularity with my fellow students for success in my studies and subsequent career.

22 I generally restrict my study to what is specifically set as I think it is unnecessary to do anything extra.

23 I try to relate what I have learned in one subject to that in another.

24 After a lecture or lab I reread my notes to make sure they are legible and that I understand them.

25 Lecturers shouldn't expect students to spend significant amounts of time studying material everyone knows won't be examined.

26 I usually become increasingly absorbed in my work the more I do.

27 One of the most important considerations in choosing a course is whether or not I will be able to get top marks in it.

28 I learn best from lecturers who work from carefully prepared notes and outline major points neatly on the blackboard.

29 I find most new topics interesting and often spend extra time trying to obtain more information about them.

30 I test myself on important topics until I understand them completely.

31 I almost resent having to spend a further three or four years studying after leaving school, but feel that the end results will make it all worthwhile.

32 I believe strongly that my main aim in life is to discover my own philosophy and belief system and to act strictly in accordance with it.

33 I see getting high grades as a kind of competitive game, and I play it to win.

34 I find it best to accept the statements and ideas of my lecturers and question them only under special circumstances.

35 I spend a lot of my free time finding out more about interesting topics which have been discussed in different classes.
36 I make a point of looking at most of the suggested readings that go with the lectures.

37 I am at college/university mainly because I feel that I will be able to obtain a better job if I have a tertiary qualification.

38 My studies have changed my views about such things as politics, my religion, and my philosophy of life.

39 I believe that society is based on competition and schools and universities should reflect this.

40 I am very aware that lecturers know a lot more than I do and so I concentrate on what they say is important rather than rely on my own judgment.

41 I try to relate new material, as I am reading it, to what I already know on that topic.

42 I keep neat, well-organized notes for most subjects.
STUDY PROCESS QUESTIONNAIRE

Name: ____________________________

College/University/Institution: ____________________________

Faculty/School: ____________________________

Course: ____________________________

Favourite subject: ____________________________

Today's date: / / 19

INSTRUCTIONS

Completely fill the oval for each question.

Only use a 2B pencil.

Do not use blue/black or red pens.

Completely erase any errors or stray marks.

SEX

5 means ... Always or almost always true of me

4 means ... Frequently true of me

3 means ... True of me about half the time

2 means ... Sometimes true of me

1 means ... Never or only rarely true of me

N.B. ITEM NUMBERS GO ACROSS IN GROUPS OF THREE.

SM 1 2 3 4 5 6 7 8 9

SS 10 11 12 13 14 15 16 17 18

DM 19 20 21 22 23 24 25 26 27

AM 28 29 30 31 32 33 34 35 36

AS 37 38 39 40 41 42

DATE OF BIRTH

Day  Month  Year

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Appendix C

Post-instruction questions for each of the four instructional topics (ear, eye, mitosis, photosynthesis)

Please circle the correct response from each of the following multiple choice questions. There is only one correct response to each question. If you do not know the answer, feel free to have a guess:

1. Which of the following elements is contained within the outer ear:
   a. malleus, incus and stapes
   b. auricle, auditory canal and fluid
   c. auricle, auditory canal and ear drum
   d. auricle, cochlea and nerve fibres

2. The inner ear contains the cochlea that houses the sound analysing cells which:
   a. transmit signals to the incus and stapes
   b. is connected to the brain, via the auditory nerve
   c. are transmitted to the middle ear
   d. are analysed by the auricle

3. When the ear drum vibrates, the sound waves are:
   a. detected by nerve fibres which transmit signals to the brain
   b. amplified and transmitted to the outer ear
   c. reduced as they enter the cochlea
   d. amplified and transmitted by the middle ear to a membrane in the wall of the cochlea

4. Nerve fibres are frequency sensitive. Where would the lowest frequencies of sound be detected:
   a. on the surface of the cochlea
   b. at the opening of the cochlea
   c. at the deepest part of the cochlea
   d. none of the above
5. Sound waves are initially transmitted by the air in the outer ear. Which other medium transmits the sound waves in the inner ear:
   a. bone  
   b. fluid  
   c. cartilage  
   d. soft tissue

6. How would wax in the outer ear cause deafness:
   a. by blocking transmission of the soundwaves  
   b. by preventing movement of the malleus, incus and stapes  
   c. by reflecting the sound out of the ear  
   d. none of the above

7. What does air pressure have to do with hearing:
   a. sound waves enter the cochlea and alter the air pressure, allowing signals to be transmitted to the brain  
   b. the air pressure produced by the sound waves is analysed by the incus, malleus and stapes, and is then transmitted to the brain, via the nerve fibres  
   c. air pressure in the middle ear is transmitted to the brain, via the nerve fibres  
   d. sound waves cause alterations in air pressure which is sensed by the eardrum and is transmitted to the brain

8. How would the ear's functioning be affected if the nerve fibres died?
   a. the volume of sound would be reduced  
   b. temporary deafness would occur  
   c. sound waves would not be transmitted to the brain  
   d. none of the above
Please circle the correct response from each of the following multiple choice questions. There is only one correct response to each question. If you do not know the answer, feel free to have a guess:

1. When light passes into the eye, it enters through an opening called the:
   a. iris
   b. cornea
   c. sclera
   d. pupil

2. The sclera is:
   a. the transparent membrane covering the eye
   b. attached to the iris and opens and closes in response to light
   c. it the white outer covering of the eye
   d. sends electrical signals that travel along the optic nerve to the brain

3. When you look at an object, the rays of light which are reflected off the object enter the eye and pass through the lens. What then happens:
   a. the lens straightens the light so that rays originating from one point on the object diverge to two points on the retina
   b. the lens bends the light so that rays originating from one point on the object converge to a single point on the retina
   c. the retina bends the light so that rays originating form one point on the object converge to a single point on the lens
   d. none of the above

4. To focus on nearby objects, the lens changes shape and:
   a. becomes smaller in size, causing the light rays from the object to converge on the retina
   b. flattens, causing light which has passed through the lens to become more focused on the retina
   c. thickens, causing light rays from the object to converge on the retina
   d. none of the above

5. What would happen to the function of the eye if the lens looses its flexibility:
   a. the eye will be able to focus, however, colour blindness will occur
   b. the eye will be unable to focus
   c. the eye will be unable to move
   d. none of the above
6. How does the eye respond to darkness:
   a. the iris dilates
   b. the pupil constricts to allow more light to enter the retina
   c. a & b
   d. the pupil dilates to allow more light to enter

7. What would happen if the retinal cells died:
   a. an image would be inadequately formed on the retina, causing blindness to varying degrees
   b. the pupil would be unable to open and close in response to the level of light
   c. the lens would be incapable of focusing on an object
   d. none of the above

8. Which structure in the eye might be specifically helped by wearing spectacles:
   a. retina
   b. lens
   c. pupil
   d. pupil and lens
Please circle the correct response from each of the following multiple choice questions. There is only one correct response to each question. If you do not know the answer, feel free to have a guess:

1. Mitosis is the process whereby:
   a. new genetic information is formed
   b. a body cell divides producing 2 new daughter cells
   c. genetic information is replicated
   d. both b & c

2. During mitosis, the membrane surrounding the nucleus changes to become:
   a. thicker
   b. less distinct
   c. thinner
   d. spindly

3. Two identical parts of each double chromosome are called:
   a. spindle fibres
   b. chromatids
   c. centrioles
   d. membranous material

4. What happens to the chromosomes just before cell division. Do they;
   a. divide to become two chromatids
   b. divide to become centrioles
   c. separate and line the cell with the spindle fibres
   d. move apart along the spindle fibres to the opposite ends of the cell

5. What would happen if chromatids failed to separate and move apart:
   a. the cell would fail to divide
   b. the cell would produce only one daughter cell
   c. the new daughter cell's would be devoid of the genetic information of that of the parent cell
   d. none of the above

6. What is the function of the spindle fibres:
   a. they ensure that the cell wall divides into two new daughter cells
   b. they act as the control mechanism for mitotic reproduction
   c. they act as guidelines for the chromatids
   d. they provide nutrients for each new daughter cell
7. What happens to the cell's wall in mitosis:
   a. it grows during mitosis to accommodate the cell information
   b. it constricts, then divides into two new cells
   c. it divides into two new cells, then increases in size
   d. none of the above

8. Which stage in mitosis would ensure that chromosomal information within the cell remains complete:
   a. the chromosomes of the parent cell replicate before cell division
   b. that the cell appears normal
   c. the precise alignment of the chromatids at the cell's equator
   d. the arrangement of spindle fibres
Please circle the correct response from each of the following multiple choice questions. There is only one correct response to each question. If you do not know the answer, feel free to have a guess:

1. Leaves use the energy from the sun to:
   a. produce water which is then carried through the leaf veins, to the roots
   b. turn simple material into energy rich food
   c. synthesise carbon dioxide, which is then released through the stomata
   d. produces chlorophyll

2. Immediately beneath the upper epidermis of the leaf skin lies the:
   a. spongy cells
   b. stomata
   c. lower epidermis
   d. palisade cells

3. Carbon dioxide combines with water and is:
   a. photosynthesised and absorbed by the plant
   b. photosynthesised into oxygen and sugar
   c. dissolved by the process of photosynthesis
   d. removed form the plant through the stomata

4. Sugar is dissolved in water and is carried throughout the plant to provide energy for growth. True / False

5. In what ways is gas exchange in photosynthesis, different from that which takes place in animals:
   a. In plants, carbon-dioxide and sugar produces oxygen and water which is then released into the atmosphere. In humans, however, oxygen and sugar produce carbon dioxide, which is then released into the environment
   b. In humans, oxygen and sugar is transformed into carbon-dioxide, whereas in plants, chlorophyll is transformed into carbon-dioxide which is then released into the atmosphere, via the stomata
   c. In humans, oxygen and sugar produce carbon-dioxide, which is released into the environment. In plants, however, carbon-dioxide and water produce sugar and oxygen, the latter being released - via the stomata - into the atmosphere
   d. None of the above
6. What would be the result if the leaf's stomata did not open:
   a. photosynthesis would not occur because gaseous exchange could no longer take place
   b. photosynthesis would still occur as gaseous exchange can occur through the upper epidermis
   c. photosynthesis would occur, however, oxygen would be transported away from the leaf to the root system, and absorbed into the ground
   d. Photosynthesis will occur, but it will proceed at a slower rate than normal.

7. What would you expect to be the immediate effect of a lack of chlorophyll:
   a. photosynthesis would not take place
   b. photosynthesis will occur at a slower rate
   c. the palisade and the upper epidermis will die
   d. a & c

8. Why would you expect young plants in a darkened room to bend towards a source of light:
   a. so the plant will grow
   b. so that photosynthesis can occur
   c. because the plant lacks water
   d. none of the above
Appendix D

Learner Feedback Survey, comprising questions for the Preference for Visual Instruction Scale (PVIS)

Please circle the response which best suits you:

1. How helpful was the text only in learning the material?
   Not helpful  a little  somewhat  helpful  very helpful
   1  2  3  4  5

2. How did the text add to your understanding of the animation?
   Not at all  a little  somewhat  useful  very useful
   1  2  3  4  5

3. Please rate which of the following features would have provided extra understanding if added into the text:
   1 = detrimental  2 = unnecessary  3 = neutral  4 = desirable  5 = essential
   a. illustrations containing labels ___
   b. fully animated sequence, with narration ___
   c. narrative ___

4. How would you rate the following features as being helpful to you in understanding the information:
   No use  a little  somewhat  useful  very useful
   a. The textual passage  1  2  3  4  5
   b. The animation  1  2  3  4  5
   c. The narrative  1  2  3  4  5
   d. The animation and narration  1  2  3  4  5
   e. The illustrations  1  2  3  4  5
   f. The animation and the text  1  2  3  4  5
5. To what extent did the illustrations motivate you to learn:

<table>
<thead>
<tr>
<th>Not at all</th>
<th>a little</th>
<th>somewhat</th>
<th>useful</th>
<th>very useful</th>
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6. How much do you think the annotations added to the illustrations:

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7. How much do you think the labels added to the illustrations:

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8. To what extent did the animation motivate you to learn:

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9. How much do you think the narration added to the animation:

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10. How much do you think the labels added to the animation:

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11. Is there any way we could have made the learning experience more enjoyable and valuable for you? If yes, how? ____________________________________________________________

________________________________________________________________________

________________________________________________________________________

12. If there is any additional comments you would like to make, please do so in the following paragraph. ____________________________________________________________

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________
Appendix E

Textual passages for each of the four instructional topics (ear, eye, mitosis, photosynthesis) comprising the text-only, text supplementation condition
The Ear & Hearing:

The ear is the organ of hearing and balance, and comprises three divisions – outer, middle, and inner.

The outer ear is the portion of the hearing apparatus lateral to the eardrum, or tympanic membrane. It comprises the auricle (the external flap of the ear), the auditory canal and the ear drum. The middle ear, on the inner side of the eardrum, embodies the mechanism for the conduction of the sound waves to the inner ear. It is a narrow passage that extends vertically for about 15mm. Traversing the middle ear is a chain of three small, movable bones called the malleus; incus; and the stapes. These bones connect the eardrum acoustically to the fluid-filled inner ear. The inner ear is the part of the temporal bone containing the organs of hearing and balance to which the filaments of the auditory nerve are distributed. It is separated from the middle ear by the fenestra ovalis. The inner ear consists of membranous canals housed in a dense portion of the temporal bone and is divided into the cochlea, the vestibule and three semicircular canals. All these canals communicate with one another and are filled with cochlea fluid. The cochlea houses the sound analysing cells that are connected to the brain through the auditory nerve.

Sound waves, which are actually changes in air pressure, are carried through the auditory canal to the eardrum, causing it to vibrate. These vibrations are communicated by the malleus, incus and stapes in the middle ear through the membrane in the wall of the cochlea, to the fluid in the inner ear. The movement of the cochlea fluid stimulates the movement of a set of fine hair-like projections as the cochlea vibrates. These hair cells transmit signals directly to the auditory nerve, via the nerve fibres, which carry information to the brain. The overall pattern of response of the hair cells to the vibrations of the cochlea encodes information about sound in a way that is interpretable by the brain’s auditory centre. Nerve fibres at the deepest part of the cochlea detect the lowest frequencies.

The range of hearing, like that of vision, varies in different people. The least noticeable changes in tone that can be picked up by the ear varies with pitch and loudness. The most sensitive human ears can detect a change of vibration frequency corresponding to about 0.03 per cent of the original frequency.
The Eye and Sight:

The eye is the light-sensitive organ of vision in animals. The function of the eye is to translate the electromagnetic vibrations of light into patterns of nerve impulses that are transmitted to the brain.

The eyeball is a spherical structure with a pronounced bulge on its forward surface. The front of the eye contains an elaborate complex of structures that are mainly concerned with bending light rays and bringing them into focus at the back of the eye.

At the very front of the eye is a transparent membrane called the cornea, through which light is admitted to the interior of the eye via an opening called the pupil. The pigmented iris which provides the eye with its “colour”, surrounds the pupil. Muscles in the iris around the edge of the pupil are responsible for controlling the size of the pupil. As these muscles contract or relax, the pupil becomes larger or smaller, varying the amount of light entering the eye.

The lens is situated behind the pupil, and its shape – either rounded or flattened – is controlled by the muscle surrounding the lens. From the lens, light projects to the retina in the back of the eye were light sensitive cells cause electrical signals to travel along the optic nerve to the brain.

The white outer covering of the eye, which is continuous with the cornea, is known as the sclera. Small muscles attached to its exterior control the directional movement of the eyeball. The choroid, which is a vascular layer lining the rear three-fifths of the eyeball lies between the sclera and the retina and provides the retina with support and blood supply.

When looking at an object, the rays of light which are reflected off the object enter the eye and pass through the lens. The lens then bends the light so that the light rays originating from any one point on the object converge to a single point on the retina. Rays leaving the top of the object end up on the bottom of the retina and produce an inverted image. To focus on nearby objects the lens changes shape and thickens. This causes light rays from the object to converge on the retina. To see objects far away, tiny muscles flatten the lens and bring the image into focus.
Mitosis:

Mitosis is the standard way in which a living cell nucleus divides and replicates itself, producing two offspring or daughter cells, normally with the same genetic information. It occurs all the time in the human body, and other multicellular living things, especially during growth to make more cells, and for maintenance to replace damaged and worn-out cells. In single celled organisms, mitosis represents asexual reproduction. In plants, it is the basis of asexual or vegetative reproduction (making cells for sexual reproduction involves another type of cell division, known as meiosis). Genes exist as chemical codes on lengths of chemical DNA, inside the nucleus. During a cell’s “resting” period, the DNA copies or replicates itself to form two complete sets. Mitosis then occurs in four main stages, whereby certain crucial events take place during each stage. While cell division is often described as a sequence of unfolding stages, mitosis is a continual process with no distinct breaks between each of the stages.

When a body cell divides, each new daughter cell must carry with it identical genetic information. When mitotic cell division begins, the genetic code is replicated exactly, and two sets of chromosomes develop from one. Chromosomes are the vehicle for heredity and this determines the characteristics of the cell. As mitosis begins, the membrane surrounding the nucleus becomes less distinct and the chromosomes become more distinct. Pairs of chromosomes soon become attached to each other at the centre of the cell. Spindle fibres begin to form and radiate between the centrioles, and start stretching between the two opposing centriole pairs. The two identical parts of each double chromosome are called chromatids. Paired chromatids align themselves across the middle of the cell. Chromatids then start separate and move along the spindle fibres towards the opposing poles at the edge of the cell. The cell begins to pinch inwards like a tightening belt around the cell’s equator, and eventually the chromatids move to opposite poles. The spindle fibres then start to break up. The cell membrane divides and the nuclei start to form. Chromatids (which become the new chromosomes of the daughter cell) gradually become less distinct. When cell division is complete, there are two new cells genetically identical to the original one. These cells will then repeat the process of mitosis, themselves reproducing and dividing to form more cells that comprise the same genetic information contained in the original parent cell.
**Photosynthesis:**

Photosynthesis is the process by which chlorophyll-containing organisms – such as green plants, algae, and some bacteria – capture energy in the form of light and convert it to chemical energy. Therefore, it is the process of turning simple material into energy rich food. Growth, repair, reproduction and other dynamic processes performed by organisms require light energy that is absorbed by chlorophyll pigments in green plants, stored as chemical energy in organic products, especially carbohydrates.

Photosynthesis consists of two stages: a series of light-dependent reactions that are temperature-independent and a series of temperature-dependent reactions that are light independent. Although it is convenient to divide photosynthesis into two stages, one requiring light, and the other not, it is important to appreciate that both stages go on simultaneously, provided that light is present.

The leaves of a green plant are generally thin and flat to minimise the distance over which diffusion of carbon dioxide takes place. The leaf’s skin is called the epidermis and comprises cuticularised epidermis cells, whereby the upper surface of the leaf – known as the upper epidermis – is thicker than that on the bottom. Beneath the upper epidermis lie the palisade cells, which are the chief food producers. Between the palisade layer and the lower epidermis are the spongy mesophyll cells which are partly surrounded by pockets of air which enable the cells to exchange gases with the atmosphere. These are small openings called stomata under the leaf in the lower epidermis. Leaf veins carry water and nutrients from the roots. Carbon-dioxide enters through the stomata. Cells in the palisade and spongy layers contain chlorophyll, which helps absorb the sunlight and transforms light energy into chemical energy. Carbon dioxide combines with water and is photosynthesised into oxygen and sugar. Oxygen then escapes through the stomata. The sugar is then dissolved in water, and is carried throughout the plant providing energy for growth.

The amount of light, the carbon dioxide supply, and the temperature are the three most important environmental factors that directly affect the rate of photosynthesis. Water, and minerals in sufficient quantities are also necessary. The plant species and its physical state – such as its health, maturity and whether or not it is in flower – also determine the rate of photosynthesis in green plants.
Appendix F
Illustrations for each of the four instructional topics (ear, eye, mitosis, photosynthesis) comprising the illustrations text supplementation condition
The Ear & Hearing:

1. The ear consists of outer, middle and inner parts.

2. The outer ear comprises the auricle, auditory canal and ear drum (or tympanic membrane).

3. In the middle ear, 3 small bones (the malleus, incus and stapes) connect the eardrum to the inner ear. The inner ear contains the cochlea which houses the sound analysing cells connected to the brain, via the auditory nerve.
4. Sound waves enter the ear, causing changes in the air pressure in the auditory canal.

5. The eardrum vibrates and the waves are amplified and transmitted by the middle ear to a membrane in the wall of the cochlea.

6. Fluid in the cochlea is set in motion. The vibrations are detected by nerve fibres which transmit signals to the brain, through the auditory nerve. These frequency sensitive fibres detect the lowest frequencies by fibres at the deepest part of the cochlea.
**The Eye and Sight:**

1. The cornea is the transparent membrane covering the eye. Light passes into the eye through an opening called the pupil, which is surrounded by the iris, which opens and closes by degrees to control the amount of light the eye receives. The white outer covering is called the sclera, whereby small muscles attached to it control eye movements (the eye muscle).

2. Light passes through the lens into the retina at the back of the eye. The choroid attaches to the back of the retina and provides it with support and blood for nourishment. Light sensitive cells in the retina produce electrical signals that travel along the optic nerve to the brain.

3. When you look at an object, rays of light reflected off the object, enter the eye and passes through the lens.
4. The lens bends the light so that rays originating from any one point on the object converge to a single point on the retina. Rays leaving the top of the object end up on the bottom of the retina producing an inverted image.

5. To focus on nearby objects the lens changes shape and thickens, causing light rays from the object to converge on the retina.

6. To see objects far away tiny muscles flatten the lens and bring the image into focus.
Mitosis:

1. When a body cell divides each new daughter cell must carry with it identical genetic information. A cell does this through the process of mitosis.

2. When cell division begins the genetic code is replicated exactly, and 2 identical sets of chromosomes are made from 1. The membrane surrounding the nucleus becomes less distinct, and the chromosomes become more distinct. There are pairs of chromosomes attached to each of the centres.

3. Spindle fibres begin to form and radiate between the centrioles.
4. The 2 identical parts of each double chromosome are called chromatids, which are paired across the middle of the cell. Chromatids separate and move apart along the spindle fibres to each pole.

5. The cell begins to pinch inwards with the chromosomes at opposite poles, the spindle fibres break up. The cell membrane divides and the nuclei form. Chromosomes become less distinct.

6. When division is complete, there are 2 new cells genetically identical to the original one.
Photosynthesis:

1. Green plants make food by the process of photosynthesis.

2. Using the sun's energy, leaf cells turn simple materials into energy rich foods.
3. Palisade cells lie beneath the upper epidermis and are the chief food producers.

4. Spongy cells, partly surrounded by air pockets enable cells to exchange gases with the atmosphere. There are small openings called stomata under the leaf in the lower epidermis. Leaf veins carry water and nutrients from the roots.
Carbon dioxide enters through the stomata. Cells in the palisade and spongy layers contain chlorophyll which helps absorb sunlight and transforms light energy into chemical energy.

Carbon dioxide combines with water and is photosynthesised into oxygen and sugar. Oxygen escapes through the stomata. The sugar dissolved in water is carried throughout the plant providing energy for growth.
Appendix G

Correlation coefficients for all variables
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*Note:* * significance is less than .05; ** significance is less than .01