THE EFFECT OF QUESTIONS AND FEEDBACK USED TO COMPLEMENT
STATIC AND ANIMATED VISUALIZATION ON TESTS MEASURING
DIFFERENT EDUCATIONAL OBJECTIVES

A Thesis in

Instructional Systems

by

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ABSTRACT

Motivated by recent advances in educational technology, this study was conducted to investigate the relative effectiveness of different types of visuals (static and animated) and instructional strategies (no strategy, questions, and questions plus feedback) used to complement visualized materials for student learning with different educational objectives in a computer-based instructional (CBI) environment. Specifically, the study was designed to determine (1) which type of visuals (static versus animated) used to complement text material is more effective in facilitating student achievement of different educational objectives; (2) whether the use of questions to focus students’ attention on relevant learning cues and giving feedback to students’ responses to questions are effective instructional variables in improving student achievement of visually illustrated content material; and (3) whether there exists a difference in the amounts of time students in different treatment group spent interacting with their respective treatments.

The sample involved in the study consisted of 582 undergraduate students enrolled in The Pennsylvania State University. In this study, each student completed a demographic survey, took a prior knowledge test on physiology, interacted with assigned treatment material, and received four individual criterion posttests. The study employed a posttest only, a 2 x 3 factorial experimental design. The two independent variables in the study were visual type and instructional strategy. The independent variable, visual type, consisted of two levels: static visuals versus animated visuals. The second independent variable, instructional strategy, consisted of three levels: no strategy, questions, and questions plus feedback. The dependent variables were four criterion posttests and a composite test score. The instructional module used in this study contained a 2,000-word
physiology unit focusing on the human heart, its parts, locations, and functions during the diastolic and systolic phases (Dwyer & Lamberski, 1977).

The data analysis was composed of two phases. The first phase analyzed data that included all items in the four criterion posttests (80 items) plus a composite score. The second phase analyzed data that included enhanced items only (34 items), plus a composite score that was calculated based on these 34 items. In addition, the amount of time spent on the task (time-on-task) was entered into the analysis as a covariate in both phases of data analysis.

The results of the study indicated that there was no interaction between visual type and instructional strategy on all criterion posttests or the composite score across the two phases of analysis. Students who received either the animated or static visual treatments did not score differently for the level of instructional strategy they received. However, the main effect of visual type and instructional strategy was detected on some criterion posttests. For the visual type, students who received the animated visual treatment scored significantly higher on all criterion posttests than those who received the static visual treatment. For the instructional strategy, students who received the “Questions+Feedback” scored significantly higher than those who received “No strategy” on both the terminology and comprehension tests. In addition, students who received the “Questions” treatment scored significantly higher than those who received “No strategy” on the terminology test. All observed differences between the “Questions+Feedback” and “Questions” treatments failed to reach statistical significance at the .05 level.

In regard to the second phase of the analysis, the result indicated that students who received animated visuals scored significantly higher than those who received static
visuals on the drawing, terminology, and comprehension criterion posttests. Students who received animated visuals also had a significantly better overall performance than those who received the static visual treatment as indicated from the composite score of the 34 enhanced items. In regard to the instructional strategy, students who received the “Questions+Feedback” treatment scored significantly higher than those who received the “No strategy” treatment on the terminology and comprehension criterion posttests in addition to a higher composite score. Students who received the “Questions” treatment scored significantly higher than those who received “No strategy” only in the terminology criterion posttest. All observed differences between “Questions+Feedback” and “Questions” failed to reach significant differences at the .05 level. The data analysis on the time-on-task for each treatment group yielded different results. Students who received the animated visual treatment spent significantly more time on the instruction than those who received the static visual treatment. Students in both the “Questions+Feedback” and “Questions” treatment groups spent significantly more time in studying the material than those who received “No strategy.” However, no significant differences on instructional time were found between “Questions” and “Questions+Feedback.” Considering that the amount of time needed to engage in the learning task may contribute to the students’ learning achievement, a series of follow-up analyses holding the time constant were conducted.

The results, when adjusting for the time-on-task, indicated that the relationship observed from the initial analysis, where the time-on-task was not controlled, was inflated. There was no interaction between the visual type and the instructional strategy on all criterion posttests or the composite score across the two phases of analysis. Furthermore, no significant differences between the static and animated treatments on all
criterion posttests were observed in the first phase of the analysis. In the second phase of the analysis, however, the students’ achievement on the drawing test was effectively facilitated by the animated visuals while their achievement on the other three tests was not significantly different. In addition, when controlling for the time-on-task, “No strategy” was found to be significantly more effective than both “Questions” and “Questions+Feedback” in facilitating the students’ learning of lower-level learning outcomes as reflected in their higher scores in the drawing test and the identification test (the first phase). “No strategy” is significantly more effective than “Questions” in facilitating the achievement of the drawing test (the second phase). All observed differences between “Questions” and “Questions+Feedback” were not statistically significant at the .05 level.
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CHAPTER 1

INTRODUCTION

Recent advances in technology have made the distribution of information more rapid and information more readily accessible. These advances have also made possible individualized learning opportunities and instruction that integrate multiple ways of presentations combining such media devices as audio, varied types of visuals, graphics, and sounds. There has been a long history of using visualization to complement textual material (Feaver, 1977; Slythe, 1970; Anglin, Vaez, & Cunningham, 2004). With the increasing popularity and proliferation of visualization developed especially for learning and instruction in a computer-based environment, it is important to investigate their effects on students’ learning particularly in this context.

The primary purpose of this study was to investigate the effect of varied types of visuals (static versus animated) on students’ learning of different educational objectives in a computer-based instructional (CBI) environment. In addition, the study investigated the relative effectiveness of using varied instructional strategies (questions and feedback) used to complement static and animated visualization on students’ learning. An examination of the interaction effect between the use of varied visuals and different instructional strategies on students’ learning was conducted. Furthermore, the data of the time-on-task required for students to process the respective instructional module was collected to provide extra insight into the students’ appropriate use of visualization and instructional strategy in the learning process and to help further illustrate the learning gains that may be attributed to the treatment.
Research Background

This section presents a general theoretical foundation and background of the variables of interest in this study. General educational theories related to learning were used to provide justifications for the use of these strategies and an overview of research studies related to visualization, animation, questions, and feedback are described and discussed.

*Instructional Visualization*

Technological advances have significantly transformed the forms that instructional materials can take and the means by which they can be delivered. One promising potential of technology lies in its capability to create a multimedia learning environment in which sounds, visuals, and animation can be added to traditional text-based material to make it more effectively attentive to students and thereby improve their learning achievement. Visualization, which has been widely used in both face-to-face learning environments and online distance education, has the capability to present instructional material in a more appealing way, to illustrate and contrast similar and salient portions of the material, as well as to facilitate information processing when it is incorporated to complete text-based materials (Dwyer, 1994). Visualization also has been used as a rehearsal strategy that, when appropriately employed, would enable learners to retain incoming information in their short-term memory for a longer period of time, engage in a deeper information processing, and then retrieve it more efficiently and effectively. The higher the level of information processing, the greater the possibility that the information will move from short-term memory to long-term memory and
subsequently stored and retained (Murray & Mosberg, 1982).

Research findings have generally supported the proposition that human beings remember pictures better than words (Anglin, Vaez, & Cunningham, 2004). Two theories have been especially important in explaining the superiority of pictures over text. These theories are identified as the dual-coding theory and the information processing view of human cognitive architecture (Anglin et al., 2004). It was believed that human memory is composed of two interdependent types of memory mode to process and store information—the verbal and nonverbal modes. Verbal information containing words and sentences is processed specifically in the verbal system and nonverbal information such as images or illustrations are processed in the nonverbal system (Paivio, 1971, 1978, 1991). Paivio (1990) believed that the dual coding of pictures both in its verbal and nonverbal forms is more likely to occur than words, which are more likely to be encoded verbally only. This assumption explained the superior effect of pictures to words when used in instruction. Researchers and educators in the instructional design arena have been drawing on research findings and knowledge discovered by researchers in cognitive science when designing instructional materials. Evidence from empirical research findings related especially to human cognitive architecture is of particular importance in providing research-based justifications for the use of specific instructional strategies along with general learning and instructional theories that instructional designers and researchers conventionally rely upon for decision making.

An information processing view (IPV) of human cognitive architecture was proposed to describe memory models in human beings, which further explains how instructional material can be appropriately designed to maximize learning. It was generally agreed from IPV that human beings have a memory architecture that is
composed of two types of memory—short-term (or working memory) and long-term. Short-term memory consciously processes incoming information that is registered through human senses. A particularly important notion associated with short-term memory is its limited capacity. Miller (1956) argued that human beings can only hold seven plus or minus one chunks (elements) of information in the working memory or when processing information at a given time. Cowen (2001) also suggested that human beings’ attention span is limited and that recalled information is highly restricted by this limit. However, the depth of information processing in working memory determines how effective and efficient the stored information can be recalled and retrieved. The longer and deeper the information is processed, the better the chance that it will be recalled and retrieved successfully.

However, long-term memory is believed to be unlimited in the amounts of information that it can store (Sweller, van Merrienboer, & Paas, 1998). Long-term memory interacts with short-term memory when humans process incoming information that could be traced from existing information and is related to the new information. The implications of IPV for instructional design are that learners should be provided with learning strategies that will maximize the efficient and effective uses of working memory and that the use of instructional material that would induce the overloading of information in working memory should be avoided.

*Animation, Learning and Instruction*

Animation has been used in various disciplines to deliver instructional material that is hard to present alone using static visuals or contains knowledge that is highly abstract or invisible to human eyes. A large body of research has investigated the effect of
animation on different levels of learning outcomes; however, the results have been inconclusive and inconsistent. About half of the animation studies yielded results that were contradictory to expectations as well as instructional designers’ intuitions that well-designed animation would benefit students’ learning.

Park and Gittelman (1992) defined animation as “…artificially generated movements of pictures or graphics in computer displays, resulting in apparent motion…..” (p. 27). Animation, presented as pictures in motion, is analogous to a subset of visual graphics (Weiss, Knowlton, & Morrison, 2002). In a computer-based instructional (CBI) environment, animation is typically used due to its inherent characteristics that facilitate the instructional and learning processes. For example, when simply used as a “cosmetic function” (p. 467), animation tends to make instructional material more impressive or interesting to learners but does not significantly contribute to students’ learning. This function may sometimes be counter-effective due to the way it distracts learners.

Another function of animation is to focus learners’ attention by employing special effects either to highlight the importance of a topic or to demonstrate the beginning or ending of a section. This function of animation has been questioned in terms of its effectiveness in facilitating learning since students’ attention may be aroused but not sustained on critical attributes of the instructional material. Animation also has the potential to provide feedback in various forms that may be both entertaining and motivating to learners striving for the correct response.

Theoretical justifications for the use of animation in the presentation of instructional material have been well established in supporting its use in CBI or Web-based learning environments. Among them, the most widely recognized and
empirically validated justification is Paivio’s dual coding theory. This theory suggested
the extreme of two cognitive information-processing systems in human beings. One
system deals with verbal input or linguistic, language-like information, and the other
deals with visual information such as pictures. The theory proposed that these two
distinct information processing systems function separately when the incoming
information is coded respectively but simultaneously when “… building referential
connections between corresponding elements in the learners’ verbal and visual

Much prior research on the instructional effect of animation has been conducted;
however, the results are mixed and inconclusive. So far, most animation studies have
been conducted in the science-related disciplines. A few empirical studies of algorithm
animation indicated “… a non-significant trend favoring the animation group….” when
comparing learners’ achievement of a posttest evaluating procedural understanding. The
researchers attributed the lack of significant effect for animation to the fact that the
animations represent an expert’s understanding of the algorithm, not a novice’s, i.e.,
students do not possess prerequisite knowledge or “[a] foundation of understanding to
construct visualization mapping….” (Stasko, Badre, & Lewis, 1993, p. 61). Another
study conducted by Byrne, Catrambone, and Stasko (BCS) examined whether or not
animation could facilitate learners’ predictions about an algorithm’s operation. The results
indicated that the addition of animation is only beneficial on simple but not complex
algorithm operations (1999). In a series of experimental studies on the effect of animated
graphics on children’s learning of Newton’s laws of motion when practice was integrated
into the module, Rieber (1990b) indicated that animated graphics were superior to static
graphics and no graphics as long as practice was provided and that cognitive practice was
generally superior to either behavior practice or no practice at all. The result suggested that animated presentations do promote learning under certain conditions and are especially effective when integrating with cognitive-based practice activities.

In a similar study in which animation was embedded into a lesson based on pilot studies, Rieber (1990b) indicated that no support for animation was shown. The researcher found that children indicated that the material containing the knowledge on Newton’s law of motion was too difficult and they did not spend time viewing the animated visuals but used the time to read the text. The same study was replicated with adults with a modification of content. The results showed that animated graphic presentation did not differ from either text or static visuals in regard to students’ achievement as measured by a posttest. The series of studies suggested that the effect of animation could be reduced by factors such as the difficulty level of the content, poor instructional design, or the inability of students to focus on critical information represented in the animated presentation (Rieber, 1991a).

Students’ cognitive styles, e.g., field dependent/independent, spatial ability, or prior knowledge, are variables that researchers of animation have been interested in incorporating into the research design given the fact that different cognitive styles may interfere with learning especially in a computer-based learning environment. Hays’ study (1996) investigated spatial abilities and the effects of computer animation on short-term and long-term comprehension. The results showed that low-spatial ability subjects receiving animated instruction made significantly greater gains than low-spatial ability subjects not receiving animation. Hays concluded that spatial ability was a significant factor for short-term comprehension; however, the types of presentation had a significant effect on subjects’ performance on long-term understanding. In a more recent study
conducted on spatial ability and the impact of visualization/animation on learning electrochemistry, Yang, Andre and Greenbowe (2003) indicated that animations led to significantly better performance overall, but more so for students with a high spatial ability. To summarize, computer-generated animation only facilitated learning under certain conditions. Rieber (1991b) suggested that animation presented in chunks is more likely to improve learning compared to static visuals.

Mayer and Sims (1994) observed that high-spatial ability students benefit more from animated instruction than do their low-spatial ability counterparts because spatial ability allows high-spatial learners to devote more cognitive resources to building referential connections between visual and verbal representations of the represented material, whereas low-spatial ability learners must devote more cognitive resources to building representation connections between visually presented material and its visual representation. Furthermore, animation is more likely to improve the comprehension of a procedural text rather than a descriptive text (Large, Beheshti, Breuleux, & Renaud, 1996).

**Strategies of Questions/Questioning**

The construct of meta-cognition is considered to be a critical factor for the human learning process. It is generally agreed that learners have in their possession various degrees of meta-cognitive resources that enable them to engage in the lesson content with varying degrees of depth (Osman & Hannafin, 1994). Different types of questions or questioning strategies can be used to engage learners in deeper cognitive information processing and therefore enhance their learning. The effects of questions or questioning strategies lie in the fact that the “… explicitness of the questions and … relationship to
instruction...focus [the] learner process on question-specific information” (Osman & Hannafin, 1994, p. 5). Research has indicated that questions help to activate prior knowledge and integrate it with new knowledge and the application of that knowledge (Adams & Bruce, 1980; Anderson & Biddle, 1975; Anderson & Pearson, 1984; Mayer, 1984; Osman & Hannafin, 1994). King (1992) indicated that having students asking and answering high-level questions facilitates the students’ comprehension of the text material by engaging them in tasks such as “... focusing attention, organizing the new material, and integrating the new information with existing knowledge” (p. 304).

Wagner and Mory (1993) used Gagne’s (1985) model of information processing as a framework to explain the different roles that questions may serve in the different stages of instruction. For example, in the attention-gaining stage, questions may be used to gain attention from students. Questions are “... motivational stimuli capable of having arousal outcomes...” (Frase, 1970; Rothkopf, 1970) as cited by Wagner & Mory (p. 60). Although gaining students’ attention will not guarantee that the material to follow will be learned, no subsequent processes will occur without the reception of the stimuli by the receptors. The registration of information by sensory registers depends on what is detected, which depends on what a learner is expecting. Questions may serve the function of behavioral objectives in that they inform learners what they can expect to learn. During the stage in which selective perception has to be exercised to identify information to be stored in the short-term memory, questions could be used to aid students in recalling prerequisites stored in the long-term memory into short-term memory so as to enable the integration of previously learned information with the new information. Different rehearsal activities can be used to maintain information in the short-term memory once it is perceived and selected. Questions in this stage can aid learners in “... organizing
information into manageable chunks or propositions…. “ (Wager & Mory, 1993, p. 65). For information to be successfully stored into the long-term memory, it has to be semantically encoded. Questions in this stage can encourage learners to integrate new knowledge into their existing cognitive structures. To facilitate the retrieval of information in their long-term memory, learners must perform some tasks. Questions in this sense can act to retrieve the information and to provide practice in generalization.

Previous research has shown that different types of questions have different levels of effectiveness on learning (Osman & Hannafin, 1994). Anderson and Biddle (1975) have indicated that “… higher order questions consistently increased both recall and application of information…. “ (p. 10). By responding to embedded questions inserted before or after the text, students can activate their prior knowledge, engage in a deeper information processing and therefore enhance their recall and retention of the instructional material (Anderson & Pearson, 1984). In addition, orienting questions were regarded as being able to “… focus learner processes on question-specific information…. ” by making the question explicit and relating them to the forthcoming instruction (Osman & Hannafin, 1994, p. 9).

Findings of several empirical studies that implement the strategy of questions or questioning in text are discussed here. Denner and Rickards (1987) in their comparison study of the effects of provided and generated questions on text recall indicated that after being provided conceptual post-questions, grade-level students significantly increased their recall of both main ideas and factual details when compared to the no-question condition. In another study that compared self-questioning, summarizing, and note taking-review as strategies for learning from lectures, King (1992) suggested that self-questioning is a significantly more effective study strategy for the long-term
retention of material from a lecture. Wilhite (1983, 1984) conducted research on the effectiveness of questions and the positioning of questions on learning. They suggested that post-passage questions containing the answers served for learners as a cognitive review of previously encountered material and enhanced the indirect retention; however, pre-passage questions reinforced indirect retention when learners used the questions to facilitate the encoding process.

**Feedback in the Learning Process**

The importance of feedback in the learning process has long been recognized and has been a variable of interest in educational research. Research findings regarding the effect of feedback on learning have been mixed due to a combination of factors associated with it such as the timing of its presentation and type and content of the feedback. During a learning process, feedback generally plays a role as motivator or an incentive to encourage accurate performance or as an information confirmer that learners can use to judge the correctness of a previous response. In terms of the purpose of feedback, it has both reinforcing and an informational attributes. It is believed that letting learners know how well they are performing a task and/or giving them the opportunity to monitor/assess their learning progress can result in a better learning effect (Kulhavy & Wager, 1993). The type of feedback, a common variable of interest in the research literature, specifically relates to the amount and content of information contained in a feedback message.
Kulhavy and Wager (1993, p. 3) summarized the types of feedback as:

1. No feedback: includes only a question and learners are required to make a response to the question. No feedback is given in terms of the correctness of the response.

2. Simple verification feedback of the knowledge of results (KOR): provides indications whether the response is correct or incorrect.

3. Correct response feedback or knowledge of correct response (KCR): provides the correct response to the question.

4. Elaborated feedback: provide information or an explanation for why the learner’s response is incorrect or correct along with additional material relevant to the correct response.

5. Try-again feedback: allow students to make several trials after he/she submitted an incorrect response.

Research on the types of feedback used either one or a combination of the above feedback types. Research findings on feedback have been inconsistent and mixed. Smith and Ragan (1993), Kulhavy (1977), and Schimmel (1983) noted that the only conclusion that can be drawn from research on instructional feedback is that some feedback is better than no feedback. For research that investigated the no-feedback and varied types of feedback, i.e., knowledge of response (KOR) and knowledge of correct response (KCR), the results are also inconclusive. However, for those studies that found no significant differences, there is empirical evidence that suggested some plausible interpretation of such a failure (Lublin, 1965; Rosenstock, Moore, & Smith, 1965). Two
studies conducted by Lublin (1965) and Rosenstock, Moore, & Smith (1965) employed programmed text in which the question and answer appeared immediately below the frames. Such an arrangement of frames of text and questions/feedback on the same page arouse a short-circuiting of attention, a term employed by Anderson, Kulhavy, and Andre (1971). This short-circuiting of attention comes as a result when the correct answer is readily available, i.e., students may just look in the text for the correct answer without reading the material in the frame. Kulhavy (1977) indicated that placing the questions/answer on the same page as the text makes “…accidental exposure of the answers…” difficult to avoid. Researchers have also argued that students tend to employ the law of least effort (Anderson, 1970, p. 349). In other words, students, especially when they are tired or the instructional task is not interesting, often would not make the effort to learn a lesson when it is possible to “short-circuit” the instructional task.

Salomon & Globerson (1987) have argued that feedback of any kind only has an effect when it promotes mindful learning. Feedback that encourages mindlessness is, on the other hand, detrimental to learning. Snow (1972) used the term “mathemathantic” to describe a process that may “kill” learning (p. 214). This may occur in two situations. First, when students are so highly motivated or are capable of producing their own feedback or when the difficulty level of a learning task is low, external feedback becomes unnecessary and even to the point of being “cognitively” or “motivationally” inhibiting (Clark, Aster, & Hession, 1987; Corno & Snow, 1986; Snow & Lohman, 1984). Mathemathantic effect may also occur if feedback was available before students “mindfully” generate a response to a given question. That is, the presence of the answer in the text from which the question is derived may prevent students from practicing
information retrieval or elaboration. In other words, students may just choose an answer that has been exposed in the text and not engage in any information-processing or integration, which makes the subsequent presence or absence of feedback less important.
Statement of the Problem

Previous research on visualization has yielded mixed results. Researchers have identified many issues to be resolved when conducting educational research, particularly with regard to visualized instruction. Among the issues, the first concerned the potential for increased learning offered by the addition of visuals. Dwyer (1978) and Levin & Mayer (1993) argued that before any visualization is developed and integrated into instructional material, there is a need to first determine if the textual passage alone would produce the same effect. If students can acquire the intended information from the textual material alone, any additional learning effects that the inclusion of external visuals would produce would be limited.

Furthermore, when determining the type of visuals to be used, the nature of learning tasks needs to be taken into consideration. There are two perceptual characteristics that distinguish static and animated visuals—motion attribute and trajectory. Rieber (1996) proposed that animation could be used to provide the illusion of movement (motion) and the path of travel (trajectory). Consequently, the learning tasks or content should depend on the understanding of the changes of an object over time or the direction towards which the object is moving. Greater learning gains would be expected if the learning task involves the understanding of concepts that concern motion and trajectory and if the animated visuals are integrated to enhance learning.

In addition, although there is increasing interest in conducting animated visual research, there has been little work done to precisely specify what educational objectives animated visuals are most effective in facilitating. There is a need to specify the levels of learning outcomes that animated visuals are most effective in improving due to the high
cost associated with the development of animated instruction. Furthermore, a series of studies has shed light on factors that may have undermined the effectiveness of animation. Among them is the inability of students to focus on or attend to the information intended to be presented in the animated presentation. Researchers indicated that learners, when presented with the animated instruction, were not able to “...effectively attend to the animation” or were “...distracted by the combination of visual and verbal information presented to them” (Rieber, 1990a, p. 81). Owens & Dwyer (2005) also found that learners failed to focus on critical aspects of the animation that depicted important concepts. They were not able to effectively interact with the animation and fully benefit from it. Wilson and Dwyer (2001) suggested in their study that learners be given sufficient and appropriate prompts that help them focus on essential and critical aspects of the information.

Based on the research findings, varied instructional strategies are necessary to accompany animated instruction to scaffold students when they are learning from animated instruction. Researchers have compared the relative effectiveness of enhancement strategies used in traditional classrooms and Web-based learning environments. The results seemed to indicate that some strategies that are successfully used in traditional classrooms are equally effective when applied in CBI. Questions, with or without feedback, are two strategies that were traditionally used in print material or face-to-face instruction. However, as a result of technological advances, researchers and educational practitioners have also intended to extend their use to computer-based or online learning environments. In addition, question formats can be constructed using existing advanced technology and therefore are expected to be even more effective than those observed in conventional classrooms.
Based on previous research, this study was designed to explore the effects of varied visual types (static and animated) and instructional strategies to accompany the visualization on students’ learning achievement of different educational objectives in a computer-based learning environment. The study sought to address the limitations and issues observed in previous research by (1) establishing the need for external animated visualization; (2) using content material that involves the perceptual attributes of animation-motion and trajectory; (3) specifying the levels of learning outcomes that varied types of visuals and instructional strategies are especially effective in promoting; and (4) using instructional strategies to maximize the effects of visualization as suggested from previous research.

Research Objectives

Specifically, the study was designed to:

1. Investigate the effectiveness of varied types of visuals, i.e., static versus animated when used in a computer-based learning environment in facilitating student achievement of different educational objectives.

2. Determine which type of instructional strategy, i.e., no strategy, questions, and questions plus feedback, is most effective in promoting student achievement of different educational objectives when they are used to complement visualized materials.
Research Questions

Three research questions were formulated according to the research objectives above.

Q1: Are there differences between students who received either static visual or animated visual treatment on their learning achievement of criterion posttests measuring different educational objectives?

Q2: Are there differences among students who received varied instructional strategy (no strategy, questions, and questions plus feedback) on their learning achievement of criterion posttests measuring different educational objectives?

Q3: Is the relationship between instructional strategy and learning achievement as measured by the criterion posttests different for the static and animated treatment group?
Definition of Terms

**QUESTION**—Inserted before or after the text for learners to activate their prior knowledge, engage in a deeper information processing, and therefore enhance their recall and retention of the instructional material (Anderson & Pearson, 1984).

**FEEDBACK**—Generally played a role as motivator or as an incentive to encourage accurate performance or as an information confirmer that learners can use to judge the correctness of a previous response (Kulhavy & Wager, 1993).

**VISUALIZATION**—Visuals that are used to illustrate and contrast similar and salient portions of instructional material. Visualization has been used as a rehearsal strategy to assist learners to retain incoming information in their short-term memory for a longer period of time, engage in a deeper information processing, and retrieve it more efficiently and effectively (Dwyer, 1994).

**INFORMATION PROCESSING**—A cognitive information processing system used by human beings to actively manage the stimulus/information that the environment creates, carefully selects, encodes, and stores and organizes it for later use (Wittrock, 1990).

**KNOWLEDGE OF CORRECT RESPONSE (KCR)**—A type of feedback that provided an indication as to whether a learner’s response to a question is correct or incorrect followed by the correct response.
**KNOWLEDGE OF RESPONSE (KOR)**—A type of feedback that provides to the learner an indication whether his/her response to a question is correct or incorrect.

**TWEENING**—A term related to animation. It is short for “in-betweening,” the process of generating intermediate frames between two images to give the appearance that the first image is evolving smoothly into the second image. Tweening is a key process in all types of animation, including computer animation. Sophisticated animation software enables one to identify specific objects in an image and define how they should move and change during the tweening process.

**INSTRUCTIONAL CONSISTENCY/CONGRUENCY**—A conceptual rationale used in the development of a useful instructional module. It assumes a hierarchy of learning objectives. Students will not achieve at the rule/principle level if they do not possess the prerequisite conceptual base for such learning to occur. Students need to possess the conceptual base, and the instructional environment needs to bring together the relevant concepts in a manner which facilitates rule/principle level integration (Dwyer 1994, pp. 383-401).

**LEVELS OF LEARNING**—A hierarchy of learning objectives. When students are introduced to unfamiliar content, they first have to learn the basic terminology and facts which make up the basic components of the language of the discipline, which would prepare them for the learning of concepts. The more concepts students possess, the easier it is for them to form rules and procedures (Dwyer 1994, pp. 383-401).
ANIMATION—A series of graphics that change over time and space and are used to represent complex structural, functional, and procedural relationships among objects.

INSTRUCTIONAL STRATEGY—A device used to “…increase the potential for the perception and use of visualizations” and to “…provide assistance to students who need help in correctly interpreting the information provided by the visualization (Milheim, 1993, p. 173)

TIME on TASK—The total amount of time students spent on studying the respective treatment material.

HIGH/LOW LEVEL OF LEARNING—Concerns the difficulty level of learning materials. Material that contains interacting elements that need to be comprehended simultaneously is more difficult to learn than material that contains low interacting elements or elements that can be understood in isolation (Sweller, 1993, 1994; Sweller & Chandler, 1994).
CHAPTER 2
LITERATURE REVIEW

This study aimed to investigate the effect of varied visual types and instructional strategies on students’ learning of different educational objectives in a CBI environment. Consequently, its focus is on how to design visuals for learning and identify strategies that can be used to enhance learning from the visuals. The purpose of this chapter is to introduce theories relevant to instructional design and in particular to visual design. It will describe first how human beings learn from the perspectives of information processing and then introduce theories particularly relevant to visual design in greater detail. The theories commonly cited as important in the literature to provide justifications for the design and use of visuals for learning include cognitive load theory (CLT), dual coding theory, and cognitive theory of multimedia learning. This chapter presents these theories in greater detail, their importance to visual design, and implications for instructional visual design. The second section of this chapter reviews studies that are relevant to the variables of interest in this study, i.e., static visuals versus animation, types of questions, and feedback.

This chapter concludes with a summary of principles to follow when designing visuals for instructional purposes as suggested from the theories and a summary of research findings so far in the literature regarding the use of animation, questions, and feedback in a learning environment.
Theoretical Justifications

Three theories that are particularly important and relevant to instructional visual design as commonly cited in the literature are: (1) cognitive load theory (CLT), (2) dual coding theory, and (3) cognitive theory of multimedia learning. These theories have one feature in common. They all draw on research findings from cognitive science and are based on how human beings process information and, in particular, how the components of human memory deal with the information. Before introducing the three theories in detail, a general description of how human beings process information is provided.

Information Processing of Human Beings

A cognitive perspective of information processing assumes that our brain is not a passive consumer of information; instead, it actively manages the stimulus that the environment around us creates, and it also carefully selects, encodes, and stores information detected by our sensory system and organizes the information in our memory system for later use (Wittrock, 1990). The human memory is viewed as a complex system that is in charge of both the process and organization of our knowledge. It actively selects the information perceived by our sensory system, processes and transforms it in a meaningful way, and then stores it in our memory for later retrieval.

The most dominant perspective on the nature of human memory is the multistage concept. Broadbent (1958) first described the conception of a multistage memory. The multistage concept of human memory assumes that human beings process information in a sequential way. That is, information is processed in several sequential stages in the memory system. These sequential stages of information processing are activated in the structures of our memory system. These structures include sensory registers, short-term
memory, and long-term memory.

An executive control in the memory system takes control and manages every step of information processing. It determines the cognitive activities to be undertaken during each step and makes sure the amount of information resources to be processed in each structure is appropriately allocated (Gredler, 2001). Our sensory system deals with a huge amount of incoming stimuli from our senses. These stimuli are presented in varied forms of signals, both auditory and visual, and they compete to be attended to by the sensory system. However, these sensory memories can be extinguished very quickly. There is only about half a second for visual information and three seconds for auditory information to be registered by the sensory system (Cooper, 1997). Not all of the signals are processed. Some are retained in the sensory register for a very short period of time and are lost; some are selected for further processing. Information that is selected for further processing then enters the so-called working memory or short-term memory. The information in the working memory either is transformed into meaningful forms to be stored in the long-term memory or is actively processed for immediate utilization and is not processed further beyond this stage.

Working memory is believed to be conscious in that it is aware of what to do with the selected information in an effective and efficient way. It is associated with its limitations both in regards to the capacity and the amount of information that it can process at a given time. It can only deal with no more than seven chunks of information simultaneously (Miller, 1956).

Cooper (1997) suggested that the capacity of working memory can be expanded if the information originally presented can be meaningfully organized and take the form of either visuals or audio because it was believed that our memory system contains channels
that process information while taking either one of the forms separately.

On the contrary, our long-term memory is believed to be unlimited in its capacity and holds a body of knowledge and skills in a permanently accessible form (Cooper, 1997). The knowledge and skills stored in the long-term memory is accessible in a form of schema. It is believed that our knowledge is represented by mental abstract structures, which are organized into so-called “schemata.” A schema could be organized information about an object, an event, or a situation. Schemata are continually organized and restructured through a dynamic process of assimilation and accommodation between new information and the existing memory structures or schemata (Anderson & Pearson, 1984; Armbruster, 1986). Long-term memory interacts with short-term memory when encoding incoming information and preparing the information to be meaningfully processed and organized to be stored in the long-term memory.

Within the theory of information processing, several factors are believed to affect learning. Some factors specially related to this study are discussed here:

(1) Practice effect: Conventional wisdom tells us that practice makes perfect. According to the theory of information processing, active practice or rehearsal improves retention, thus extending the time information is retained in the working memory. Two typical types of practice are mass practice and distributed practice. The latter is more effective than the former. Mass practice is only effective when a single connection is needed, for example, associating a word with its context. Distributed practice involves the use of a single word in various contexts, i.e., multiple associations were made by distributed practice.

(2) Organization effects: organization effects have a role to play in learning when the material being learned is chunked or organized in a way that is meaningful to the
learners. If the material is not chunked meaningfully, the learners would need to chunk or categorized it in a way that he/she can understand to assimilate the material. Organized material is easier to remember than material that is presented in serial order. Typical structural strategies such as advance organizers, previews, outline formats, and highlighting of main ideas are built into a passage to assist learning. These strategies facilitate the subsumption of material into schemas, enable encoding to be a sense-making process, and help organize the body of knowledge.

(3) Levels of processing effects: the more deeply information is processed, the better chance it will be remembered. Elaborative encoding of information is more effective than superficial encoding of information in terms of the efficiency and effectiveness of the retrieval of that information from the long-term memory (Good & Brophy, 1986; Hilgard & Bower, 1975).

Cognitive Load Theory (CLT)

Cognitive load theory (CLT) originated in the 1980s, and since then researchers have worked with educational theorists to extend and refine the theory by incorporating empirical evidence observed in research studies (Paas, Renkl, & Sweler, 2003; Sweller, Van Merrienboer, & Paas, 1998; Rikers, Van Gerven, & Schmidt, 2004). CLT, which heavily relies upon theories drawn from cognitive architecture and the memory system of human beings, provides instructional designers with theory-based guidelines when designing instructional materials. It focuses on how to make efficient use of the limited capacity of working memory when designing instructional material, both in the way it is presented and the way learners interact with the material (Sweller, 1988).
Taking into consideration human beings’ information processing and cognitive structure, CLT suggested instructional strategies and procedures that would maximize learning achievement and performance (Rikers, Van Gerven, & Schmidt, 2004). The core element of cognitive load theory lies in its recognition of the limitation of our working memory and that working memory should be efficiently and effectively managed to cope with huge amount of information occurring during a learning process (Van Gerven, Paas, & Schmidt, 2000). It is assumed that manipulating factors that would lead to cognitive overload would lead to more effective instruction and therefore greater learning gains and performance. CLT distinguished three types of cognitive loads: intrinsic load, extraneous load, and germane load. Intrinsic load can be measured by the level of element interactivity within the material itself and the amount of interaction required between the material being learned and the expertise of the learners. Intrinsic load can not be directly manipulated by instructional designers because it results from the nature of the instructional material. Material that contains more complex or abstract information usually induces a higher intrinsic cognitive load from the learners because it requires significant mental efforts to integrate the knowledge so that comprehension and acquisition of the knowledge is possible (Crooks, Ou, White, Olivarez, Wang, 2005).

Extraneous cognitive load is the extra load resulting from poor instructional design. The level of extraneous cognitive load is determined by the format and manner in which the instructional material is presented and by the amount of capacity that working memory is used when learners engage in the instructional activities (Sha & Kaufman, 2005). Poorly designed instructional material can induce extraneous cognitive load by distracting students to perform irrelevant information searching or through the disorganized presentation of information. Material that contains a lot of mutually
referring information such as text and pictures is also likely to induce a more extraneous
cognitive load.

Germane cognitive load is induced by the effort that learners make in processing
and comprehending the instructional material and is associated mainly with the process in
which the construction and automation of schemas was required (Paas, Tuovinen, Tabbers,
& van Gerven, 2003; Sha & Kaufman, 2005). Both extraneous and germane loads can be
controlled and manipulated by instructional designers. The basic rule is that since the
working memory of human beings is limited in its capacity, the total amount of intrinsic,
extraneous, and germane loads should not exceed working memory limits. Based on CLT,
extraneous cognitive load, which is irrelevant to the construction and automation of
schemata, should be minimized and germane cognitive load, which is directly relevant to
the schemata construction, should be optimized.

Paas and van Merrienboer (1994) provided a comprehensive overview of factors
that determine the level of cognitive load. The factors can be distinguished as causal and
assessment factors. Causal factors include the characteristics of the subject, the task, the
environment, and their mutual relations. Characteristics of the subject may include the
subject’s age and his/her cognitive abilities. Task complexity and time required to finish a
task could be attributed to the task factor. Noise and temperature of the environment in
which the task is being carried out are examples attributable to the environment factor.

In regard to the assessment factors, mental load, mental effort, and performance
were identified by Paas and van Merrienboer as three measurable dimensions of cognitive
load. Mental load is defined as “… the portion of cognitive load that is imposed
explosively…” by the task and the environment (p. 506). Mental effort refers to the exact
amount of capacity in the working memory that is allocated to the fulfillment of the task.
Performance is a reflection of causal factors interacting with mental load and mental efforts and is the result of learning. For meaningful and successful learning to take place, germane cognitive load is required since it involves the construction and storage of schemata into long-term memory. A schema is defined as a “cognitive construct” in which multiple elements of information are treated as a single one, and it is categorized in the manner in which it will be used (Marcus, Cooper, Sweller, 1996). The process of transforming incoming information/knowledge elements into the schemata requires considerable mental effort since this information is chunked and integrated into wholes. The development of schemata saves storage capacity in the long-term memory and facilitates cognitive processing in the working memory (van Gerven, Paas, & Schmidt, 2000).

Marcus, Cooper, and Sweller (1996) identified three sources of cognitive load that may impede understanding in the instructional context: prior experience, the intrinsic nature of the material, and the organization of the instruction. Prior experience is relevant to the presence or absence of existing schemas available to be used in long-term memory to integrate with the new information as that automation of schema can be facilitated and, as a result, the working memory capacity won’t be exceeded. If there is little or no prior experience, information needs to be processed individually, which is likely to exceed working memory capacity, and the understanding of the information would fail. Therefore, the presence of prior knowledge will significantly reduce cognitive load and enhance learning.

Some types of material are more difficult to learn than other types of material because of the intrinsic nature of the material itself (Sweller, 1993, 1994; Sweller & Chandler, 1994). Material that contains interacting elements that need to be
comprehended simultaneously is more difficult to learn than material that contains low interacting elements or elements that can be understood in isolation. Interacting elements needed to be processed in the working memory simultaneously in order for comprehension to take place. Therefore, if material contains huge amounts of information that is interacting in nature, the comprehension would be impeded since working memory is overloaded. The absence of appropriate schemata in the long-term memory can make the learning process even more difficult because all these interacting elements need to be processed individually without integrating preexisting schemas.

The organization of instructional material can determine the levels of cognitive load induced when learners are learning it. Identical material, when presented in different ways, varies in the amount of loading on working memory (Marcus, Cooper, & Sweller, 1996). Levin and Mayer (1993) indicated that concise material, such as diagrams that contain only important information or focus on essential elements of material, would significantly reduce cognitive load on working memory and enhance understanding. In addition, some material, presented in specific format, is easier to trigger relevant schemas. For example, diagrams may be more effective than text in trigger spatial schemas. Therefore, if the learning objectives include the identification of relative positions, information presented in a diagram may be easier to understand than if it is presented in text.

Cognitive load theory assumes a cognitive system in human beings that is composed of a working memory with limited capacity and a long-term memory with unlimited capacity in storage. The core element of CLT lies in its assumption that working memory is limited and the total amount of information needed to be attended to and processed should not exceed its limit. Three factors may determine the amount of
cognitive load induced on working memory: the characteristics of the learner, the
intrinsic nature of the material, and the characteristics of the instructional procedures
(Marcus, Cooper, & Sweller, 1996).

Generally speaking, if learners have prior knowledge of the subject matter being
learned, they have in their possession relevant schema in their long-term memory to
facilitate the automation process of new schema and make the processing of each new
piece of information unnecessary and, therefore, the working memory is not overloaded.
Instructional designers, when designing materials, may need to provide background
knowledge or pre-learning activities to help develop domain-specific schemas before new
material is introduced. Some domains, such as advanced science and physics, deal with
material that typically contains a high element of interactivity. These elements must be
processed and understood simultaneously for comprehension to take place. Again, if
relevant schema is not available in the long-term memory for integration, learning is
impeded.

Furthermore, some material is presented in a way that unnecessary cognitive load
is induced on the working memory and therefore the effective and efficient use of
working memory is impeded. Drawing on CLT, instructional designers should utilize
strategies that would maximize the use of limited capacity in the working memory since
meaningful learning takes place depending on how much information a learner can hold
in his/her working memory simultaneously rather than the amount of information that
needs to be processed. Instructional material needs to be designed and presented in a
manner in which extraneous cognitive load is minimized and germane cognitive load is
maximized.
In addition, cognitive resources should be directed toward activities relevant to learning. Instructional strategies should be embedded into the instructional material to facilitate the integration of individual elements when the level of interactivity is high and, therefore, facilitates understanding. Furthermore, a dual mode of instructional techniques may be used when designing instruction. Assuming that working memory is limited in its capacity, the simultaneous use of aural and visual working memory is expected to increase its cognitive capacity. Comprehension and learning can be enhanced when the working memory is expanded by presenting both forms of presentations simultaneously (Mayer & Anderson 1991, 1992).

The Dual-Coding Theory

Dual coding theory (Paivio 1971, 1978, 1986, 1990, 1991) provided theoretical justifications for the use of visuals in the instructional presentations. According to the dual coding theory, human memory is composed of two independent but interconnected coding systems. The visual system primarily deals with visual codes, such as images, pictures, concrete objects, or events; the other system, the verbal system, deals with non-visual codes such as words, speech, language, or semantic codes. Generally, each of the systems functions independently but most information processing requires connections and reinforcement between the two systems (Lai, 2000).

Dual coding theory has a strong foundation on human cognitive systems. It assumes that (1) working memory is comprised of both a auditory working memory and a visual working memory (Baddeley, 1986, 1992), (2) the capacity of either visual or auditory working memory is limited, and (3) for meaningful learning to occur, information, either in the visual or auditory modes, has to be selected, organized into an
appropriate representation, and then connected (Clark & Paivio, 1991; Moreno & Mayer, 2000, 2002; Paivio, 1986).

Dual coding theory consisted of two essential assumptions (Kobayashi, 1986; Rieber, 1990a). First, information coded in both systems will have a better chance to be remembered than it is coded in either one of the systems since the two codes have additive effects. The second assumption is that each coding system is different for visual and verbal information. Verbal information is likely to be solely coded by the verbal system; however, the visual information is likely to be dually coded by both verbal and visual systems. The second assumption is especially important for the use of visual material in instructional presentation since the visuals are more likely to be processed in both verbal and visual systems, and hence the probability that they are retained in the working memory and retrieved later from long-term memory is higher than when the presentation contains verbal information alone. Furthermore, the availability of dual coding of visual information ensures that information is not lost because of the unavailability of either one of the coding systems (Rieber, 1991b). Dual coding theory supports the notion that pictures are better remembered than words because of the redundant encoding. In addition, external visual stimuli that invoke both visual and verbal systems are believed to be able to reduce cognitive load in working memory and free some capacity for learning (Yang et al., 2003).

Dual coding is more likely to occur when material contains concepts that are imageable or are concrete, such as a “house” or a “tree” (Paivio & Csapo, 1973). People generally are not trained to develop internal images for concepts that are more abstract or invisible in nature such as “noble” or “humble.” Providing images that can communicate salient features of the concept or correct misconceptions of internally
developed images is believed to be able to enhance comprehension of the concepts. Paivio (1986) proposed that concrete concepts are saved as visual representations and abstract concepts are stored as verbal representations in our long-term memory.

Mayer and Anderson (1992) developed a contiguity principle based on Paivio’s (1991) dual coding theory. This theory assumes that learners construct three basic cognitive connections with incoming information. The first connection occurs at the representational level. Learners have to build a connection between the received information and its represented system. The second connection occurs at the associative level. Relative informational units within either the verbal or visual systems have to be activated (Rieber, 1996). The last level of processing has to do with building a referential connection “… between corresponding elements in the learners’ verbal and visual representations…” (Mayer & Anderson, 1992, p. 444). The contiguity principle predicts that referential connections are easier to make when words and pictures are presented contiguously.

Two assumptions supported by the dual coding theory are particularly related to the effectiveness of using animation in delivering instructional material. First, information coded both visually and verbally is more likely to be remembered than when it is coded alone and, therefore, the chance of it being retrieved is doubled (Kobayashi, 1986; Rieber, 1996; Sadoski, Goetz, & Fritz, 1993). The second assumption is that visual material is likely to be coded visually and verbally; however, verbal material is less likely to be coded visually. This assumption supports the use of visuals since it will activate both the verbal and visual information-processing systems.
In addition, providing internal stimuli that activates both systems during the learning process is believed to be able to reduce the cognitive load and free some capacity of working memory for learning (Ishii & Yamauchi, 1994).

Based on the information-processing theory, dual coding theory further distinguishes two sub-memory systems within human beings’ working memory for the independent but interconnected processing of information of varied types, i.e., verbal and visual. One of the major practical implications of the dual coding theory is its assumption that visual information is more likely to be coded twice or redundantly, making that visual information easy to be remembered, retained, and retrieved for later use. This assumption provided a theoretical rationale for the use of visuals in instructional presentations.

Mayer (2001) claimed that since our memory system processes the visual and verbal types of information independently, more information can be processed at a given time. Furthermore, there is an additive effect of the double channel of information processing—i.e., the visual and auditory channels process information independently but combine and trigger each other during the information processing and, in the long run, enhance each other (Lohr, Roberts & Gall, 2004). Research-based instructional design principles are needed since there is a need for the use of and a tendency to use varied types of visuals in both the learning and instructional environments.

Research so far seems to agree upon the superior effect of visuals/pictures or a combination of visuals/words over words/text alone. However, how varied types of visuals are processed in the memory system is unknown, and their relative effectiveness needs to be investigated and clarified.
Visuals, especially static versus dynamic, are distinguished by their intrinsic nature and therefore require different cognitive processing. There is a need to look at the effects of varied types of visuals while taking into consideration the level of expertise of the learners, the placement of the visuals or text, and other accompanying instructional strategies such as chunking, questioning, narration, or audio.

A Generative Theory of Multimedia Learning

Mayer and his colleagues developed a generative theory of multimedia learning to provide design principles of multimedia instructional materials (1994). This theory draws upon several theories and the extension of these theories, including Wittrock’s generative theory (1974, 1989) and its extensions by Mayer (1984, 1993) and Sternberg (1985); and Paivio’s dual coding theory (1986) as well as its extensions by Baddeley (1992), Mayer (1992, 1993) and Schnotz (1993). The basic tenet of the generative theory of multimedia learning is that learners are active knowledge constructors who are involved in a meaningful learning process. A meaningful process occurs when learners consciously select information from presented stimuli, organize information into coherent representations, and then make efforts to integrate new information with other or existing information. All this information processing is assumed to take place in a cognitive system composed of a visual system that processes visual information and a verbal system that processes verbal information.
Mayer posits the following three conditions for meaningful learning to take place in a multimedia learning environment:

(1) Selection: learners pay attention to relevant verbal and visual information presented through the ears and eyes. The same process was referred to as “selective encoding” by Sternberg (1985, p. 107) and “representational processing” by Paivio (1986, p. 69).

(2) Organization: involves organizing selected verbal and visual information into mental representations. In this process, the selected information is organized into a “coherent whole” (Mayer, 1984, p. 32). The same process is referred to as “selective combination” by Sternberg (1985, p. 107) and “associative processing” by Paivio (1986, p. 69), respectively.

(3) Integration: connections have to be made to connect information presented by the two representations. In this step, new information needs to be connected with other knowledge that is already in the memory. Sternberg (1985) refers to this process as “selective comparison” (p. 107) and is regarded as a “referential processing” by Paivio (1986, p. 69). The last process is the most critical in determining if meaningful learning can take place. For the integration process to occur, both the verbal and its corresponding visual information must be held in the verbal and visual working memories simultaneously. It is the step when the learner “builds one-to-one mappings” between all elements in the verbal and visual representations (Mayer, 1997, p. 6).
Review of Empirical Studies

*Research on Static versus Animated Visuals*

Recent advances in instructional technology have made it possible to design instruction that incorporates varied visualizations. Diagrams and images, typically presented as still or static in both print and CBI environments, can now be animated or programmed to be dynamic to vividly present abstract concepts or phenomena that are invisible to human eyes (Hegarty, 2004). The potential that advanced technology has brought to instructional design, which heavily uses visualization, has excited instructional designers and educational practitioners. However, visualization has a long history in instructional material and previous research has shown that simply adopting a new technology does not necessarily improve learning (Hegarty, 2004). Empirical evidence drawn from theoretically sound research has to be provided to understand the conditions under which dynamic visualizations would be effective and variables that may interact with the dynamic representation of visuals to produce varied effects.

Generally speaking, static and animated graphics can be used to represent materials that are different in nature and their characteristics. Animated visualization is more likely than static visuals to present effectively motions or movements imperceptible to the human eye or changes in shapes or motions of objects (Caraballo, 1985; Wong, 1994). The most powerful and direct application of animation is its use in presenting instructional materials that are dynamic in nature, too abstract to be understood without a concrete example, such as in physics concepts, or typically hidden from view, such as the flow of blood in a human heart (DiSessa, 1982; Dwyer, 1994; Kaiser, Proffitt, & Anderson, 1985; Rieber, 1990a; Rieber & Kini, 1991).
Rieber and Kini (1991) have suggested a number of advantages of animation over static graphics. For example, with animated graphics, learners do not need to generate a mental image of the event or action being targeted and, therefore, avoid the risk of creating a false understanding. In addition, animation provides an increased capacity to present information regarding a continuity of motion (Wong, 1994).

Research so far conducted to compare the effects of static and dynamic/animated visualization on students’ learning has been mixed and mostly discouraging. With the overwhelming excitement on animated visualization, research studies have not been able to conclude that it is any more effective than static visualization. Szabo and Poohkay (1996) reviewed 20 studies that investigated animation in the CBI environment and found that half of the studies show a significant effect in favor of animation while the other half showed no significant differences. They further cautioned that the widespread belief in the superiority of animated to static presentations should be based on more studies.

Research investigating the effects of static and animated visualization also took into consideration several factors such as learning task, learners’ cognitive style and prior knowledge, and other instructional strategies because these factors may significantly interact with each other and the visual presentation to jointly affect the overall learning.

One of the factors considered to significantly affect students’ learning from visualization material has been the learners’ spatial ability. This has been based on the dual coding theory. This theory predicts that students’ ability in the verbal and non-verbal systems will influence their preferences for using verbal or non-verbal representations (Paivio, 1986). According to Yang et al. (2003) and Mayer (1994), the spatial visualization ability concerns the ability to mentally rotate objects presented in two or three dimensions and to imagine “changing configurations” when objects are manipulated.
(p. 334). Consequently, students with high spatial abilities were believed to be able to implement imagery strategies as required by animated instruction than those with low spatial abilities. In addition, animated visualization demands more cognitive processing from learners and is expected to consume more cognitive resources than do static visuals (Moreno & Mayer, 1999). Three studies that investigated the effect of learners’ spatial ability on their learning from static versus animated visualization are described here. Hays (1996) examined the effects of three levels of visual presentations (no graphics, static graphics, and animated graphics) on learning with spatial abilities. Results showed that low spatial ability students, when receiving animated presentations, made significantly greater learning gains than their counterparts who received no animation.

Mayer and Sims (1994) conducted two experiments with high and low spatial ability students viewing a computer-generated animation depicting the workings of a bicycle tire pump or the human respiratory system. The result supports a contiguity effect. High spatial ability students devoted more cognitive resources to building connections between visual and verbal representations of the material. Yang et al. (2003) also investigated the effects of animation on students’ learning of electrochemistry; these subjects possessed varied spatial ability. The results indicated an interaction between the treatment type (static and animated presentation) and spatial ability (high versus low). Students receiving animated instruction scored higher in the posttest, but high spatial ability students receiving animated visualizations outperformed their counterparts who received no animated presentations.

Mayer (1994) conducted a series of experimental studies on the effects of animation when incorporating narrations, on-screen text, and agents, and concluded that students lower in spatial ability may have encountered difficulties when encoding
information presented in animated visualization and therefore were not able to benefit from animated instruction; however, students with a higher spatial ability were able to profit from animated visualization. The same conclusion has been reached by studies conducted by Mayer & Sims (1994), Hays (1996), Koroghlanian & Klein (2004), and Yang et al. (2003).

A large body of animation research has also looked at individual learner differences and their effects on learning from animated instruction. Variables of interests have included learners’ prior knowledge and cognitive styles. Prior knowledge is “…the knowledge, skills, or abilities that the student brings to the learning environment prior to instruction…” (Jonassen & Grabowsky, 1993, p. 419). Two conceptions of prior knowledge are specifically related to instruction. Prerequisite knowledge is the specific knowledge related to certain domains that learners need to have to be able to learn the new material. Prerequisite knowledge can be assessed via a pretest developed specifically for a certain content domain (Tobias, 1982). The second conception is the “…total existence of knowledge…the learner brings to the learning environment…what the learner already knows both directly germane and remotely related to the content” (Jonassen & Grabowski, 1993, p.419).

Research has confirmed a relationship between prior knowledge and instructional support. As the level of prior knowledge increases, the need for instructional support may decrease or increase. External instructional aids such as media or methods should be designed in accordance with how they will influence learners’ cognitive activities when they possess different levels of prior knowledge. ChanLin (1999) examined the effectiveness of different visual presentation strategies (still graphics and animated graphics) on students possessing different levels of prior knowledge. Learning
achievements were assessed with a criterion-referenced test that included descriptive and procedural content. The results indicated that for descriptive content tests, high prior knowledge students outperformed low prior knowledge students in animated visual instruction but not static visual instruction. ChanLin concluded that her study supported the hypothesis that visual presentations affect learning only under a specific prior knowledge level.

Learning procedural facts or descriptive facts represented via visualization is significantly related to students’ prior knowledge. For low prior knowledge students, both animated and static graphics can help with the learning of descriptive facts; however, for high prior knowledge students, animation was more effective since it promotes a higher level of visual information processing. ChanLin (1998) found similar results in a previous study that investigated the interactive effect of prior knowledge, visual types (no graphics, still graphics, and animated graphics) in learning descriptive and procedural knowledge. For the low prior knowledge group, both still graphic and animated visualization outperformed the group that received no graphics in learning descriptive facts. However, in learning procedural knowledge, the high prior knowledge group receiving still graphics outperformed significantly the group that received no graphics.

Another individual learner difference that has been widely explored in visualization research is cognitive style. Cognitive style has been regarded as a reliable predictor of learning (ChanLin 1998, Lin, Davidson, & Gayle, 1996; Dwyer & Moore, 1994; Hansen, 1997). Learners with different cognitive styles adopted different information processing strategies and problem solving styles in learning; in addition, research has shown that cognitive styles also affect viewing strategies employed in different instructional presentations (ChanLin, 1998; Dwyer & Moore, 1994). Learners
with field dependent cognitive styles are believed to rely more on the providing of an established structure in the learning material while, on the other hand, field independent learners were able to construct their own reasoning out of the instructional material. For instructional material in which conceptual representation is needed for comprehension, learners with field independent styles are more likely to perform better than their field dependent counterparts.

As discussed earlier in the chapter, animation studies conducted so far have produced mixed results. For studies suggesting insignificant results, researchers indicated that learners, when presented with the animated instruction, were not able to effectively attend to the animation or was distracted by the combination of visual and verbal information presented to them (Rieber, 1991a). Owens & Dwyer (2005) have also indicated that learners may have failed to focus on critical aspects of the animation and therefore were not able to effectively interact with the animation to be able to fully benefit from it.

Lin, Chin, Ke, & Dwyer (2005) conducted a meta-analysis to examine the relative effectiveness of varied enhancement strategies used to complement animated instruction on different educational objectives. The enhancement strategies included advance organizers, chunking strategies, scaffolding, and audio/narration. The criterion measures were composed of four criterion tests measuring different educational objectives. The result of the meta-analysis generally supported that varied enhancement strategies can be used to improve students’ learning from animated instruction; however, the overall effect of each enhancement strategy is not equal nor is it similar for different learning outcomes. Both advance organizer and chunking strategies produced greater effect sizes in almost all learning outcomes. Audio and other strategies produced generally low effect sizes
across all learning outcomes.

The results of this analyses indicates that when the type of enhancements employed in this study are used to complement animated instruction they can have either a positive or negative effect depending on the type of enhancement and the type of learning objective to be facilitated. The size of the effects both positive and negative would indicate that the additional information processing initiated by the different enhancements was similar to that generated by the carefully positioned animation; consequently, their additional impacts were at best marginal. The negative effect sizes may be explained by the fact the specific enhancements impeded rather than facilitated information acquisition. The enhancements themselves may have distracted students’ attention from the critical information designed to be imparted by the animation, thereby reducing their effectiveness. These results would indicate that further research should concentrate on the design of enhancements that ensure that more intense interaction occurs between the content and the learner and that this interaction be assessed in terms of its effectiveness in facilitating achievement of different types of educational objectives.

Rieber (1990a) after conducting a review of static versus animated visualization studies indicated that animation has been used “…with the intent to impress rather than to teach….” (p. 77). He strongly suggested that animation be used only when its attributes are congruent to the learning task and that interactive graphic applications are the greatest contributor of animations. He also cautioned that complex animation may be difficult for novice learners without prior knowledge in the content area, i.e., they may not know how to attend to critical information delivered by the animation; he suggested that additional instructional strategies may be needed to accompany the animated instruction. Research conducted so far on the effects of static versus animated visualization has produced either
inconclusive or sometimes conflicting results. However, evidence suggests that other factors such as learners’ cognitive styles, prior knowledge, and age level were significantly related to the effect of varied types of visualization; additional instructional strategies may be needed to accompany the visualization presentations to facilitate students’ learning. Generally, due to the difference in cognitive processing and learning styles, high spatial ability students are more likely to benefit from animated instruction than low spatial ability ones. With prerequisite schemas to encode dynamic presentations induced by animation, learners with high prior knowledge are believed to be able to benefit more from animated instruction than those with lower prior knowledge.

Quality research on the effect of instructional strategies used to complement animated instruction is significantly lacking; however, the meta-analysis that Lin and her colleagues conducted indicated that the effect of varied instructional strategies on complementing animated instruction also varies depending on the designated educational objectives. More research on this aspect should be conducted.

Research on Feedback

Since computers have been used as both teaching and learning tools, instructional strategies developed specifically to be used in a computer-based learning environment have been increasing in numbers. Computers offer a variety of features that instructional designers and educational practitioners can take advantage of to advance both learning effectiveness and instructional efficiency. Computers also afford more instructional presentation formats and learner-controlled or learner-centered learning strategies, which are otherwise more difficult to achieve in conventional face-to-face instructional environments. However, with the ever-increasing features that computers can afford and
accommodate, educational technologists are faced with design decisions with regard to which feature to use to maximize students’ learning when designing CBI lessons (Pridemore & Klein 1995).

Feedback is one of the important design strategies commonly used in CBI. Feedback specifically for instructional purposes has been defined as an advisement strategy that can help students make “intelligent decisions” in terms of the sources of errors and thereby facilitates self-correction (Schloss, Wisniewski, & Cartwright, 1988, p. 142). Although different feedback strategies can be developed in a CBI lesson, the most common formats found are: (1) knowledge of response feedback (KOR), which informs the learner whether his/her response was correct or incorrect; (2) knowledge of correct response feedback (KCR), which provides the correct response; and (3) elaborative feedback, which provides additional information relevant to the correct response in addition to identifying the correct response (Clariana, Ross, & Morrison, 1991; Merrill, 1985).

Different types of feedback may produce different amounts of effectiveness under different learning conditions, with different learning tasks and learners of various ages and levels of expertise. Studies on types of feedback have indicated conflicting and sometimes confusing results. Some studies showed that KCR is more effective than KOR, which is more effective than no feedback at all (Gilman, 1969, Kulhavy, 1977, Waldrop, Justin, & Adams, 1986, Clariana, Ross, & Morrison, 1991). Bangert-Drowns, Kulik, Kulik, and Morgan (1991) argued that an understanding of the purpose and function of feedback may be needed before the conditions of effective feedback can be established. According to them, feedback can have different levels of “intentionality” depending on whether it is designed to inform learners about the appropriateness of specific
performance or it is presented as an “incidental consequence” of the learning experience (p. 215). The targeted aspect of feedback may also be different. Some feedback is used to affect a specifically affective aspect of learning and others may be targeted at providing “self-monitoring” or “self-regulated” learning opportunities (p. 215).

Kulhavy and Stock (1989) distinguished types of feedback in terms of its content, which includes: (1) load, which refers to the amount of information provided in the feedback; (2) form, i.e., the difference between the feedback and original instructional content in terms of the structure; and (3) type of information concerning whether or not the information provided in the feedback can be found in the instructional material itself or if it presented new information. Feedback research so far has produced inconsistent and confusing results. Kulhavy (1977) indicated that this may due to an overwhelming belief in feedback as a reinforcing rather than informational event that occurs in the learning process. According to Kulhavy, feedback as a reinforcer acts as “…stimulus that increases the future probability of the response which it follows….” There is little evidence suggesting that feedback provided in a programmed instruction acts in a “reinforcing” manner (p. 213).

Feedback effectiveness is influenced by many external factors such as the nature of the learning task, timing of feedback, type of feedback, and type of instruction (Bangert-Drowns, Kulik, Kulik, & Morgan, 1991; Huang, 1995). The results of two meta-analyses conducted in the 1990s on feedback research are described here. Bangert-Drowns, Kulik, Kulik, & Morgan (1991) reviewed 40 studies that generated 58 effect sizes and found that the effect of feedback varied when controlling for pre-search availability, type of feedback, use of pretests, and type of instruction.
In this meta-analysis, four categories involving 16 characteristics were used to code each study. More specifically, five variables were used to code the feedback treatment: type of feedback, timing of feedback, counts for grade, instructional item type, and the error rate during instruction. Type of feedback included (1) right/wrong feedback, (2) provision of the correct answer when the first attempt was incorrect, and (3) extended explanations of a given response. A general result of the meta-analysis revealed the weak effects of feedback on students’ achievement. Approximately one third of the studies analyzed yielded negative effect sizes and, on average, feedback only contributed a positive and small achievement to students’ learning. However, the researchers found out that when controlling for pre-search availability, feedback made significantly more contributions to student achievement. Pre-search availability was found to be a mediator in feedback effects; furthermore, the mediating effect of pre-search availability was also found to be confounded with the forms of instruction, especially between programmed instruction and other forms of instruction. When controlling for the type of instruction, the feedback provided in programmed instruction is associated with the lowest effect size. The researchers suspected that detailed and redundant questions typically found in programmed instruction may have made the feedback less important and thus its effect was not robust.

The meta-analysis identified four variables that are significantly related to feedback effects: pre-search availability, type of feedback, use of pretests, and type of instruction. Generally speaking, providing a pre-search opportunity for students significantly reduces the effects of feedback; the type of feedback that provides a correct response is more effective than feedback that informs learners if his/her response is correct. In addition, pretests are not recommended in CBI lessons involving feedback
because the provision of pretests changed learner expectancies and served as practice or advance organizers of upcoming information. The meta-analysis also found that the type of instruction has an effect on the effectiveness of feedback. Feedback used in programmed instruction or computer-based instruction is less effective than that used in text comprehension or conventional testing situations. The superior effect of feedback as observed in a text comprehension situation is due to the fact that the material used in this situation is generally more difficult and complex and also students typically were given less instructional support than they would if the material was presented in a programmed instruction format.

Another meta-analysis on feedback research was conducted by Azevedo and Bernard (1995). The meta-analysis was conducted to investigate the effects of feedback on learning specifically from CBI; 22 studies involving administration of immediate posttests and nine studies involving delayed posttests were included in the meta-analysis. The effect of feedback was found to be different depending on the CBI typology, format of unit content, and access to supplemental material. The overall weighted effect size computed as a result of the meta-analysis was .35, indicating a small and positive effect of the provision of feedback versus a non-feedback situation. However, since the effect size violated the assumption of homogeneity of variance, the researchers suspected that there may be other intervening variables that contribute to the effect of feedback on student achievement. CBI typology was identified as one of the possible intervening factors. Feedback delivered by an adaptive instructional system obtained the greatest effect size compared to that delivered by a computer-driven interactive video. Linear CAI and branching CAI were the least effective in presenting feedback in terms of improving student achievement. The meta-analysis result suggested the provision of adaptive and
“tailor-made” feedback based on dynamic and continuing monitoring of students’
learning process (p. 16).

Gaynor (1981) investigated the effect of delay feedback on short- and long-term
retention of instructional material when feedback is presented in three formats:
immediate feedback, end of session feedback, or no feedback. The findings suggested
that the format of feedback does not effect the short-term or long-term retention of the
material, indicating that instruction that provides no feedback may produce an effect
equal to instruction that provided either immediate or end of session feedback. Gilman
(1969) investigated the effect of varied types of feedback used in a computer-assisted
instructional unit to teach science concepts. The types of feedback explored included no
feedback, knowledge of results (KOR), knowledge of correct response feedback (KCR),
response contingent feedback, and a combination of the above three types of feedback.
The results indicated that providing a statement of the correct response and an
explanation of why a given response is incorrect is more effective than simply informing
students if her/his response is correct. The research also found that KOR feedback is no
more effective than providing no feedback.

Clariana, Ross, & Morrison (1991) also investigated the effects of different
feedback strategies on learning science material. Five feedback conditions were explored:
KCR, delayed KCR, answer until correct (AUC), no feedback, and no questions. The
results overall supported the provision of feedback in facilitating science learning with
lower level educational objectives. Feedback is more important when supporting text is
not available. In particular, the effectiveness of AUC is increased as the wording of
questions changes from identical wording to reworded wording. Instructional strategies
embedded into a lesson may influence the effect of various types of feedback.
Research on feedback also has explored the relation between feedback strategy and learner response confidence. Clark and Dwyer (1998) examined the effect of different types of computer-assisted feedback strategies in student achievement and response confidence. Achievement was measured via posttests that assessed facts, concepts, and principal types of knowledge. The results indicated that feedback strategies had an insignificant effect on student achievement. Contrary to expectation, both the no feedback and elaboration feedback groups scored the highest in the posttests while the KOR and KCR were associated with low scores. The superior effect of elaboration feedback to both KOR and KCR is consistent with previous research conducted by Clariana (1993). However, the reason behind the finding that no feedback is more effective than KOR and KCR is not clear. The researchers suggested that these types of feedback were not equally effective depending on the correctness of the initial response made by students.

Whether requiring a covert or overt response to questions followed by varied types of feedback was also a variable of interest in feedback research. De Klerk and De Klerk (1978) conducted an experiment to measure the effect of overt and covert responses with no feedback or KCR with overt or covert response patterns. Achievement was measured by five administrations of a 25-item multiple-choice test. The results indicated that a covert response pattern was significantly more effective than an overt response pattern and also was superior to a no feedback condition. The author concluded that the use of the covert response mode is more desirable when feedback is presented after each item.
A general literature review on feedback research, specifically on the availability of feedback, seems to indicate that feedback helps students learn from an instructional unit. Kulhavy (1977) identified two conditions under which students would not benefit from feedback given in an instructional unit. One is the availability of a pre-search. The availability of pre-searching simply renders students from a reader into a writer because they may just copy answers into questions without reading the material in an attempt to find the answers. The other negative condition preventing feedback from having an effect is when the material is too difficult for the learners. Under this circumstance, students may just guess their answer and try to match the feedback with the question given the fact that the question may be too difficult to answer. An alternative explanation for the superiority of the no feedback condition over simple types of feedback such as KCR or KOR may be that learners receiving no feedback spent more time looking for information in the text and therefore have a more thorough understanding of the text as opposed to learners receiving either KCR or KOR. No extra mental effort was required by these learners and, therefore, the achievement was not significantly better than their counterparts who received no feedback (Pridemore & Klein, 1995; Kulhavy & Stock, 1989).
CHAPTER 3
RESEARCH METHODOLOGY

This chapter describes the development of the CBI material, respective treatment modules, nature of the criterion posttests, subject recruitment, the participants, and the experimental procedure. In addition, this chapter provides a preview of descriptive data for the sample, actual scores obtained by respective treatment groups on all tests, and an analysis of the reliability of criterion measures. The chapter ends with a description of the statistical analysis to follow that will answer the research questions.

Development of the CBI Module

For the purpose of the study, the instructional content, originally presented in print material, was further developed into a CBI format with either static or animated visuals, which were accompanied with varied instructional strategies. The software packages used to develop the CBI module included Adobe PhotoShop, Macromedia Dreamweaver, and Macromedia Flash 6. The instructional module consisted of five units: 1) the heart’s structure; 2) the veins and arteries; 3) the valves of the heart; 4) the bloodflow through the heart; and 5) the phases of the heart cycle. The content for each unit was presented in several frames and ranged between two and eight frames depending on the amount of information that needed to be covered. The total number of instructional frames for the module was 20.

To be consistent across all treatments, all instructional frames were split into the five sections with the title of each unit on top of the screen. In the bottom was a
navigation bar that allowed students to go back or move forward within the instructional module. The column on the very left side of the frame showed which lesson students were currently viewing. At the top left side of the screen, the current page number within each current unit was displayed. Visuals, either static or animated, were displayed on the right-hand side of the screen. These visuals were designed to complement the text to their left. A program control was implemented to make sure that students did not skip any page of the instruction. Preceding the instructional frames was an introduction page, which described the purpose of the study, procedures to be followed during the study, the instructional content and its organization, as well as criterion tests that students needed to complete. Figure 3.1 presents a screenshot of a sample frame of the instructional module.

![Screenshot of a sample frame.](image-url)

*Figure 3.1. Screenshot of a sample frame.*
**Instructional Material**

The instructional material used in this study contained a 2,000-word physiology unit focusing on the human heart, its parts, locations, and functions during the diastolic and systolic phases (Dwyer & Lamberski, 1977). The instructional script was accompanied by 20 visuals of the human heart, which were designed and positioned utilizing the principles of instructional consistency and congruency (Dwyer, 1994; Canelos, 1983). This instructional unit was selected to explore the effect of two types of visuals, i.e., static versus animated and three types of instructional strategies, i.e., no strategy, questions, and questions plus feedback. In addition, criterion measures were developed to accompany the instructional module to test the objectives at each level.

**Development of Treatment Material**

*Two Pilot Studies*

To effectively develop animated visuals that would facilitate the students’ learning and comprehension of more difficult and complex concepts presented in the treatment instructional material, two pilot studies were conducted to precisely identify the portions of the instructional material that students experienced learning difficulties with so that animated visuals as well as additional instructional strategies, i.e., questions and feedback, could be developed and embedded to facilitate comprehension and achievement. The results of the two pilot studies suggested that there were nine (N=9) items in the drawing test, none (N=0) in the identification test, and twelve items (N=12) and thirteen items (N=13) in the comprehension test for which students’ achievement need to be improved. A detailed description of the procedure and results of the two pilot studies can be found in Appendix H.
Animation

The animation developed for the purpose of the study was based on guidelines provided by Wong (2000, pp. 28-33) and suggestions from the literature on animated tutorials. These guidelines were:

1. Animation is used with a purpose: the animation used in the study was to explain the text material, guide students’ attention, and make the instructional material more concrete to facilitate understanding.
2. Attention-getting stimuli were kept to a minimum level. Blinking or repetitive movements were kept to a minimum level so as not to distract students.
3. Avoid the use of transition effects: transition effects typically used to serve a changeover purpose were avoided in this study.
4. Animate essential objects only: only difficult concepts were complemented by the animated visuals to help the learners focus on the most important information.
5. The amount of information delivered by the animation was kept to a minimum: the animation displayed on each frame was developed to deliver a limited amount of information and the sequence was made as distinct and smooth as possible.

The extra amount of time to view all the animation once in the animated treatment is an addition of approximately six minutes. To ensure that each animation sequence was viewed, a system control was implemented so that each animation could not be stopped in the middle while it was playing; also, students would not be able to proceed to the next frame without viewing the complete animation sequence.

Appendix A provides a description of each animation sequence, strategies used to develop the animation, and the total time for each sequence.
Questions

Questions were developed, as were the animated visuals, based on the item analysis conducted in the two pilot studies, which were conducted to identify the difficult portion of the instructional module. The purpose of the questions was to draw students’ attention to the relevant visual learning cues presented in the instructional module. The questions were positioned in frame(s) that followed the instructional content that contained concepts that were found to be difficult to comprehend. Each question consisted of a stem and two or three alternatives. Students were required to make an overt response to the questions by recalling the material contained in the preceding frame. There was only one question on each frame; however, several questions were sometime needed to address all the difficult concepts contained on one instructional frame. In addition, only selective instructional frames were followed by questions and the number of questions following each selective frame was different depending on the difficulty level of the material contained in that frame. In total, 34 questions were developed for 14 frames. A complete list of questions can be found in Appendix B.

Feedback

The type of feedback used in the study is a combination of KOR (knowledge of response) and elaborative feedback. Knowledge of response feedback informs the learner whether his/her response is correct. Elaborative feedback informs the learner whether or not his/her response is correct in addition to extra information on the correct answer (Clariana, 1993). Specifically, each question developed was followed by a feedback, which contained two parts: (1) information regarding whether the response submitted by the learner is correct or incorrect, and (2) an elaboration of the correct response to the question. For example, the feedback given to a response to the question “what is the chamber of the
heart that pumps blood to the body” would be “your answer is (in) correct, the left ventricle is the chamber of the heart that pumps blood to the body.” The purpose of the feedback was to provide either negative or positive reinforcement of students’ responses to the questions, which were designed to draw students’ attention to the most important concepts/knowledge contained in the instructional module. The provision of feedback to the previous responses enabled the students to (1) correct misconceptions developed if their submitted response was incorrect, and (2) to reinforce the correct concepts acquired when the response submitted was correct. Figure 3.2 provides a screenshot of the type of feedback employed in the study.

![Figure 3.2. Screenshot of a sample feedback.](image)

**Respective Treatment Material**

*Group one. Animation alone.* Participants assigned to this treatment group received instructional material that contained text and animated visuals in selective frames. In total, 14 animation sequence developed to address 34 difficult items were embedded in these frames. Students in this treatment group were instructed to first read the text carefully and then play the animation. Each animation sequence was developed to complement a portion
of the text and to facilitate the understanding of complex concepts which had been found in the pilot studies to be difficult to comprehend with static visuals only. Students were encouraged to relate the animation to its corresponding text and play the animation as many times as needed to comprehend the information being presented. Figure 3.3 provides a screenshot of the instructional frame that contained an animated visual.

![Figure 3.3. Instructional frame containing an animation sequence.](image)

**Group two. Animation + questions.** Participants assigned to this treatment group received instructional material that contained text, animated visuals, and questions in selective frames. Students in this treatment group received exactly the same instructional material as did the “animation alone” group; however, 32 questions addressing 34 difficult items were embedded after the 14 frames to reinforce students’ comprehension and acquisition of the difficult knowledge contained in previous frames. Participants in this treatment group were informed that they needed to read the text carefully before clicking on the “play the animation” button. After viewing the animation sequence, they needed to answer questions that followed the specific frame. A system control was implemented to ensure that skipping the answer was not possible. Students needed to read the question,
select a best alternative and submit the response. No feedback was given after the submission of the response as to whether the submitted response was correct or incorrect. Figure 3.4 provides a screenshot of the instructional frame that contained a follow-up question to specific material in a previous frame.

![Instructional frame containing a question.](image)

**Figure 3.4. Instructional frame containing a question.**

**Group three. Animation + questions + feedback.** The instructional material used for the treatment group contained the text, animated visuals in 14 frames, questions following these 14 frames, and corresponding feedback. Participants assigned to this treatment group were instructed to read the text carefully, play the animation, and try their best to relate the text to the animated visuals. After viewing the animation, students proceeded to a frame that contained a question. Similar to the participants in the “animation + questions” treatment group, the participants in this group needed to make an overt response to each question. In addition, after a response was submitted, feedback on the correctness of the response was displayed as either “incorrect” or “correct.” A short sentence elaborating upon the correct answer was provided as well. Students could compare their submitted response with the feedback and correct any misconceptions that they had by reading the
elaborated answer. Figures 3.5 and 3.6 provide screenshots of an instructional frame that contained feedback to a correct and an incorrect answer.

Figure 3.5. Feedback to an incorrect response.

Figure 3.6. Feedback to a correct response.

Group four: Static visuals alone. The instructional module received by participants in this treatment group consisted of text and static visuals used to complement the text. The visuals were developed using simple line drawings, not realistic pictures. Participants
were informed that they should study the text carefully and then relate the text with the picture, which was displayed to the right side of the text. Participants assigned to this treatment group received no instructional strategies embedded to enhance their learning from the instructional module. In total, there were 20 static visuals in this module, with one static visual accompanying each instructional frame. The 20 visuals matched those in the previously described treatments, with all being static in this treatment. Consistent with other treatment groups, participants could move forward to the next frame or go back to the previous one sequentially by manipulating the navigation tools provided. However, a system control was implemented to ensure that participants visit all instructional frames. Figure 3.7 provides a screenshot of an instructional frame that students in this treatment group interacted with.

![Instructional frame containing a static visual.](image)

**Figure 3.7.** Instructional frame containing a static visual.

**Group five. Static visuals + questions.** Participants in this treatment group received exactly the same instructional material as that received by the “static visuals alone” treatment group; however, an additional instructional strategy was embedded in the instructional module. Questions following the same 14 instructional frames as those in the
animated visual treatments were provided to students in this group as an enhancement strategy to focus attention on relevant visual cues presented in the previous frame as well as to serve as a practice question to test their comprehension of the material contained in the previous frame. The questions were exactly the same as those received by the “animation + questions + feedback” and “animation + questions” treatment groups. The students were informed that they should read the question carefully, recall what they have learned from previous frames, and choose a correct answer. There was no feedback in regard to the correctness of the submitted response; however, a system control was implemented to make sure that the students submit an answer to each question in order to be able to proceed to the next frame.

*Group six. Static visuals + questions + feedback.* The instructional module received by this treatment group was exactly the same as that received by the static visuals + questions group; however, the students received immediate feedback on their responses right after each submission. The feedback, presented in the same format and with the same amount of information as that received by the “animated visuals + questions + feedback” treatment group, first assessed the students’ submitted responses as either correct or incorrect, then provided a simple elaboration of the correct response. The elaboration of the correct response was the same regardless of the correctness of the submitted response.
Treatment Validity

The intended content portrayed by the animation was validated by a panel of experts, which included:

- A professional visual designer who has been offering visual design classes.
- Two doctoral students majoring in biology.
- Two faculty members who had used the same instructional content and published articles on research that used the same material.

The validity of the experimental material was established by having the panel of experts review the treatment materials online and complete an evaluation form. Each reviewer was asked to evaluate the effectiveness of the animated visuals in communicating and helping them understand the designated concepts on a 5-point scale in the evaluation form. The result was then calculated item by item. Thirty out of 34 concepts were marked in category 5, indicating that the animation sequences developed to communicate these concepts were effective. Four animated sequences that were rated as not very effective were modified by incorporating suggestions from the panel. Appendix C is the evaluation form used by the panel to establish the validity of the animated visuals. The web pages developed for “static visuals alone” and “animation alone” can be found in Appendix D and Appendix E.

Criterion Measures

Four criterion measures developed by Dwyer (1972) were used to assess students’ understanding and achievement of the instructional material. These four criterion tests measured different levels of learning outcome, e.g., facts, concepts, rules/procedures, comprehension, and problem solving. Each criterion test consisted of 20 items with each
item worth 1 point. The maximum score for each test was 20. Except for the drawing test, the terminology, identification, and comprehension tests each consisted of 20 multiple choice questions. Students were asked to choose the most appropriate alternatives from a provided list. As for the drawing test, students were asked to draw a diagram of the human heart on a provided piece of paper. All the tests except the drawing test were converted to a CBI format so that after students received their respective treatment, they could immediately take the tests. A detailed description of the criterion measures is summarized below.

**Drawing Test**

The purpose of the drawing test was to measure students’ overall understanding of the instructional material as well as their ability to “… reproduce the parts of the heart in their appropriate context….“ (Dwyer, 1994, p. 391). This criterion test was developed to assess specifically the level of intellectual skills/concept learning regarding the instructional module according to the types of learning outcomes developed by Gagne (1985). Each student was provided with a blank piece of paper on which they were required to draw a simple diagram of the human heart. Twenty (20) parts of the human heart were to be correctly identified and located on the diagram. The quality of the drawing was not assessed; only the correct positioning of each part of the human heart was evaluated.

**Identification Test**

The purpose of the identification test was to assess the students’ ability to identify parts of the human heart. The level of knowledge measured in this test was verbal information based on Gagne’s types of learning outcomes (1985). Verbal information or
factual knowledge, although generally regarded as “… parrot-like recitation and rote memorization of isolated facts…” is a prerequisite to learners’ acquisition of more advanced concept learning or problem solving (Ausubel, 1963, p. 15). In this test, a diagram of the human heart with 20 numbered arrows was provided to students, who had to then choose the corresponding letter to the numbered arrow from four possible answer choices. Figure 3.8 provides a screen shot of a sample question in the identification test.

**Identification Test**

![Identification Test](image)

*Figure 3.8. A sample question on the identification test.*

**Terminology Test**

The terminology test measured several levels of learning including verbal information, concepts, and rules/procedures. The students’ knowledge of specific terms of the human heart and their association with various functions of the human heart were assessed. For example, students were assessed if they knew “superior and inferior vena cava” is the term for the part of the human heart through which blood from the body enters the heart. Figure 3.9 provides a screenshot of a sample question in the terminology test.
**Comprehension Test**

The test measured a higher-level learning outcome; the mastery of this learning outcome would require the students’ competent acquisition of knowledge concerning facts, rule/procedures, concepts, and problem solving pertaining to the instruction. The test covered questions that asked about the function of the human heart in both the diastolic and systolic phases. In particular, given a description of how a part of the human heart was functioning, students were to identify a simultaneous functioning of another part(s) of the human heart. In other words, position or status of relative parts while specific parts of the human heart are operating needed to be fully comprehended by the students for them to score high on the test. Figure 3.10 provides a screenshot of a sample question in the comprehension test.

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**Figure 3.9.** A sample question on the terminology test.

---

<table>
<thead>
<tr>
<th>Terminology Test</th>
<th>1/20</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Question:</strong> ___ is (are) the thickest walled chamber(s) of the heart.</td>
<td></td>
</tr>
<tr>
<td>• Atriales</td>
<td></td>
</tr>
<tr>
<td>• Myocardium</td>
<td></td>
</tr>
<tr>
<td>• Ventricle(s)</td>
<td></td>
</tr>
<tr>
<td>• Pericardium</td>
<td></td>
</tr>
<tr>
<td>• Endocardium</td>
<td></td>
</tr>
</tbody>
</table>

Submit
Total Composite Score

Two composite scores were calculated. One composite score was calculated by adding the separate scores of all items on the drawing, identification, terminology, and comprehension tests. Another total composite score was calculated by adding the separate score of enhanced items only on the drawing, terminology, and comprehension tests. The purpose of the first composite score was to measure the students’ overall achievement of the material contained in the instructional module. The purpose of the second composite score was to measure specifically the students’ achievement of the portions of the material enhanced by animation and varied instructional strategies. Complete test items for the four criterion tests as appeared in the CBI module can be found in Appendix F.

Covariates

Two covariates—the physiology prior knowledge test and the time-on-task—were used as control variables in this study. A description of each of the covariates follows.
Physiology prior knowledge test. The purpose of this test is to evaluate the students’ knowledge of general physiology. The test consisted of 36 multiple choice questions. The students chose one answer from the alternatives that was most appropriate to the question. Only 6 of the 36 questions on the test are directly related to the material content used in the study. The test score was collected and analyzed to investigate whether or not there existed initial differences among the treatment groups on their prior knowledge generally related to the content of the material used in the study. When significant differences were detected, the test was entered into analysis to adjust for its effect on the students’ achievement on the criterion posttests. For the complete list of questions on the test, see Appendix G.

Time-on-task. Time-on-task was employed as another control variable in this study. It was defined as the total time students spent studying the respective treatment material. It was recorded by the computer from the moment students began the first frame of the instructional material to the moment when he/she clicked on a button to indicate that he/she had finished studying the material and was ready to take the tests. The amount of time was collected in seconds. As with the physiology prior knowledge test score, time-on-task was analyzed prior to any statistical procedures performed on the criterion posttests. If there existed significant differences among the treatment groups on the amount of time spent on a task, the variable was entered into the analysis of criterion posttests as a covariate to adjust for its effects on the students’ achievement scores.

Reliability of Criterion Measures
Cronbach’s alpha coefficients were calculated to establish the reliability and internal consistency of the dependent variables and the physiology prior knowledge test in
this study. The reliability analysis results are summarized in Table 3.1. All of the Cronbach’s alpha coefficients calculated reached the acceptable level of .65, indicating the criterion measures employed to measure the students’ achievement reached acceptable levels of reliability.

Table 3.1
Reliability Coefficients of the Dependent Measures

<table>
<thead>
<tr>
<th>Measures</th>
<th>All Items</th>
<th>Enhanced Items</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Alpha</td>
<td>Number of Items</td>
</tr>
<tr>
<td>Drawing</td>
<td>.92</td>
<td>20</td>
</tr>
<tr>
<td>Identification</td>
<td>.87</td>
<td>20</td>
</tr>
<tr>
<td>Terminology</td>
<td>.84</td>
<td>20</td>
</tr>
<tr>
<td>Comprehension</td>
<td>.84</td>
<td>20</td>
</tr>
<tr>
<td>Composite Score</td>
<td>.96</td>
<td>80</td>
</tr>
</tbody>
</table>

Research Participants

Recruitment of Subjects

The application to use human research participants in this study was approved by the Institutional Review Board (IRB) of The Pennsylvania State University before the study was conducted. An e-mail seeking research participants was sent to instructors of selected undergraduate classes in the summer of 2005. The e-mail described the purpose of the research and the procedure that prospective participants would need to follow to complete the research. Instructors were asked to offer extra class credit to encourage students’ participation. Upon the approval of the instructors, the researcher arranged a time and gave a recruitment talk in the class. During the recruitment, the researcher described the research purpose, procedure, and time expected to complete the study and the amount of extra credit offered by the instructor. Students who agreed to participate were asked to
sign up and complete a form in which they needed to identify their priorities from a list of experiment sessions. Students were thanked and informed that they would receive an e-mail notifying the time and location of the experimental section that would be assigned to them and that they would need to report to the location on time to participate in the study. Upon completion of the study, the researcher e-mailed attendance lists to the instructors so they could give extra credit to students who participated in and completed the research.

The Participants

The final participant pool was comprised of 582 (N=582) undergraduate students, enrolled in The Pennsylvania State University at the time of the study during the fall semester of 2005. The mean age was 20.10, with a standard deviation of 1.89. The range of ages was between 18 and 44. Among them, 324 participants were females and 258 were males. 13% of the participants were freshmen (N=77); 29% were sophomores (N=169); 35% were juniors (N=202); and 23% were seniors (N=134).

Participants were recruited from a number of classes: IST 331 (Organization and Design of Information Systems: User and System Principles); SOC 001 (Introduction to Sociology); SOC 023 (Population and Policy Issues); SOC 422 (World Population Diversity); MGMT 100 (Survey of Management); RPTM 410 (Marketing of Recreation Services); STAT 200 (Elementary Statistics); STAT 250 (Biostatistics); COMM 160 (Basic News Writing Skills); and COMM 381 (Telecommunications Regulation).

Research Design

The sample involved in this study consisted of 582 undergraduate students enrolled in The Pennsylvania State University (freshmen, sophomores, juniors, and seniors). Each
participant was randomly assigned to one of the six treatment groups according to the order he/she reported to the experimental site. Each student completed a demographics survey, interacted with his/her respective treatment material, and received four criterion posttests. The demographics survey collected information on the participants’ age, gender, current academic status, major, and the class from which the researcher conducted the recruitment. This study employed a posttest only, a 2 X 3 factorial experimental design.

The two independent variables were visual type and instructional strategy. The dependent variables were four criterion posttests measuring differences in subjects’ understanding of the materials after being exposed to the learning materials. The first independent variable, i.e., visual types, consisted of two levels: static visuals or animated visuals. The second independent variable, i.e., instructional strategy, was comprised of three levels: no strategy, questions, and questions plus feedback. Figure 3.11 described the research design employed in the study.

*Figure 3.11. 2 X 3 factorial posttest-only research design.*
Experimental Procedures

The study was conducted in a multimedia computer lab equipped with 60 IBM desktops. In total, 50 lab sessions were reserved for the purpose of the study. Each lab session lasted for 1 hour and 30 minutes. Participants reported to the lab based on the priority they identified when the researcher conducted the recruitment. Participants were asked to sign an informed consent form upon their arrival at the experimental site and then were randomly assigned to respective treatments. The random assignment was based on the order participants reported to the multimedia computer lab.

Prior to the study, the researcher made an introduction that detailed the purpose of the study and the procedures to follow. A special emphasis was made on the restriction of inappropriate behavior. Participants were informed not to engage in any activities irrelevant to the study such as checking their e-mail, browsing the Web, or using an instant messenger. Participants who violated the experimental rules were expelled from the study. Each instructional module, which was self-paced, was installed on a server located in the College of Education.

Participants first read through an introduction page that described the study procedure and then after logging in, filled out a demographics survey. A physiology prior knowledge test was then given before they received their respective treatment. Participants were encouraged to interact with their instructional material for as long as needed to fully comprehend the information presented and, when they were ready to take the tests, they should hit “take the drawing test” button.

A sealed envelope containing the first criterion posttest—the drawing test—was distributed to participants when the study began. Instructions on the screen indicated the appropriate time for participants to open the envelope and take the drawing test. The study
on average took about 1 hour and 20 minutes to complete, including studying the instructional material and completing the four criterion posttests.

Data Analysis Procedures

The purpose of the study was to investigate the relative effectiveness of varied visual types and instructional strategies in facilitating the students’ achievement of specifically designated educational objectives. Due to the time and cost needed to develop visualized instruction, it was assumed that if two types of visuals or instructional strategies are equally effective in improving student achievement, the least expensive and the most effective type or strategy should be used (Dwyer, 1972). It was not justifiable to design and develop instruction that was more costly when the less expensive type can produce equal instructional effectiveness. Consequently, the data in the study were collected and analyzed in terms of instructional effectiveness. The type of data collected in the study included the demographic information of participants, scores of the physiology prior knowledge test, four criterion posttests, and a composite score and the time-on-task for each treatment group. Two phases of analyses were conducted in the study to answer the research questions. The data analysis in the first phase investigated the effectiveness of respective treatments by comparing the participants’ achievement scores on all 80 items contained in the four criterion posttests and a composite score based on these 80 items. The second phase of analysis focused on the 34 enhanced items distributed in the four criterion posttests. The latter analysis aimed to assess students’ achievement in those portions of the instructional module which included animated visuals, questions, and feedback through the comparison of their performance specifically on these 34 items.

A two-way analysis of variance (ANOVA) was used in both phases of analysis to compare the mean difference among the treatment groups on each criterion posttest. When
significant differences between/among groups were obtained, Tukey’s W-Procedure was employed to analyze the differences between the pairs of means. All analyses were two-tailed and the significance level, (i.e., $\alpha$ value) was set at the .05 level. When comparing the mean scores between/among treatment groups on the criterion posttests, the ANOVA source data were presented first, followed by the descriptive data to compare the mean differences. The interactive effects of the independent variables were examined first, followed by the inspection of respective treatment main effects. Tukey Post hoc tests were then conducted if a main effect was detected for the variable of interest.

Furthermore, to factor out the effect of time-on-task on learning achievement on posttests, time-on-task was also entered into the analysis as a covariate in both phases of the analyses using a two-way analysis of covariance. The entire analysis procedure was exactly the same as above.
CHAPTER 4  
DATA ANALYSIS

This chapter summarizes the research questions set forth for the study, statistical procedures followed to analyze the data, and descriptive and inferential statistical results of the data analysis. The data analysis was based on the data collected from 582 participants. Prior to any statistical analyses, scores for all dependent measures were entered into Excel files. Score entries were double-checked by the researcher to be certain that all scores were within acceptable ranges. The first phase of data analysis analyzed the four separate criterion measures (20 items each) plus a composite score based on the entire set of 80 items. The second phase of data analysis dealt only with the enhanced items (34 items) plus a composite score based on these 34 items. Two separate preliminary analysis of covariates—the physiology prior knowledge test score and the time-on-task—was conducted to determine if there existed differences among the treatment groups on these two covariates.

Preliminary Data Analysis

Covariate 1: Physiology Prior Knowledge Test

A variance of analysis was conducted on the physiology test scores to determine if there was a significant difference among the treatment groups on the physiology test. An obtained significant difference would indicate the use of a two-way analysis of covariance (ANCOVA) in the following data analysis; however, if no significant differences were found among all treatment groups on the physiology test, a two-way analysis of variance (ANOVA) would be used as the data analysis method to answer the research questions.
The result of the ANOVA analysis indicated that there were no significant differences among the treatment groups on the physiology test score: $F(5/581)=1.126$, $p=.345$. The result indicated that the participants were approximately equal in their prior knowledge on the content material used in the study and therefore any results of treatment effects would not be attributed to the difference in participants’ prior knowledge. For a summary of descriptive statistics of physiology prior knowledge test scores for each treatment group, see Table 4.1.

Table 4.1

<table>
<thead>
<tr>
<th>Treatment Groups</th>
<th>N</th>
<th>Mean</th>
<th>Std. Dev.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Static alone</td>
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<td>20.44</td>
<td>3.63</td>
</tr>
<tr>
<td>Static+Questions</td>
<td>97</td>
<td>20.84</td>
<td>3.85</td>
</tr>
<tr>
<td>Static+Questions+Feedback</td>
<td>97</td>
<td>20.52</td>
<td>4.29</td>
</tr>
<tr>
<td>Animation alone</td>
<td>97</td>
<td>20.02</td>
<td>3.91</td>
</tr>
<tr>
<td>Animation+Questions</td>
<td>97</td>
<td>20.53</td>
<td>4.39</td>
</tr>
<tr>
<td>Animation+Questions+Feedback</td>
<td>97</td>
<td>21.33</td>
<td>4.27</td>
</tr>
</tbody>
</table>

Covariate 2: Time-on-Task

Two analyses of variance were conducted to determine if the treatment groups—visual types and instructional strategies, respectively—were different in the amount of time they spent learning the material.

Visual type. Data on the total time students assigned to either static visual or animated visuals were collected and analyzed. The data were aimed to provide information on the extent to which students in the animated visual treatment group took advantage of the animation sequence. A one-way ANOVA was conducted to analyze whether or not
there was a significant difference between the animated visual and static visual treatment groups in regard to the time they spent interacting with the instructional module.

Table 4.2 summarized the ANOVA source data for the covariate time-on-task. There was a significant difference between the two treatment groups on the time-on-task, F(1/581)=108.029; p=.000.

Table 4.2
Analysis of Variance Table for the Relationships between the Visual Type and the Time-on-Task

<table>
<thead>
<tr>
<th>Instruction</th>
<th>Sum of Squares</th>
<th>DF</th>
<th>Mean Squares</th>
<th>F</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Between</td>
<td>17762902</td>
<td>1</td>
<td>17762902.02</td>
<td>108.029</td>
<td>.000</td>
</tr>
<tr>
<td>Within</td>
<td>95367867</td>
<td>580</td>
<td>164427.358</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>113130769.498</td>
<td>581</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

An inspection of the means for the static visual and animated visual treatment groups indicated that participants assigned to the animated visual (\(\bar{M}=1344.199;\) SD=337.418) spent significantly more time in instruction than did the static visuals (\(\bar{M}=994.797;\) SD=463.685).

*Instructional strategy.* Data on the time-on-task for students assigned to either “no strategy”, “questions” and “questions+feedback” were collected and analyzed. The data were aimed to provide information on the extent to which students in each instructional strategy treatment group took advantage of the embedded strategy. A one-way ANOVA was conducted to analyze whether or not there was a significant difference among the three treatment groups in regard to the time they spent on the instructional module. Table 4.3 summarized the ANOVA source data for the time-on-task. There was a significant difference among the three treatment groups on the time-on-task, F(2/581)=36.572; p=.000.
Table 4.3

Analysis of Variance Table for the Relationships between the Instructional Strategy and the Time-on-Task

<table>
<thead>
<tr>
<th></th>
<th>Sum of Squares</th>
<th>DF</th>
<th>Mean Squares</th>
<th>F</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Instruction Between</td>
<td>12688698</td>
<td>2</td>
<td>6344349.1975</td>
<td>36.572</td>
<td>.000</td>
</tr>
<tr>
<td>Within</td>
<td>100442071.1031</td>
<td>579</td>
<td>173475.0796</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>113130769.4983</td>
<td>581</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Post hoc tests indicated that the “questions+feedback” treatment significantly spent more time on instruction than did the “no strategy” treatment. The “questions” treatment also significantly spent more time on instruction than did the “no strategy” treatment. However, no significant difference was found between the “questions+feedback” and “questions” treatments on the time-on-task. See Tables 4.4 and 4.5 for the mean time-on-task for each instructional strategy group and post hoc test results.

Table 4.4

Mean and Standard Deviation of the Time-on-task for Different Instructional Strategies

<table>
<thead>
<tr>
<th>Instructional Strategy</th>
<th>Number of Cases</th>
<th>Mean</th>
<th>Std. Dev.</th>
</tr>
</thead>
<tbody>
<tr>
<td>No strategy</td>
<td>194</td>
<td>960.85</td>
<td>412.73</td>
</tr>
<tr>
<td>Questions</td>
<td>194</td>
<td>1266.58</td>
<td>447.76</td>
</tr>
<tr>
<td>Questions+Feedback</td>
<td>194</td>
<td>1281.06</td>
<td>386.78</td>
</tr>
</tbody>
</table>

Table 4.5

Post Hoc Tests of the Main Effect Instructional Strategy on the Time-on-Task

<table>
<thead>
<tr>
<th>A</th>
<th>B</th>
<th>A-B^a</th>
<th>Std. Dev.</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>No strategy</td>
<td>Questions</td>
<td>-305.73</td>
<td>537.38</td>
<td>.000***</td>
</tr>
<tr>
<td>No strategy</td>
<td>Questions+Feedback</td>
<td>-320.21</td>
<td>489.40</td>
<td>.000***</td>
</tr>
<tr>
<td>Question</td>
<td>Questions+Feedback</td>
<td>-14.48</td>
<td>523.93</td>
<td>.924</td>
</tr>
</tbody>
</table>

^a Mean difference.

*** p<.001.
Data Analysis

*Data Analysis Not Adjusting for the Time-on-Task*

A Two-way analysis of variance (ANOVA) procedures was conducted to determine: (1) if there was a significant difference between students who received either the static visual or animated visual treatment on each of the criterion posttests; (2) if there were significant differences among students who received either the “no strategy,” “questions,” or “questions+feedback” treatments on each of the criterion posttests; (3) if students who received either the static visual or animated visual treatments score differently on each of the criterion posttests depending on the type of instructional strategy they received in the treatment material, i.e., the interactive effect of visual type and instructional strategy. For both phases of analysis, ANOVA results for the relationships between factors and the dependent variables were provided. Based on the result of the analysis of variance, the interactive effect between two independent variables was examined first. Inspections of the main effects, visual type, and instructional strategy were conducted and Tukey post hoc tests were carried out when appropriate.

*The First Phase*

*The drawing test.* Table 4.6 summarizes the ANOVA source data for the dependent variable, the drawing test. As indicated, the interaction between the visual type and instructional strategy was not statistically significant, \( F(2/576)=.352, p=.704 \). The main effect of the visual type was significant, \( F (1/576) =25.452, p=.000 \). However, the main effect of the instructional strategy was not significant, \( F (2/576) =.991; p=.372 \).
Participants receiving the animated visual treatment ($\bar{M}=12.66; \text{SD}=5.80$) scored significantly higher in the drawing test than did participants receiving the static visual treatment ($\bar{M}=10.22; \text{SD}=5.89$).

Table 4.6

*Analysis of Variance Table for the Relationships of the Visual Type and the Instructional Strategy to the Drawing Test Score*

<table>
<thead>
<tr>
<th>Source of variation</th>
<th>Sum of Squares</th>
<th>DF</th>
<th>Mean Squares</th>
<th>F</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>96842.00</td>
<td>582</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Explained</td>
<td>962.983</td>
<td>5</td>
<td>192.597</td>
<td>5.628</td>
<td>.000***</td>
</tr>
<tr>
<td>Visual type</td>
<td>871.038</td>
<td>1</td>
<td>871.038</td>
<td>25.452</td>
<td>.000***</td>
</tr>
<tr>
<td>Instructional Strategy</td>
<td>67.859</td>
<td>2</td>
<td>33.930</td>
<td>.991</td>
<td>.372</td>
</tr>
<tr>
<td>Interaction</td>
<td>24.086</td>
<td>2</td>
<td>12.043</td>
<td>.352</td>
<td>.704</td>
</tr>
<tr>
<td>Residual</td>
<td>19712.412</td>
<td>576</td>
<td>34.223</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*** $p<.001$.

*The identification test.* Table 4.7 summarizes the ANOVA source data for the dependent variable, the identification test. The interaction between the visual type and instructional strategy was not statistically significant, $F(2/576)=.655$, $p=.520$. The main effect of the visual type was significant, $F(1/576)=20.716$, $p=.000$. However, the main effect of instructional strategy was not significant, $F(2/576)=.154$; $p=.857$. Participants receiving the animated visual treatment ($\bar{M}=14.51; \text{SD}=4.71$) scored significantly higher in the identification test than did participants receiving the static visual treatment ($\bar{M}=12.70; \text{SD}=4.85$).
Table 4.7

Analysis of Variance Table for the Relationships of the Visual Type and the Instructional Strategy to the Identification Test Score

<table>
<thead>
<tr>
<th>Source of variation</th>
<th>Sum of Squares</th>
<th>DF</th>
<th>Mean Squares</th>
<th>F</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>121508.000</td>
<td>582</td>
<td>23.633</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Explained</td>
<td>512.515</td>
<td>5</td>
<td>102.503</td>
<td>4.467</td>
<td>.001</td>
</tr>
<tr>
<td>Visual type</td>
<td>475.388</td>
<td>1</td>
<td>475.388</td>
<td>20.716</td>
<td>.000***</td>
</tr>
<tr>
<td>Instructional Strategy</td>
<td>7.082</td>
<td>2</td>
<td>3.541</td>
<td>.154</td>
<td>.857</td>
</tr>
<tr>
<td>Interaction</td>
<td>30.045</td>
<td>2</td>
<td>15.022</td>
<td>.655</td>
<td>.520</td>
</tr>
<tr>
<td>Residual</td>
<td>13218.165</td>
<td>576</td>
<td>22.948</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*** p<.001.

The Terminology Test. Table 4.8 summarizes the ANOVA source data for the dependent variable, the terminology test. The interaction between the visual type and instructional strategy was not statistically significant, F(2/576)=2.026 p=.133. However, the main effects for both the visual type and the instructional strategy were significant, for the visual type, F(1,576)=4.706; p=.030, and for the instructional strategy, F (2/576) =5.969; p=.003.
### Table 4.8

**Analysis of Variance Table for the Relationships of the Visual Type and the Instructional Strategy to the Terminology Test Score**

<table>
<thead>
<tr>
<th>Source of Variation</th>
<th>Sum of Squares</th>
<th>DF</th>
<th>Mean Squares</th>
<th>F</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>13078.318</td>
<td>581</td>
<td>22.510</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Explained</td>
<td>453.637</td>
<td>5</td>
<td>90.727</td>
<td>4.139</td>
<td>.001</td>
</tr>
<tr>
<td>Visual type</td>
<td>103.136</td>
<td>1</td>
<td>103.136</td>
<td>4.706</td>
<td>.030*</td>
</tr>
<tr>
<td>Instructional Strategy</td>
<td>261.674</td>
<td>2</td>
<td>130.837</td>
<td>5.969</td>
<td>.003*</td>
</tr>
<tr>
<td>Interaction</td>
<td>88.828</td>
<td>2</td>
<td>44.414</td>
<td>2.026</td>
<td>.133</td>
</tr>
<tr>
<td>Residual</td>
<td>12624.680</td>
<td>576</td>
<td>21.918</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* p < .05.

An inspection of the means for the static visual and the animated visual treatment groups indicated that animated visual (M = 12.09; SD = 4.80) outperformed static visuals (M = 11.25; SD = 4.66). For the main effect of the instructional strategy, post hoc tests indicated that the “questions+feedback” treatment (M = 12.30, SD = 4.88) outperformed the “no strategy” treatment (M = 10.74, SD = 4.49), and the difference is significant at the .003 level. In addition, the “questions” treatment (M = 11.97; SD = 4.74) also outperformed the “no strategy” treatment (M = 10.74; SD = 4.49), and the difference was significant at the .026 level. The observed differences between the “questions+feedback” and the “questions” treatments were not significant at the .05 level.

**The Comprehension Test.** Table 4.9 summarizes the ANOVA source data for the dependent variable, the comprehension test. The interaction between the visual type and the instructional strategy was not statistically significant, F(2/576) = 1.685; p = .186.
However, the main effects for both the visual type and the instructional strategy were significant, for visual type, \( F(1, 576)=8.789; p=.003 \), and for the instructional strategy, \( F(2, 576)=4.154; p=.016 \).

Table 4.9  
*Analysis of Variance Table for the Relationships of the Visual Type and the Instructional Strategy to the Comprehension Test Score*

<table>
<thead>
<tr>
<th>Source of Variation</th>
<th>Sum of Squares</th>
<th>DF</th>
<th>Mean Squares</th>
<th>F</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>13164.653</td>
<td>581</td>
<td>22.659</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Explained</td>
<td>451.704</td>
<td>5</td>
<td>90.341</td>
<td>4.093</td>
<td>.001</td>
</tr>
<tr>
<td>Visual type</td>
<td>193.979</td>
<td>1</td>
<td>193.979</td>
<td>8.789</td>
<td>.003*</td>
</tr>
<tr>
<td>Instructional Strategy</td>
<td>183.364</td>
<td>2</td>
<td>91.682</td>
<td>4.154</td>
<td>.016*</td>
</tr>
<tr>
<td>Interaction</td>
<td>74.361</td>
<td>2</td>
<td>37.180</td>
<td>1.685</td>
<td>.186</td>
</tr>
<tr>
<td>Residual</td>
<td>12712.948</td>
<td>576</td>
<td>22.071</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* *p < .05.

An inspection of the means for the static visual and the animated visual treatment groups indicated that animated visual (\( \bar{M}=11.63; SD=4.64 \)) outperformed static visuals (\( \bar{M}=10.47; SD=4.81 \)). For the main effect of the instructional strategy, post hoc tests indicated that the “questions+feedback” treatment (\( \bar{M}=11.66; SD=4.64 \)) outperformed the “no strategy” treatment (\( \bar{M}=10.30, SD=4.72 \)), and the difference was significant at the .005 level. The observed differences between the “questions+feedback” and the “questions” treatments and the “questions” and the “no strategy” treatments were not significant at the .05 level.

The composite score. Table 4.10 summarizes the ANOVA source data for the composite score, which was calculated by adding the scores of all four dependent measures (20 items each). The interaction between the visual type and the instructional
strategy was not statistically significant, $F(2/576)=1.063; p=.346$. However, the main effect for the visual type was significant, $F(1/576)=17.235$, $p=.000$. The main effect for the instructional strategy was not significant, $F(2/576)=1.388; p=.250$. An inspection of the means for the static visual and the animated visual treatment groups indicated that animated visual ($M=50.89; SD=18.33$) outperformed static visuals ($M=44.64; SD=18.03$).

Table 4.10

*Analysis of Variance Table for the Relationships of the Visual Type and the Instructional Strategy to the Composite Test Score*

<table>
<thead>
<tr>
<th>Source of Variation</th>
<th>Sum of Squares</th>
<th>DF</th>
<th>Mean Squares</th>
<th>F</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>197301.69</td>
<td>581</td>
<td>339.590</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Explained</td>
<td>7302.510</td>
<td>5</td>
<td>1460.502</td>
<td>4.428</td>
<td>.001***</td>
</tr>
<tr>
<td>Visual type</td>
<td>5685.156</td>
<td>1</td>
<td>5685.156</td>
<td>17.235</td>
<td>.000***</td>
</tr>
<tr>
<td>Instructional Strategy</td>
<td>915.784</td>
<td>2</td>
<td>457.892</td>
<td>1.388</td>
<td>.250</td>
</tr>
<tr>
<td>Interaction</td>
<td>701.570</td>
<td>2</td>
<td>350.785</td>
<td>1.063</td>
<td>.346</td>
</tr>
<tr>
<td>Residual</td>
<td>189999.18</td>
<td>576</td>
<td>329.860</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*** $p<.001$

*Summary of Results*

Table 4.11 presents a summary of results for the data analysis of the learning achievement of all items based on visual type. As indicated, differences on all criterion tests between static and animated visuals were significant in favor of animated visuals.
Table 4.11
Summary of Results of the First Phase Analysis of All Items Based on the Visual Type

<table>
<thead>
<tr>
<th>Measures</th>
<th>Static (S)</th>
<th>Animated (A)</th>
<th>Result</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drawing</td>
<td>10.22(5.89)</td>
<td>12.66(5.80)</td>
<td>A&gt;S</td>
<td>.000***</td>
</tr>
<tr>
<td>Identification</td>
<td>12.70(4.85)</td>
<td>14.51(4.71)</td>
<td>A&gt;S</td>
<td>.000***</td>
</tr>
<tr>
<td>Terminology</td>
<td>11.25(4.66)</td>
<td>12.09(4.80)</td>
<td>A&gt;S</td>
<td>.030*</td>
</tr>
<tr>
<td>Comprehension</td>
<td>10.47(4.81)</td>
<td>11.63(4.64)</td>
<td>A&gt;S</td>
<td>.003**</td>
</tr>
<tr>
<td>Composite</td>
<td>44.64(18.03)</td>
<td>50.89(18.33)</td>
<td>A&gt;S</td>
<td>.000***</td>
</tr>
</tbody>
</table>

a Mean score.
b Value in the parentheses is the standard deviation.
*p<.05. **p<.01. ***p<.001.

Table 4.12 summarizes the results of the first phase analysis based on instructional strategies. As indicated, both “questions” and “questions+feedback” were significantly more effective than “no strategy” in the terminology test, and “questions+feedback” was significantly more effective than “no strategy” in the comprehension test.

Table 4.12
Summary of Results of the First Phase Analysis of All Items Based on the Instructional Strategy

<table>
<thead>
<tr>
<th>Measures</th>
<th>NO a</th>
<th>QS</th>
<th>QF</th>
<th>Result</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drawing</td>
<td>11.56</td>
<td>10.97</td>
<td>11.78</td>
<td>ns d</td>
<td>.372</td>
</tr>
<tr>
<td>Identification</td>
<td>13.72</td>
<td>13.46</td>
<td>13.64</td>
<td>ns</td>
<td>.857</td>
</tr>
<tr>
<td>Terminology</td>
<td>10.74</td>
<td>11.97</td>
<td>12.30</td>
<td>QF&gt;NO</td>
<td>.003**</td>
</tr>
<tr>
<td>Comprehension</td>
<td>10.30</td>
<td>11.18</td>
<td>11.66</td>
<td>QF&gt;NO</td>
<td>.005**</td>
</tr>
<tr>
<td>Composite</td>
<td>46.33</td>
<td>47.59</td>
<td>49.39</td>
<td>ns</td>
<td>.250</td>
</tr>
</tbody>
</table>

a NO=No Strategy. QS=Questions. QF=Questions+Feedback.
b Mean score.
c Value in the parentheses is the standard deviation.
d p>=.05
*p<.05. **p<.01.
The Second Phase

The second phase of the data analysis was focused on the items for which the instructional strategy and animation were particularly designed to improve achievement. Specifically, there are nine (9) items in the drawing test, none (0) in the identification test, twelve (12) in the terminology test, thirteen (13) in the comprehension test, and thirty-four (34) in the composite test score. As with the first phase of data analysis, a two-way ANOVA was conducted to compare the mean scores of the enhanced items in each dependent variable among the treatment groups.

The drawing test. Table 4.13 summarizes the ANOVA source data for the nine enhanced items in the dependent variable, the drawing test. The interaction between the visual type and the instructional strategy was not statistically significant, $F(2/576)=.042$, $p=.959$. However, the main effect of the visual type was significant, $F (1/576) =38.328$, $p=.000$. The main effect of the instructional strategy was not significant, $F (2/576) =1.147$; $p=.318$. Participants receiving the animated visual treatment ($\bar{M} =5.10; \ SD=3.04$) scored significantly higher on the enhanced items in the drawing test than did the participants receiving the static visual treatment ($\bar{M} =3.57; \ SD=2.92$).
Table 4.13  
Analysis of Variance Table for the Relationships of the Visual Type and the Instructional Strategy to the score of the Enhanced Items on the Drawing Test

<table>
<thead>
<tr>
<th>Source of Variation</th>
<th>Sum of Squares</th>
<th>DF</th>
<th>Mean Squares</th>
<th>F</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>16428.000</td>
<td>582</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Explained</td>
<td>362.983</td>
<td>5</td>
<td>72.597</td>
<td>8.141</td>
<td>.000</td>
</tr>
<tr>
<td>Visual type</td>
<td>341.780</td>
<td>1</td>
<td>341.780</td>
<td>38.328</td>
<td>.000***</td>
</tr>
<tr>
<td>Instructional Strategy</td>
<td>20.457</td>
<td>2</td>
<td>10.229</td>
<td>1.147</td>
<td>.318</td>
</tr>
<tr>
<td>Interaction</td>
<td>.746</td>
<td>2</td>
<td>.373</td>
<td>.042</td>
<td>.959</td>
</tr>
<tr>
<td>Residual</td>
<td>5136.351</td>
<td>576</td>
<td>8.917</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* *p < .001.

The terminology test. Table 4.14 summarizes the ANOVA source data for the enhanced items in the dependent variable, the terminology test. The interaction between the visual type and the instructional strategy was not statistically significant, F(2/576)=1.392; p=.249. However, the main effects for both the visual type and the instructional strategy were significant, for the visual type, F(1,576)=4.140; p=.042, and for the instructional strategy, F(2/576)=7.603; p=.001.

Table 4.14  
Analysis of Variance Table for the Relationships of the Visual Type and the Instructional Strategy to the score of the Enhanced Items on the Terminology Test

<table>
<thead>
<tr>
<th>Source of Variation</th>
<th>Sum of Squares</th>
<th>DF</th>
<th>Mean Squares</th>
<th>F</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>29516.000</td>
<td>582</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Explained</td>
<td>206.639</td>
<td>5</td>
<td>41.328</td>
<td>4.426</td>
<td>.001</td>
</tr>
<tr>
<td>Visual type</td>
<td>38.660</td>
<td>1</td>
<td>38.660</td>
<td>4.140</td>
<td>.042*</td>
</tr>
<tr>
<td>Instructional Strategy</td>
<td>141.990</td>
<td>2</td>
<td>70.995</td>
<td>7.603</td>
<td>.001**</td>
</tr>
<tr>
<td>Interaction</td>
<td>25.990</td>
<td>2</td>
<td>12.995</td>
<td>1.392</td>
<td>.249</td>
</tr>
<tr>
<td>Residual</td>
<td>5378.392</td>
<td>576</td>
<td>9.337</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* *p < .05. **p < .01.
An inspection of the means for the static visual and animated visual treatment groups indicated that the animated visual ($\bar{M} = 6.67; SD=3.13$) outperformed the static visuals ($\bar{M} = 6.16; SD=3.05$). For the main effect of the instructional strategy, post hoc tests indicated that the “questions+feedback” treatment ($\bar{M} = 6.87; SD=3.26$) outperformed the “no strategy” treatment ($\bar{M} = 5.73; SD=2.84$), and the difference was significant at the .001 level. In addition, the “questions” treatment ($\bar{M} = 6.64; SD=3.08$) also outperformed the “no strategy” treatment ($\bar{M} = 5.73; SD=2.84$), and the difference was significant at the .10 level. The observed differences between the “questions+feedback” and “questions” were not significant at the .05 level.

The comprehension test. Table 4.15 summarizes the ANOVA source data for the dependent variable, the comprehension test. The interaction between the visual type and the instructional strategy was not statistically significant, $F(2/576)=.863; p=.423$. However, the main effect for both the visual type and the instructional strategy was significant, for the visual type, $F(1,576)=6.215; p=.013$, and for the instructional strategy, $F (2/576) =3.397; p=.034$. 


Table 4.15

<table>
<thead>
<tr>
<th>Source of Variation</th>
<th>Sum of Squares</th>
<th>DF</th>
<th>Mean Squares</th>
<th>F</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>29934.000</td>
<td>582</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Explained</td>
<td>127.354</td>
<td>5</td>
<td>25.471</td>
<td>3.188</td>
<td>.008</td>
</tr>
<tr>
<td>Visual type</td>
<td>49.656</td>
<td>1</td>
<td>49.656</td>
<td>6.215</td>
<td>.013*</td>
</tr>
<tr>
<td>Instructional Strategy</td>
<td>54.292</td>
<td>2</td>
<td>27.146</td>
<td>3.397</td>
<td>.034*</td>
</tr>
<tr>
<td>Interaction</td>
<td>23.405</td>
<td>2</td>
<td>11.703</td>
<td>1.465</td>
<td>.232</td>
</tr>
<tr>
<td>Residual</td>
<td>4602.351</td>
<td>576</td>
<td>7.990</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* p<.05.

An inspection of the means for the static visual and the animated visual treatment groups indicated that the animated visual ($\bar{M} =6.87$; SD=2.81) outperformed the static visuals ($\bar{M} =6.29$; SD=2.87). For the main effect of the instructional strategy, post hoc tests indicated that the “questions+feedback” treatment ($\bar{M} =6.91$; SD=2.80) outperformed the “no strategy” treatment ($\bar{M} =6.18$; SD=2.84), and the difference was significant at the .028 level. The observed differences between the “questions+feedback” and the “questions” treatments and the “questions” and the “no strategy” treatments were not significant at the .05 level.

The composite score. Table 4.16 summarizes the ANOVA source data for the composite score, which was calculated by adding the scores of 34 enhanced items in the four dependent measures. The interaction between the visual type and the instructional strategy was not statistically significant, F(2/576)=.863; p=.423. However, the main effects for both the visual type and the instructional strategy were significant, for the visual type, F (1,576) =16.889; p=.000, and for the instructional strategy, F (2/576) =3.569; p=.029.
Table 4.16
Analysis of Variance Table for the Relationships of the Visual Type and the Instructional Strategy to the Composite Score of the Enhanced Items

<table>
<thead>
<tr>
<th>Source of Variation</th>
<th>Sum of Squares</th>
<th>DF</th>
<th>Mean Squares</th>
<th>F</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>210640.000</td>
<td>582</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Explained</td>
<td>1537.230</td>
<td>5</td>
<td>307.446</td>
<td>5.151</td>
<td>.000</td>
</tr>
<tr>
<td>Visual type</td>
<td>1008.172</td>
<td>1</td>
<td>1008.172</td>
<td>16.889</td>
<td>.000***</td>
</tr>
<tr>
<td>Instructional Strategy</td>
<td>426.076</td>
<td>2</td>
<td>213.038</td>
<td>3.569</td>
<td>.029*</td>
</tr>
<tr>
<td>Interaction</td>
<td>102.983</td>
<td>2</td>
<td>51.491</td>
<td>.863</td>
<td>.423</td>
</tr>
<tr>
<td>Residual</td>
<td>34382.742</td>
<td>576</td>
<td>59.692</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* p<.05. *** p<.001.

An inspection of the means for the static visual and the animated visual treatment groups indicated that the animated visual (\(M=18.64; SD=7.88\)) outperformed the static visuals (\(M=16.01; SD=7.64\)). For the main effect of the instructional strategy, post hoc tests indicated that the “questions+feedback” treatment (\(M=18.34; SD=7.91\)) outperformed the “no strategy” treatment (\(M=16.25; SD=7.61\)), and the difference was statistically significant at the .021 level. The observed differences between the “questions+feedback” and the “questions” treatments and the “questions” and the “no strategy” were not significant at the .05 level.

Summary of Results

Table 4.17 presents a summary of results for the data analysis of the learning achievement of enhanced items based on visual type. As indicated, the differences on all criterion tests between the static and animated visuals were significant in favor of the animated visuals.
### Table 4.17

**Summary of Results for the Data Analysis of the Learning Achievement of the Enhanced Items Based on the Visual Type**

<table>
<thead>
<tr>
<th>Measures</th>
<th>Static (S)</th>
<th>Animated (A)</th>
<th>Result</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drawing</td>
<td>3.57<em>2.92</em></td>
<td>5.10 (3.04)</td>
<td>A&gt;S</td>
<td>.000**</td>
</tr>
<tr>
<td>Terminology</td>
<td>6.16(3.05)</td>
<td>6.67(3.13)</td>
<td>A&gt;S</td>
<td>.042*</td>
</tr>
<tr>
<td>Comprehension</td>
<td>6.29(2.87)</td>
<td>6.87(2.81)</td>
<td>A&gt;S</td>
<td>.013*</td>
</tr>
<tr>
<td>Composite</td>
<td>16.01(7.64)</td>
<td>18.64(7.88)</td>
<td>A&gt;S</td>
<td>.000***</td>
</tr>
</tbody>
</table>

a The maximum score for the drawing test=9; the terminology test=12; the comprehension test=13; the composite score=34.
b Mean score.
c Value in the parentheses is the standard deviation.
* p<.05. **p<.01. ***p<.001.

In regard to the learning achievement on the enhanced items based on the instructional strategy, Table 4.18 indicates that the “questions+feedback” was a significantly more effective instructional strategy than was the “no Strategy” in facilitating achievement in the terminology, the comprehension test, and the composite test.
Table 4.18
Summary of Results for the Data Analysis of the Learning Achievement of the Enhanced Items Based on the Instructional Strategy

<table>
<thead>
<tr>
<th>Measures</th>
<th>NO a</th>
<th>QS</th>
<th>QF</th>
<th>Result</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drawing</td>
<td>4.35b (3.15)c</td>
<td>4.10 (3.05)</td>
<td>4.56 (3.03)</td>
<td>ns e</td>
<td>.318</td>
</tr>
<tr>
<td>Terminology</td>
<td>5.73 (2.84)</td>
<td>6.64 (3.08)</td>
<td>6.87 (3.26)</td>
<td>QF&gt;NO</td>
<td>.001**</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>QS&gt;NO</td>
<td>.010*</td>
</tr>
<tr>
<td>Comprehension</td>
<td>6.18 (2.84)</td>
<td>6.66 (2.88)</td>
<td>6.91 (2.80)</td>
<td>QF&gt;NO</td>
<td>.028*</td>
</tr>
<tr>
<td>Composite</td>
<td>16.25 (7.61)</td>
<td>17.39 (7.97)</td>
<td>18.34 (7.91)</td>
<td>QF&gt;NO</td>
<td>.021*</td>
</tr>
</tbody>
</table>

a NO=No Strategy. QS=Questions. QF=Questions+Feedback.
b Mean score.
c Value in the parentheses is the standard deviation
d The maximum score for the drawing test=9; the terminology test=12; the comprehension test=13; the composite score=34.
e $p \geq .05$

Data Analysis Adjusting for the Time-on-Task

Since the analysis of the time-on-task indicated that there was a significant difference among the treatment groups on the time needed to finish the studying of the instructional modules, further analysis was conducted to factor out the effect of the time-on-task on learning achievement. An analysis of covariance was conducted for the analysis dealing with all items and the enhanced items respectively to investigate whether the relationships observed between the visual groups and among the instructional strategy groups on learning achievement were altered when the time-on-task was not held constant.
The First Phase

The drawing test. Table 4.19 presents the results of the two-way analysis of covariance. The interaction between the visual type and the instructional strategy was not statistically significant, $F(2/575)=.032$, $p=.969$. The main effect of the visual type also was not significant, $F (1/575) =2.25; p=.134$. However, the main effect of the instructional strategy is significant, $F (2/575) =6.049$, $p=.003$. The post hoc analysis on the main effect of the instructional strategy indicated that when controlling for the time-on-task, “no strategy” ($\bar{M} =12.57$) scored higher than did “questions” ($\bar{M} =10.51$), and the difference was significant at the .001 level. “No strategy” ($\bar{M} =12.57$) also scored higher than did “questions+feedback” ($\bar{M} =11.25$), and the difference was significant at the .028 level. There was no significant difference between the “questions” and “questions+feedback”.

Table 4.19
Two-way ANCOVA Table for the Relationships of the Visual Type and the Instructional Strategy to the Drawing Test Score Controlling for the Time-on-Task

<table>
<thead>
<tr>
<th>Source of variation</th>
<th>Sum of Squares</th>
<th>DF</th>
<th>Mean Squares</th>
<th>F</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>20675.395</td>
<td>581</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Explained</td>
<td>2864.294</td>
<td>6</td>
<td>477.382</td>
<td>15.411</td>
<td>.000</td>
</tr>
<tr>
<td>Visual type</td>
<td>69.686</td>
<td>1</td>
<td>69.686</td>
<td>2.25</td>
<td>.134</td>
</tr>
<tr>
<td>Instructional Strategy</td>
<td>374.768</td>
<td>2</td>
<td>187.384</td>
<td>6.049</td>
<td>.003*</td>
</tr>
<tr>
<td>Interaction</td>
<td>1.958</td>
<td>2</td>
<td>.979</td>
<td>.032</td>
<td>.969</td>
</tr>
<tr>
<td>Residual</td>
<td>17811.101</td>
<td>575</td>
<td>30.976</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* $p<.05$.

The identification test. Table 4.20 summarizes the ANCOVA source data for all items in the dependent variable, the identification test. As indicated, the interaction between the visual type and the instructional strategy was not statistically significant,
F(2/575)=.413, p=.662. The main effect of the visual type was not significant either, F(1/575) =1.645, p=.20. However, the main effect of the instructional strategy was significant, F (2/575) =4.574, p=.011. The post hoc analysis result indicated that when controlling for the time-on-task, “no strategy” (\(\bar{M} =14.48\)) scored higher than did “questions” (\(\bar{M} =13.11\)), and the difference was significant at the .005 level. “No strategy” (\(\bar{M} =14.48\)) also scored higher than did “questions+feedback” (\(\bar{M} =13.24\)), and the difference was significant at the .012 level.

Table 4.20

*Two-way ANCOVA Table for the Relationships of the Visual Type and the Instructional Strategy to the Identification Test Score Controlling for the Time-on-Task*

<table>
<thead>
<tr>
<th>Source of Variation</th>
<th>Sum of Squares</th>
<th>DF</th>
<th>Mean Squares</th>
<th>F</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>13730.680</td>
<td>581</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Explained</td>
<td>1592.474</td>
<td>6</td>
<td>265.412</td>
<td>12.573</td>
<td>.000</td>
</tr>
<tr>
<td>Visual type</td>
<td>34.726</td>
<td>1</td>
<td>34.726</td>
<td>1.645</td>
<td>.200</td>
</tr>
<tr>
<td>Instructional Strategy</td>
<td>193.122</td>
<td>2</td>
<td>96.561</td>
<td>4.574</td>
<td>.011*</td>
</tr>
<tr>
<td>Interaction</td>
<td>17.451</td>
<td>2</td>
<td>8.726</td>
<td>.413</td>
<td>.662</td>
</tr>
<tr>
<td>Residual</td>
<td>12138.207</td>
<td>575</td>
<td>21.110</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* * p<.05

*The terminology test.* Table 4.21 summarizes the ANCOVA source data for all items in the dependent variable, the identification test. As indicated, the interaction between the visual type and the instructional strategy was not statistically significant, F(2/575)=.1.319, p=.268. Neither the main effect of the visual type, F (1/575) =.432, p=.511 nor of the instructional strategy, F(2/575)=.609, p=.544, reached statistical significance at the .05 level.
Table 4.21

Two-way ANCOVA Table for the Relationships of the Visual Type and the Instructional Strategy to the Terminology Test Score Controlling for the Time-on-Task

<table>
<thead>
<tr>
<th>Source of Variation</th>
<th>Sum of Squares</th>
<th>DF</th>
<th>Mean Squares</th>
<th>F</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>13078.318</td>
<td>581</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Explained</td>
<td>1286.619</td>
<td>6</td>
<td>214.436</td>
<td>10.457</td>
<td>.000***</td>
</tr>
<tr>
<td>Visual type</td>
<td>8.864</td>
<td>1</td>
<td>8.864</td>
<td>.432</td>
<td>.511</td>
</tr>
<tr>
<td>Instructional Strategy</td>
<td>24.986</td>
<td>2</td>
<td>12.493</td>
<td>.609</td>
<td>.544</td>
</tr>
<tr>
<td>Interaction</td>
<td>54.100</td>
<td>2</td>
<td>27.050</td>
<td>1.319</td>
<td>.268</td>
</tr>
<tr>
<td>Residual</td>
<td>11791.699</td>
<td>575</td>
<td>20.507</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*** p<.001.

The comprehension test. Table 4.22 summarizes the ANCOVA source data for all items in the dependent variable, the identification test. As indicated, the interaction between the visual type and the instructional strategy was not statistically significant, $F(2/575)=1.057$, $p=.348$. Neither the main effect of the visual type, $F(1/575) =.059$, $p=.848$, nor of the instructional strategy, $F(2/575)=.437$, $p=.646$, reached statistical significance at .05 level.

Table 4.22

Two-way ANCOVA Table for the Relationships of the Visual Type and the Instructional Strategy to the Comprehension Test Score Controlling for the Time-on-Task

<table>
<thead>
<tr>
<th>Source of Variation</th>
<th>Sum of Squares</th>
<th>DF</th>
<th>Mean Squares</th>
<th>F</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>13164.653</td>
<td>581</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Explained</td>
<td>1507.863</td>
<td>6</td>
<td>251.311</td>
<td>12.397</td>
<td>.000***</td>
</tr>
<tr>
<td>Visual type</td>
<td>1.195</td>
<td>1</td>
<td>1.195</td>
<td>.059</td>
<td>.808</td>
</tr>
<tr>
<td>Instructional Strategy</td>
<td>17.725</td>
<td>2</td>
<td>8.863</td>
<td>.437</td>
<td>.646</td>
</tr>
<tr>
<td>Interaction</td>
<td>42.867</td>
<td>2</td>
<td>21.434</td>
<td>1.057</td>
<td>.348</td>
</tr>
<tr>
<td>Residual</td>
<td>11656.790</td>
<td>575</td>
<td>20.273</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*** p<.001.
The composite test. Table 4.23 summarizes the ANCOVA source data for all items in the dependent variable, the composite test score. As indicated, the interaction between the visual type and the instructional strategy was not statistically significant, F(2/575)=.471, p=.625. Neither the main effect of the visual type, F (1/575) =.348, p=.556, nor of the instructional strategy, F(2/575)=1.696, p=.184, reached statistical significance at the .05 level.

Table 4.23

<table>
<thead>
<tr>
<th>Source of Variation</th>
<th>Sum of Squares</th>
<th>DF</th>
<th>Mean Squares</th>
<th>F</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>197301.686</td>
<td>581</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Explained</td>
<td>26298.727</td>
<td>6</td>
<td>4383.121</td>
<td>14.738</td>
<td>.000***</td>
</tr>
<tr>
<td>Visual type</td>
<td>103.438</td>
<td>1</td>
<td>103.438</td>
<td>.348</td>
<td>.556</td>
</tr>
<tr>
<td>Instructional Strategy</td>
<td>1008.921</td>
<td>2</td>
<td>504.461</td>
<td>1.696</td>
<td>.184</td>
</tr>
<tr>
<td>Interaction</td>
<td>280.116</td>
<td>2</td>
<td>140.058</td>
<td>.471</td>
<td>.625</td>
</tr>
<tr>
<td>Residual</td>
<td>171002.959</td>
<td>575</td>
<td>297.396</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*** p<.001.

Summary of Results

Table 4.24 summarizes the results of the learning achievement of all items based on the visual type when adjusting for the time-on-task. As shown, no significant differences were found between the static and the animated visuals in all of the criterion posttests.
When controlling for the time-on-task, “no strategy” was consistently more effective than both “questions” and “questions+feedback” on the drawing and identification tests as shown in Table 4.25.
The Second Phase

An analysis of the covariance was conducted to analyze the learning achievement of enhanced items among treatment groups when controlling for the time-on-task.

The drawing test. Table 4.26 summarizes the ANCOVA source data for enhanced items in the dependent variable, the drawing test. As indicated, the interaction between the visual type and the instructional strategy was not statistically significant, $F(2/575)=.169$, $p=.844$. The main effect of both the visual type, $F(1/575)=6.494$; $p=.011$, and the instructional strategy, $F(2/575)=5.543$, $p=.004$, were significant. When controlling for the time-on-task, the animated visual treatment ($\overline{M}=4.66$) outperformed the static visual ($\overline{M}=4.00$) in the drawing test, and the difference was significant at the .011 level. A post hoc analysis was conducted for the main effect of the instructional strategy. When controlling for the time-on-task, “no strategy” ($\overline{M}=4.87$) scored higher than “questions” ($\overline{M}=3.86$), and the difference was significant at the .004 level.

Table 4.26

Two-way ANCOVA Table for the Relationships of the Visual Type and the Instructional Strategy to the Drawing Test Score Controlling for the Time-on-Task

<table>
<thead>
<tr>
<th>Source of Variation</th>
<th>Sum of Squares</th>
<th>DF</th>
<th>Mean Squares</th>
<th>F</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>5499.333</td>
<td>581</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Explained</td>
<td>872.725</td>
<td>6</td>
<td>145.454</td>
<td>18.077</td>
<td>.000</td>
</tr>
<tr>
<td>Visual type</td>
<td>52.251</td>
<td>1</td>
<td>52.251</td>
<td>6.494</td>
<td>.011*</td>
</tr>
<tr>
<td>Instructional Strategy</td>
<td>89.196</td>
<td>2</td>
<td>44.598</td>
<td>5.543</td>
<td>.004**</td>
</tr>
<tr>
<td>Interaction</td>
<td>2.725</td>
<td>2</td>
<td>1.362</td>
<td>.169</td>
<td>.844</td>
</tr>
<tr>
<td>Residual</td>
<td>4626.609</td>
<td>575</td>
<td>8.046</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* $p<.05$. ** $p<.01$. 
The terminology test. Table 4.27 summarizes the ANCOVA source data for enhanced items in the dependent variable, the terminology test. As indicated, the interaction between the visual type and the instructional strategy was not statistically significant, F(2/575)=.823, p=.440. Neither the main effect of the visual type, F (1/575) =.329, p=.567, nor of the instructional strategy, F(2/575)=1.38, p=.252, reached statistical significance at the .05 level.

Table 4.27
Two-way ANCOVA Table for the Relationships of the Visual Type and the Instructional Strategy to the Terminology Test Score Controlling for the Time-on-Task

<table>
<thead>
<tr>
<th>Source of Variation</th>
<th>Sum of Squares</th>
<th>DF</th>
<th>Mean Squares</th>
<th>F</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>25585.031</td>
<td>581</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Explained</td>
<td>509.019</td>
<td>6</td>
<td>84.837</td>
<td>9.61</td>
<td>.000***</td>
</tr>
<tr>
<td>Visual type</td>
<td>2.904</td>
<td>1</td>
<td>2.904</td>
<td>.329</td>
<td>.567</td>
</tr>
<tr>
<td>Instructional Strategy</td>
<td>24.364</td>
<td>2</td>
<td>12.182</td>
<td>1.38</td>
<td>.252</td>
</tr>
<tr>
<td>Interaction</td>
<td>14.529</td>
<td>2</td>
<td>7.264</td>
<td>.823</td>
<td>.440</td>
</tr>
<tr>
<td>Residual</td>
<td>5076.012</td>
<td>575</td>
<td>8.828</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

***p<.001.

The comprehension test. Table 4.28 summarizes the ANCOVA source data for enhanced items in the dependent variable, the comprehension test. As indicated, the interaction between the visual type and the instructional strategy was not statistically significant, F(2/575)=.829, p=.437. Neither the main effect of the visual type, F (1/575) =.376, p=.686, nor of the instructional strategy, F(2/575)=1.696, p=.184, reached statistical significance at the .05 level.
Table 4.28
Two-way ANCOVA Table for the Relationships of the Visual Type and the Instructional Strategy to the Comprehension Test Score Controlling for the Time-on-Task

<table>
<thead>
<tr>
<th>Source of Variation</th>
<th>Sum of Squares</th>
<th>DF</th>
<th>Mean Squares</th>
<th>F</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>4279.704</td>
<td>581</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Explained</td>
<td>511.056</td>
<td>6</td>
<td>85.176</td>
<td>11.61</td>
<td>.000***</td>
</tr>
<tr>
<td>Visual type</td>
<td>3.538</td>
<td>1</td>
<td>3.538</td>
<td>.482</td>
<td>.488</td>
</tr>
<tr>
<td>Instructional Strategy</td>
<td>5.524</td>
<td>2</td>
<td>2.762</td>
<td>.376</td>
<td>.686</td>
</tr>
<tr>
<td>Interaction</td>
<td>12.160</td>
<td>2</td>
<td>6.080</td>
<td>.829</td>
<td>.437</td>
</tr>
<tr>
<td>Residual</td>
<td>4218.649</td>
<td>575</td>
<td>7.337</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

***p<.001.

The composite test score. Table 4.29 summarizes the ANCOVA source data for enhanced items in the dependent variable, the composite test score. As indicated, the interaction between the visual type and the instructional strategy was not statistically significant, F(2/575)=.327, p=.721. Neither the main effect of the visual type, F (1/575) =.248, p=.619, nor of the instructional strategy, F(2/575)=.865, p=.421, reached statistical significance at the .05 level.

Table 4.29
Two-way ANCOVA Table for the Relationships of the Visual Type and the Instructional Strategy to the Composite Test Score Controlling for the Time-on-Task

<table>
<thead>
<tr>
<th>Source of Variation</th>
<th>Sum of Squares</th>
<th>DF</th>
<th>Mean Squares</th>
<th>F</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>35919.973</td>
<td>581</td>
<td></td>
<td>15.80</td>
<td>.000***</td>
</tr>
<tr>
<td>Explained</td>
<td>5084.010</td>
<td>6</td>
<td>847.335</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Visual type</td>
<td>13.275</td>
<td>1</td>
<td>13.275</td>
<td>.248</td>
<td>.619</td>
</tr>
<tr>
<td>Instructional Strategy</td>
<td>92.812</td>
<td>2</td>
<td>46.406</td>
<td>.865</td>
<td>.421</td>
</tr>
<tr>
<td>Interaction</td>
<td>35.054</td>
<td>2</td>
<td>17.527</td>
<td>.327</td>
<td>.721</td>
</tr>
<tr>
<td>Residual</td>
<td>30835.963</td>
<td>575</td>
<td>53.628</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

***p<.001.
Summary of Results

Table 4.30 summarizes the result of the data analysis of enhanced items based on the visual type after adjusting for the time-on-task. The result indicated that animated visuals were more effective than static visuals only in facilitating the achievement for the drawing test when adjusting for the time-on-task. The other tests revealed no significant differences.

Table 4.30
Summary of Results for the Data Analysis of the Learning Achievement of the Enhanced Items Based on the Visual Type When Controlling for the Time-on-Task

<table>
<thead>
<tr>
<th>Measures</th>
<th>Animated (A)</th>
<th>Static (S)</th>
<th>Result</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drawing</td>
<td>4.66 b</td>
<td>4.00</td>
<td>A&gt;S</td>
<td>.011*</td>
</tr>
<tr>
<td>Terminology</td>
<td>6.33</td>
<td>6.49</td>
<td>ns c</td>
<td>.567</td>
</tr>
<tr>
<td>Comprehension</td>
<td>6.50</td>
<td>6.67</td>
<td>ns</td>
<td>.488</td>
</tr>
<tr>
<td>Composite</td>
<td>17.49</td>
<td>17.16</td>
<td>ns</td>
<td>.619</td>
</tr>
</tbody>
</table>

a The maximum score for the drawing test=9; the terminology test=12; the comprehension test=13; the composite score=34.
b Mean score.
c p>=.05.

Table 4.31 summarizes the result of the data analysis of enhanced items based on instructional strategy after controlling for the time-on-task. When controlling for the time-on-task, the “no strategy” treatment group scored higher than the “questions” treatment group on the drawing test. The other tests revealed no significant differences.
Table 4.31

Summary of Results for the Data Analysis of the Learning Achievement of the Enhanced Items Based on the Instructional Strategies When Controlling for the Time-on-Task

<table>
<thead>
<tr>
<th>Measures</th>
<th>NO&lt;sup&gt;a&lt;/sup&gt;</th>
<th>QS</th>
<th>QF</th>
<th>Result</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drawing</td>
<td>4.87&lt;sup&gt;c&lt;/sup&gt;</td>
<td>3.86</td>
<td>4.28</td>
<td>NO&gt;QS</td>
<td>.001**</td>
</tr>
<tr>
<td>Terminology</td>
<td>6.13</td>
<td>6.45</td>
<td>6.66</td>
<td>ns</td>
<td>.252</td>
</tr>
<tr>
<td>Comprehension</td>
<td>6.63</td>
<td>6.45</td>
<td>6.67</td>
<td>ns</td>
<td>.686</td>
</tr>
<tr>
<td>Composite</td>
<td>17.62</td>
<td>16.75</td>
<td>17.61</td>
<td>ns</td>
<td>.421</td>
</tr>
</tbody>
</table>

<sup>a</sup> NO=No Strategy. QS=Questions. QF=Questions+Feedback.
<sup>b</sup> The maximum score for the drawing test=9, the terminology test=12; the comprehension test=13; the composite score=34.
<sup>c</sup> Mean score
<sup>d</sup> p>=.05.
** p<.01.

Table 4.32 compares the results of analyses of all items based on the visual types with and without using the time-on-task as a covariate. As shown, the significant differences obtained when the time-on-task was not controlled were not significant for all criterion posttests.

Table 4.32

Comparison of Results of the Learning Achievement of All Items Based on Different Visual Types With and Without Controlling for the Time-on-Task

<table>
<thead>
<tr>
<th>Measures</th>
<th>Time not Controlled</th>
<th>Time Controlled</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Result&lt;sup&gt;b&lt;/sup&gt;</td>
<td>Sig.</td>
</tr>
<tr>
<td>Drawing</td>
<td>A&gt;S</td>
<td>.000***</td>
</tr>
<tr>
<td>Identification</td>
<td>A&gt;S</td>
<td>.000***</td>
</tr>
<tr>
<td>Terminology</td>
<td>A&gt;S</td>
<td>.030**</td>
</tr>
<tr>
<td>Comprehension</td>
<td>A&gt;S</td>
<td>.003**</td>
</tr>
<tr>
<td>Composite</td>
<td>A&gt;S</td>
<td>.000***</td>
</tr>
</tbody>
</table>

<sup>a</sup> A is animated visuals; S is static visuals.
<sup>b</sup> p>=.05.
** p<.01. *** p<.001.
Table 4.33 compares the results of the analyses of all items based on the instructional strategy with and without using the time-on-task as a covariate. As shown, significant differences obtained from the terminology and comprehension tests for which the time-on-task was not adjusted turned out to be not significant; insignificant differences that initially existed for the drawing and identification tests turned out to be significant after adjusting for the time-on-task. The composite test score was observed to be not significant before and after adjusting for the time-on-task.

Table 4.33
Comparison of Results of the Learning Achievement of All Items Based on Different Instructional Strategies With and Without Controlling for the Time-on-Task

<table>
<thead>
<tr>
<th>Measures</th>
<th>Time not Controlled</th>
<th>Time Controlled</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Result</td>
<td>Sig.</td>
<td>Result</td>
<td>Sig.</td>
</tr>
<tr>
<td>----------------</td>
<td>----------</td>
<td>---------</td>
<td>----------</td>
<td>---------</td>
</tr>
<tr>
<td>Drawing</td>
<td>ns(^a)</td>
<td>.372</td>
<td>NO&gt;QF(^b)</td>
<td>.028*</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>NO&gt;QS</td>
<td>.001**</td>
</tr>
<tr>
<td>Identification</td>
<td>Ns</td>
<td>.857</td>
<td>NO&gt;QF</td>
<td>.012*</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>NO&gt;QS</td>
<td>.005**</td>
</tr>
<tr>
<td>Terminology</td>
<td>QF&gt;NO</td>
<td>.003**</td>
<td>ns</td>
<td>.544</td>
</tr>
<tr>
<td></td>
<td>QS&gt;NO</td>
<td>.026*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Comprehension</td>
<td>QF&gt;NO</td>
<td>.005**</td>
<td>ns</td>
<td>.646</td>
</tr>
<tr>
<td>Composite</td>
<td>Ns</td>
<td>.250</td>
<td>ns</td>
<td>.184</td>
</tr>
</tbody>
</table>

\(^a\) p>=.05.  
\(^b\) NO=No Strategy. QS=Questions. QF=Questions+Feedback.  
* P<.05. **p<.01.

Table 4.34 compares the results of the analyses of enhanced items based on visual types with and without using the time-on-task as a covariate. As shown, significant differences obtained when the time-on-task was not adjusted for turned out to be not significant for three of the criterion posttests. The significant difference between the static
and the animated visuals on the drawing test was observed when the time-on-task was both controlled and not controlled.

Table 4.34

*Comparison of Results of the Learning Achievement of the Enhanced Items Based on Different Visual Types With and Without Controlling for the Time-on-Task*

<table>
<thead>
<tr>
<th>Measure</th>
<th>Time not Controlled</th>
<th>Time Controlled</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Result</td>
<td>Sig.</td>
</tr>
<tr>
<td>Drawing</td>
<td>A&gt;S</td>
<td>.000***</td>
</tr>
<tr>
<td>Terminology</td>
<td>A&gt;S</td>
<td>.042*</td>
</tr>
<tr>
<td>Comprehension</td>
<td>A&gt;S</td>
<td>.013*</td>
</tr>
<tr>
<td>Composite</td>
<td>A&gt;S</td>
<td>.000***</td>
</tr>
</tbody>
</table>

\(^{a}\) A is animated visuals; S is static visuals.

\(^{b}\) \(p\geq.05\).

\(*p<.05. **p<.001.***

Table 4.35 compares the results of the analyses of enhanced items based on the instructional strategy with and without using the time-on-task as a covariate. As shown, significant differences obtained on tests when the time-on-task was not adjusted for turned out to be not significant and vice versa. In addition, the relationship was distorted. “NO” turned out to be more effective than “QS” in facilitating achievement on the drawing test.
### Table 4.35
Comparison of Results of the Learning Achievement of the Enhanced Items Based on Different Instructional Strategies With and Without Controlling for the Time-on-Task

<table>
<thead>
<tr>
<th>Measures</th>
<th>Time not Controlled</th>
<th>Time Controlled</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Result</td>
<td>Sig.</td>
</tr>
<tr>
<td>Drawing</td>
<td>ns&lt;sup&gt;a&lt;/sup&gt;</td>
<td>.318</td>
</tr>
<tr>
<td>Terminology</td>
<td>QF&gt;NO&lt;sup&gt;b&lt;/sup&gt;</td>
<td>.001**</td>
</tr>
<tr>
<td></td>
<td>QS&gt;NO</td>
<td>.010*</td>
</tr>
<tr>
<td>Comprehension</td>
<td>QF&gt;NO</td>
<td>.028*</td>
</tr>
<tr>
<td>Composite</td>
<td>QF&gt;NO</td>
<td>.021*</td>
</tr>
</tbody>
</table>

<sup>a</sup> p>=.05.<br><sup>b</sup> NO=No Strategy. QS=Questions. QF=Questions+Feedback.<br>* p<.05. **p<.01.
CHAPTER 5
DISCUSSION AND CONCLUSION

This concluding chapter first provides a general review of the research with regard to its purposes, the methodology employed to seek answers to the research questions, and the procedures followed. The major portion of the chapter was devoted to the discussion of findings pertaining to each research question. Practical implications of the findings as applied to instructional design in a computer-based learning environment, limitations of the study, as well as the generalizability of the findings are discussed. The chapter concludes by suggesting recommendations for further research.

Summary of the Study

With the recent advances in educational technology, there has been interest among educational practitioners, instructional designers, and researchers in exploring the effects that different instructional strategies and computer-enhanced interventions can bring to improve students’ learning and instructional effectiveness specifically in a computer-based learning environment. Among the technology-enhanced interventions, computer-generated visuals have gained much more attention due to the role that visuals have played in traditional face-to-face instruction and text-based learning material. Visuals, when designed appropriately, are believed to aid memory by making abstract concepts concrete (Paivio & Csapo, 1973; Pressley, 1976; Rieber & Kini, 1991). When presented along with verbal information, the addition of visuals is believed to enhance information processing and allows information to stay longer in the short-term memory. Under these conditions visuals make information easier to retrieve after they have been stored in the long-term memory. Varied instructional strategies have been designed and investigated in terms of their effects when
accompanying different types of visuals to optimize students’ achievements. The provision of questions accompanying either with or without feedback to responses is one of several strategies.

Building on the theory of human information-processing, dual coding theory, and cognitive load theory, the study aimed to explore two types of computer-generated visuals, i.e., static and animated, and three instructional strategies, i.e., questions with or without feedback and no questions when used in a computer-based learning environment. Specifically, the study set forth to determine whether animated or static visuals and different instructional strategies are most effective in promoting student achievement of different educational objectives when they are used to complement either static or animated visualized instruction.

The specific objectives of the study were to determine (1) whether the varied types of visuals (static versus animated) are equally effective in students’ learning of different educational objectives; (2) if the varied type of instructional strategies, i.e., no strategy, questions, and questions plus feedback, produce different learning gains when used to complement either static or animated visual instruction; and (3) whether there is an interactive effect of types of visuals and instructional strategy on students’ achievement of different educational objectives.

The study employed a posttest only, a 2 X 3 factorial experimental design. The two independent variables were the visual type and the instructional strategy. The dependent variables were the four criterion posttests measuring the achievement of different learning outcomes as a result of the respective treatment instruction. The first independent variable, i.e., the visual type, was comprised of two levels: static visuals or animated visuals. The second independent variable, i.e., the instructional strategy,
was comprised of three levels: no strategy, questions, and questions plus feedback. The dependent variables were four criterion posttests and a composite score that combined the four criterion posttest scores. The 2 x 3 factorial design yielded six experimental groups as animation alone, animation with questions, animation with questions plus feedback, static graphics alone, static graphics with questions, and static graphics with questions plus feedback.

The sample population involved in this study consisted of 582 undergraduate students enrolled in The Pennsylvania State University (freshmen, sophomores, juniors, and seniors). The participants were randomly assigned to treatment categories according to the order he/she reported to the experimental site. Each student interacted with his/her respective treatment material and received four criterion posttests. The complete data analysis consisted of two phases. The first phase of data analysis involved the analyses of students’ achievement of all items in each criterion posttest. The second phase of data analysis involved the analyses of student achievement of items that were enhanced using animation and questions/feedback. Consequently, 80 items were entered into the first phase of data analysis, and 34 enhanced items were entered into the second phase of data analysis.

Summary of Findings

Findings pertaining to each designated research question are discussed here by presenting the research question, followed by the results of analysis. The effects of the visual type and the instructional strategy are discussed separately in the following section. In addition, obtained findings were compared with the results of previous studies.
Q1: Are there significant differences between students who received either the static visual or the animated visual treatment on their learning achievement of criterion posttests measuring different educational objectives?

Based on the initial results of the first phase of data analysis incorporating all items, there were significant differences between treatment groups on all criterion tests. Overall, participants receiving the animated visual treatment scored significantly higher in all of the criterion posttests than those who received the static visual treatment. The same results were obtained during the second phase of data analysis, which focused on 34 enhanced items. During the second phase of data analysis, significant differences were found between the two treatment groups on all criterion posttests. Again, students receiving the animated visual treatment significantly scored higher than those who received the static visuals in three criterion posttests (the identification test did not include any enhanced items), which contained 34 enhanced items. They also had a significantly higher composite test score than did the static visual group. However, after controlling for the time-on-task, the differences between the static and the animated visual groups on all criterion posttests in the first phase of analysis were not statistically significant. The only significant difference between the static visual and the animated visual was on the drawing test during the second phase of analysis.

Q2: Are there significant differences among students who received varied instructional strategy (no strategy, questions, and questions plus feedback) on their learning achievement of criterion posttests measuring different educational objectives?
Based on the initial results of the first phase of data analysis, significant differences were found on two of the four criterion tests: the terminology test and the comprehension test. For the terminology test, the “questions+feedback” treatment outperformed the “no strategy” treatment. In addition, the “questions” treatment also outperformed the “no strategy” treatment. For the comprehension test, the “questions+feedback” treatment outperformed the “no strategy” treatment.

During the second phase of data analysis, significant differences were found among the treatment groups on the terminology test and the comprehension test. For the terminology test, the “questions+feedback” treatment outperformed the “no strategy” treatment. In addition, the “questions” treatment also outperformed the “no strategy” treatment. For the comprehension test, the “questions+feedback” treatment outperformed the “no strategy” treatment. For the composite score, the “questions+feedback” treatment outperformed the “no strategy” treatment.

After adjusting for the time-on-task, however, the significant differences observed among the different instructional strategies initially vanished; for those that turned out to be significant, “no Strategy” was more effective than either “questions” or “questions+feedback” in selective learning objectives.

Q3: Do students receiving either the static or the animated visual treatment achieve differently on their criterion posttests depending on the instructional strategy that they received?

The results of both phases of the data analysis when either controlling or not controlling for the time-on-task indicated no significant interactive effect between the instructional strategy and the types of visuals on the learning achievement among the
treatment groups. Students receiving either the static or the animated visual treatment did not score differently depending on the type of instructional strategy that they received. In both phases of the analysis, the interaction between the instructional strategy and the visual types were not statistically significant.

The following section discusses particularly the effects of the visual types and the instructional strategies employed in the study, taking into consideration the extra findings when controlling for the amounts of the time-on-task each treatment group needed to study the instructional material.

**Effects of Instructional Strategy**

The instructional strategies investigated in this study involved no strategy, questions, and questions plus feedback. The initial findings of the study indicated that “questions+feedback” significantly outperformed “no strategy” in two of the criterion posttests and in the composite test score. The “questions” strategy significantly outperformed the “no strategy” only in the terminology test. No significant differences were found between “questions” and “questions+feedback.”

The major interest of this variable in the study concerns whether the provision of feedback would optimize students’ learning in visualized instruction. The initial results of the study, however, indicated that questions accompanied with or without feedback were equally effective in students’ learning from visualized instruction. The type of feedback utilized in this study was found to be not effective in facilitating students’ learning from visualized instruction. In this study, inserted questions were presented on a question frame that followed the illustrated page that contained difficult material identified through two pilot studies. Inserted questions in this study
were used as stimuli, which were designed to help students focus on relevant cues contained in either the static or the animated visuals.

Furthermore, the data collected on the amount of time students studied their respective material did not differ significantly between “questions” and “questions+feedback,” indicating that students receiving feedback to their responses did not spend a significant amount of time studying it. Consequently, the learning achievement of criterion posttests between the “questions” and the “questions+feedback” treatment groups were minimal at best. The data obtained in this study may suggest that the use of feedback as simple as the one used in the study was not an effective instructional technique for increasing student achievement of different types of learning objectives when accompanying visualized instruction.

Previous research has shown that inserted questions designed to focus student attention effectively reinforced relevant learning cues. By responding to the embedded questions inserted before or after the text, students may activate their prior knowledge, engage in deeper information processing, and therefore enhance their recall and retention of the instructional material (Anderson & Pearson, 1984). In addition, orienting questions were regarded as being able to “… focus learner processes on question-specific information…” by making the question explicit and relating them to the forthcoming instruction (Osman & Hannafin, 1994, p. 9).

The type of questions and feedback employed in this study to enhance learning from visualized instruction are easy to construct in a CBI environment and consequently the instructional effect that can be expected is minimal. Other types of questions and more elaborate feedback may be used to produce more desirable learning effects, as Anderson and Biddle (1975) have indicated, “… higher order
questions consistently increased both recall and application of information….” (p. 122).

However, it was also noted that since a system control was implemented that mandated an overt response to inserted questions, there was a significant difference in the amounts of time-on-task between both the “questions,” the “questions+feedback,” and the “no strategy” groups. There was no significant difference in the amounts of time-on-task between the “questions” and the “questions+feedback” treatments.

To factor out the effect of the time-on-task on the learning achievements of the treatment groups, the time-on-task was entered into the analysis as a covariate. The results indicated that when holding the time-on-task constant, the relationship between the type of instructional strategy and the learning achievement was indeed distorted. The initial significant relationships among the treatment groups on the criterion posttest before controlling for the time-on-task appeared to become insignificant while those insignificant relationships became significant. For the criterion posttests that showed significant differences among the treatment groups after adjusting for the time-on-task, the “no strategy” treatment scored significantly higher than either the “questions” or the “questions+feedback.” The results would indicate that the initial findings when the time-on-task was not controlled in which both the “questions” and the “questions+feedback” treatments were more effective than the “no strategy” were actually misleading. When given the same amount of time to interact with the treatment material as the other two treatments, “no strategy” was more effective than either “questions” or “questions+feedback” in facilitating the achievement of selected learning outcomes.
The provision of feedback to responses students made to inserted questions seems not to have produced a satisfactory instructional effect as can be seen from both phases of the data analysis, which consistently showed that the “questions+feedback” group did not outperform significantly the “questions” group in any posttests. This finding was consistent with previous studies that found the no feedback condition to be equally effective as providing feedback of some type (Clariana, Ross, & Morrison, 1991; Clark and Dwyer, 1998; Pridemore & Klein, 1995; Kulhavy & Stock, 1989). However, the finding also contradicted previous research that supported that providing some kind of feedback is superior to no feedback at all (De Klerk & De Klerk, 1978).

As indicated from the literature review on feedback research, many factors contributed to the effectiveness of feedback, and different types of feedback may not be equally effective with different learning tasks and learners under different learning conditions. The type of feedback investigated in this study was analogous to the combination of KCR and KOR. Learners were informed as to the correctness of their submitted responses as well as a statement of the correct response. This kind of feedback is simple in nature and easy to construct in a CBI environment. It is also associated with low cost in terms of instructional design and development. However, the study found out that this type of feedback did not help students in the acquisition of even the simplest factual knowledge as reflected in their performance of the drawing and identification tests, which measured lower level learning outcomes. Other types of feedback, which are more dedicated and complex in nature and developed to accompany visualization instruction to maximize students’ learning, may be found to be more effective.
Effects of Visual Type

The initial findings of the study suggested the superior effectiveness of animated visuals compared to static visuals. Students receiving the animated instructional treatment outperformed significantly on all criterion posttests across both phases of the analysis than did students who received static visuals. The findings were encouraging and consistent with previous studies that found significantly more superior effects with animation than with static visuals (Alesandrini & Rigney, 1981; Kaiser, Proffitt, & Anderson, 1985; Rieber, 1989; Rieber, Boyce, & Assad, 1990). Indeed, no other studies conducted positioned treatments via item analysis. However, the findings of this study also contradicted previous studies that suggested that animation was no more effective than static visuals (Caraballo, 1985; King, 1975; Moore, Nawrocki, & Simutis, 1979; Reed, 1985; Rieber & Hannafin, 1988).

The majority of animation studies that reported significant differences on learning achievement indicated that only low level of learning outcomes were improved, suggesting that animation is only more effective than static visuals in facilitating students’ acquisition of factual knowledge or simple rules/concepts. The initial findings of the study found that animation is more effective than static visuals in all levels of learning outcomes ranging from simple facts and rules/procedures to more advanced knowledge acquisition such as comprehension and problem solving. Students receiving animated instruction spent significantly more time in reviewing the instructional unit than those who were assigned to static visual treatment. Since a system control is implemented in the animation treatment so that students would need to view the animation at least once, it meant that the time spent on this treatment was
longer than that required to finish the static visual treatment. The difference between the two types of visual treatments on instructional time is approximately 350 seconds. The length of time is approximately equal to the amount of time (366.1 seconds) for the sequence of animation to play once. The amount of time that students receiving the animated visual treatment spent on studying the material suggested that animation sequences developed to complement and enhance learning were not taken full advantage of by the students. Students assigned to this treatment group only played the animation sequences once on average, which was mandatory by the system to ensure that the animation was played and viewed.

Furthermore, when the learning differences between the static visual and the animation treatment groups were measured by effect sizes (Eta2), the results were discouraging. Effect sizes are generally interpreted as the standard deviation units that a treatment outperforms a control group. The effect sizes calculated as the difference between the animated visual treatment and the static visual treatment on all criterion posttests were in the range of .015 and .042 (drawing test: .042, identification test: .035, terminology test: .008, comprehension test: .015, and composite score: .029). The effect size of these magnitudes were quite small following the interpretation guidelines of effect sizes developed by Cohen (1977, 1988), which suggested that an effect size of .20 is small, an effect size of .50 is medium, and an effect size of .80 or above is large. In particular, the effect sizes for a higher level of learning outcomes as indicated in the comprehension test score were smaller than the effect sizes for a lower level of learning outcomes as indicated by the drawing, identification, and terminology test scores in this study.
From a cost-effectiveness perspective, if the effect of the animation can only be expected to provide limited learning gains, its cost-effectiveness is not justified. Instead, other learning strategies or lower-cost technology may be used to produce the same effect.

Furthermore, it was noted that since the amount of time students assigned to the animated visual treatment interacted with the respective treatment material was significantly longer than that of students assigned to the static visuals due to a system control, it was suspicious whether the amounts of the time-on-task have confounded with learning achievement among the treatment groups. Follow-up analyses controlling for the time-on-task indicated that the superior effect of the animated visuals over the static visuals was inflated indicating that the time-on-task is a very important variable in visual studies. When holding the time-on-task constant, the initial significant differences on all posttests during the first-phase analysis and most of the posttests during the second-phase analysis favoring animated visuals no longer existed. The animated visuals were only more effective than the static visuals in improving the achievement of the lower-level educational objective as reflected in the students’ performances of enhanced items in the drawing test.

The time-on-task was confounding with the independent variable, the visual type, and was related to the learning achievement. When controlling for the time-on-task, there were no significant differences between the static and the animated visuals in regard to all four criterion posttest achievements during the first phase analysis and three criterion posttest achievements during the second phase of analysis. Since the time-on-task was confounded with the visual type, there was not sufficient evidence to conclude that the animated visuals were more effective than the static visuals in
facilitating student achievement. Indeed, the initial findings showing that animated visuals were more effective than static visuals were misleading. Students receiving the animated visual treatment were required to use significantly more time to view the material, and although the animated visual group scored significantly higher in all criterion posttests than did the static visual group, there was not enough evidence to suggest that it was the effect of visuals, i.e., animation, that contributed to the learning gains. Students assigned to the static visual group may have achieved equally well if required to view the information as long as the animated group. Since the time-on-task was confounding with the treatment effect, further research is needed to determine if the animated visuals are more effective than the static visuals if students in the latter group are required to view the information as long as the animated visual group.

The result of the study contradicted a widespread belief that animation was an effective instructional device if designed appropriately. A number of possible reasons may be suggested. First, although the animations explored in this study were used to depict concepts being learned, they may also change a learners’ way of cognitive processing and hence increased his/her cognitive load in an unexpected way. Schnitz and Rasch (2005) argued that interventions that were designed for facilitating functions may actually have interfered with learning since student learners were deprived of opportunities to cognitively process learning in their own way. The static visual group, although they were left to form dynamic processing out of the static visuals and text, were free in their choice of cognitive processing and consequently became more engaged in the learning task. As a consequence, the gains in learning between these two groups would not be expected to differ dramatically and reach a significant difference.
Secondly, the animation used in the study was two dimensional. This conventional 2D animation may not be sufficient enough to depict concepts that were actually as concrete as those in the instructional material used for the study. Learners may still have difficulties creating on their own the dynamic function of a human heart, which was depicted as a flat diagram in the study due to the technology limitation. Concepts such as “ventricles are the thickest chambers of the heart” was difficult to depict using a two-dimensional animation. As a result, the learning that can be enhanced through animation was not great enough to be different from static visuals.

Thirdly, Rieber (1991b) has suggested that learners do not necessarily know how to read an animation given the fact that people’s instincts about animation is for it to be entertaining but not instructive. In this study, questions and feedback were inserted after the animated visuals to cue and direct the learners’ attention to the crucial information delivered in the animation. The additions of questions or feedback to questions in the animated visuals were no more effective than the animation alone. The animation used in the study was mandatory and required temporal attention from learners, and the information contained in the animation needed to be deduced by the learners for learning to occur. Since students assigned to either one of the three animation groups did not achieve differently, it was suspected that learners did not comprehend the information presented by the animated visuals. Otherwise, the learners assigned to the “animation+questions+feedback” should at least achieve better than the other two groups because they had a chance to monitor their learning via the feedback given to them.
The animation sequences designed in this study were produced using the same illustrations used by the static visual group. It may be hypothesized that the static visuals were sufficient to provide enough information for learners to invent their own mental visuals of the concepts that needed to be learned; thus, animation is not necessarily needed and in fact, when provided, interfered with learning.

General Discussion

The study investigated the effects of different instructional strategies and visual types in a computer-based instructional environment. In this study, 582 students randomly assigned to treatments interacted with their respective instructional material and took four criterion posttests. The initial results of the study yielded an insignificant interaction between the types of instructional strategy and the types of visuals; however, both main effects of the instructional strategy and the visual types were significant. For the instructional strategy, both the “questions” and the “questions+feedback” strategies were more effective than “no Strategy” in facilitating student achievement in two of the posttests; however, no significant differences were found between the “questions” and the “questions+feedback” treatments in regard to the achievement in all of the criterion posttests. For the visual types, students who received the animated visuals scored significantly higher in all posttests than those who received the static visual treatment.

One major interest of the study lay in determining whether the provision of feedback to inserted questions would facilitate student learning from visualized instruction. The initial results of the study did not favor such an instructional technique. A number of possible explanations may be proposed to explain why feedback of the type employed in this study failed to contribute to learning. First, the
feedback designed in the study included a statement that indicated whether a submitted response was right or wrong followed by the correct response. This type of feedback did not encourage a deeper construction of their knowledge network that would lead to a thorough comprehension of the information presented. Students were rendered as passive learners since they were not required to actively process or search for material for desirable information to confirm if their submitted responses were right or wrong.

Secondly, the nature of the feedback provided in this study may also contribute to its failure to make a learning contribution. The feedback employed in the study was text-based. Although this type of feedback is the easiest to construct and the most commonly used in a computer-based learning environment, its effect may diminish due to the nature of the instructional material, the understanding of which it was designed to enhance. The instructional material used in the study was highly visualized and contained concepts that deal with motion and directional change. The textual nature of the feedback employed in the study did not provide the necessary visuals that learners may have needed to thoroughly understand the information presented in the questions and the corresponding feedback. Graphic or pictorial feedback may be more accommodating and effective in accompanying instructional material that is highly visualized.

A third plausible explanation may be that although the design and positioning of the questions and feedback were based on two pilot studies conducted to specifically locate portions of instructional material that learners experienced difficulties with, their effect may not have an opportunity to reflect because of the visuals accompanying the text. Visuals constructed to facilitate the understanding of the
instructional material may have maximized the learning effect that the inclusion of questions and feedback may not be able to result in further significant change in the learning achievement. Last but not least, the data collected on the amount of time students assigned to the “questions” and the “questions+feedback” treatments studied their instructional material indicated a very minor difference of 14.48 seconds. This minor difference in the amount of time students in these two treatment groups studied their material indicated that students in the “questions+feedback” treatment did not spend a significant amount of time studying the feedback and subsequently processed and internalized the information presented in the feedback.

From the perspective of information processing, the feedback employed in this study may have been attended to by the sensory register; however, it may be lost in seconds and not further processed in the working memory or even if it had a chance to be processed in the working memory, the depth of processing was not enough for it to be transferred into the long-term memory and stored for later retrieval. The learning effect expected from the addition of feedback therefore has not been reflected in the students’ posttest achievement.

The other major variable of interest in this study concerns the types of visuals used in a computer-based learning environment. The study investigated the effect of static and animated/dynamic visuals on the students’ learning of different educational objectives. The initial results of the study supported the proposition that animated presentations provided learners with external illustrations and helped them visualize knowledge that involved changes in direction, speed, and path of travel (Rieber, Boyce, & Assad, 1990; Rieber, 1991a; Rieber, 1991b, ChanLin, 1998). Animated presentations employed in this study was based on two pilot studies conducted to
identify the portion of instructional material that students experienced difficulty with. The addition of animation appeared to have helped students attend to the critical information presented in the text and improve their learning on the posttests. A learning task involving the visualization of motion and trajectory requiring extra cognitive processing and consequently the resulting cognitive load is high. Externally provided animated presentations were believed to be able to release significant cognitive loading because the students did not have to visualize on their own at the risk that the image visualized may be false. However, the learning difference that the employment of animated visuals improved over static visuals was minor to the extent that its incorporation in a CBI environment is not warranted. The learning gains between the treatment groups that received animated and static visuals, when measured by effect size, were minimal at best.

Data collected on the amount of time that the students receiving the animated visual treatment studied the material indicated that they did not play the animation as frequently as needed to thoroughly understand the critical information presented in the animated sequences and consequently the learning achievement was not good enough to support its use in CBI considering the cost and time needed to develop good-quality and complex animation sequences. Animation, at its core nature, has attention-gaining and entertaining features, which was believed to motivate student learning. However, from the researcher’s observation while conducting the research, the majority of students assigned to the animated visual treatment group were not motivated to play the animation more than once to refresh or consolidate information contained in the animation. Given the temporal nature of the display, students may not be able to fully capture or attend to the salient features of the animated presentations at a single play of the sequence.
Rieber (1990a, 1991b) indicated that the most powerful and effective application of animation is to use it to present instructional materials rather than focus learners’ attention or for its cosmetic function. The animation used in the study is to complement text material. The underlying motivational characteristics of this type of instructional animation were not clear and need to be investigated. Perhaps the animation employed in this study did not hold enough intrinsically motivating characteristics for learners. Rieber (1991b) and Maehr (1976) suggested that measures of continuing motivation was needed to assess learners’ willingness to return to an instructional task when external pressure no longer existed.

However, in spite of the initial results reported above, the data collected for the time-on-task revealed controversial findings. After adjusting for the time-on-task, most of the significant differences observed between the treatment groups on learning achievement became insignificant, and there was a trend in which the relationship was reversed for those that found significant difference. This further analysis controlling for the time-on-task indicated that the time-on--task was a confounding variable that was interrelated with the major treatment effect to affect learning achievement. From the perspectives of instructional design, both learning efficiency and effectiveness are important design considerations. Human instinct tells us that students would need more time to study and master complicated or enriched learning material than they need to study relatively simple material. However, whether the additional amount of time needed to learn the designated material would warrant additional learning gains is open to question, not to mention that the cost required to develop enriched learning materials such as the animated visuals used in this study needed to be critically evaluated against its effectiveness.
In this study, the task-on-time appeared as a critical factor that confounded with the initial results. Among researchers who explored time-based variables and students’ learning, Smyth (1985) pointed out that student-engaged learning time was a “necessary” but not sufficient mediating process in classroom research on learning. He argued that while allocated time was useful in interpreting learning results, it was the amount of time during which a student was actively engaged with the subject matter that was the most crucial and that directly contributed to learning.

Rothkopf (1970) also emphasized the importance of student engagement in the learning process by stating, “In most instructional situations, what is learned depends largely on the activities of the student…” (p. 325). Anderson (1970) also noted that “… the activities that the student engages in when confronted with instructional tasks are of crucial importance in determining what he will learn…” (p. 349). It was generally accepted that time was a crucial variable in terms of what people can learn with what level of mastery. The inherent differences among people may influence their learning rates, hence different amounts of time are needed to complete a learning task. Learners’ motivation, attention, and effort are crucial factors in evaluating learning effectiveness.

Carroll (1962) developed a Model of School Learning (MSL) in his studies that aimed to predict success in complex learning tasks. Three variables in the model were associated with time as: (1) aptitude, the amount of time that a student would need to learn something to certain level of mastery; (2) perseverance, the amount of time in which a student is engaged in active learning; and (3) opportunity, the amount of time in which a student is allowed to learn. The other two variables that would be expected to interact with the above three variables in the model are: (4) the ability to
understand instruction, which predicted that the better the quality of the instruction, the more able a student would be to understand the instruction; and (5) the quality of instruction, which would affect the amount of time students need to master a task. The better the quality of the instruction, the less time students would need to master the subject matter.

Carroll argued that the time spent on learning is the key to mastery. The basic assumption of Carroll’s model was that aptitude determines the rate of learning and most students can achieve the mastery of a specified level if they devote the amount of time needed to learning. This model provided two implications: first, a student must devote the amount of time needed to the learning task and secondly, he must be allowed enough time for the learning to take place. In opposition to Carroll’s point of view, other researchers have suggested that the sheer quantity of time allocated to learning is not necessarily critical in determining if a student will learn what he/she is expected to learn (Buss & Poley, 1976); what is crucial is the quality of learning that goes on in the allocated time.

Furthermore, the time-on-task, interpreted as the time accompanied by student involvement, was actually a variable that can be altered. One example was programmed instruction. While research findings generally supported that programmed instruction produced greater learning gains, students generally do not like the mastery-learning manipulating procedures and thus spent less time than they needed to spend, compared to those learning settings under which self-pacing was provided. Bloom (1985) found a zero or a slightly negative relationship between final grades and amount of time spent on homework. The amount of time spent on homework does not seem to be a very good predictor of achievement in the subject in
a study conducted by Husen (1967) that investigated the correlation between achievement test scores in mathematics and the number of hours per week of homework in mathematics as reported by students. In this study, students were allowed as much time as needed to interact with the subject matter; however, there was no scientific way to measure the amount of time within the allocated time in which students were actively engaged in learning. The time differences observed between the static versus animated groups were the “mechanical time” needed for the animated visuals to display. When the amount of time was limited, the animation developed in this study failed to function as an intervention for the active engagement in the learning process to happen.

Limitations of the Study

The results of the study reflected that the difference in the learning gains between static and animated visualization in previous studies, in which time-on-task was not a controlling variable, may need to be reinterpreted. However, the results of the study definitely warrant a cautious interpretation due to a number of limitations.

First, there was no control of how much mental effort subjects were willing to contribute to the study and hence the time-on-task differed. The study employed a convenient sample with students earning extra credit for their participation. The instructional material selected for the study did not relate to any of the students’ disciplines and consequently, the motivation of some of the students may have been low.

The study took about one and half hours to complete; however, a number of subjects finished the study within a very limited period of time, indicating they were
making little mental effort to learn the material, which might have more or less prevented the treatment effects from occurring. Rieber (1991a) indicated that for instructive animation to be effective, sustained meaningful effort is required.

Secondly, the initial results of the study were inconsistent with those of the follow-up analysis after controlling for the time-on-task. For the visual type, there was not sufficient evidence to determine which type of visuals, i.e., animated or static, were more effective in a CBI environment since the effect of the animation after controlling for the time-on-task were mostly not significant; animation was found only to be a significant factor in facilitating achievement on the drawing test, although instructional designers may believe that the static visual group, even if given the same amount of time to interact with the visuals, would not make a greater achievement than the animated group. Not having access to enriched visuals, i.e., animation may put the static visual group at a disadvantage. Nevertheless, this proposition needs to be tested based on the empirical evidence that may be drawn from future studies that control for the time-on-task.

Significance of the Study

The potential effects of technology on learning are immense. While educators and instructional designers are in passionate pursuit of using technology to either deliver instruction or enhance learning, research-based guidelines are needed to base their decision making for instructional design. The significance of the study is threefold. First, the results provide instructional designers with empirical evidence that would support the use of varied types of visuals in a computer-based learning environment specifically to achieve designated instructional objectives. Previous studies have not been able to determine the levels of learning outcomes that specific
type of visuals would be most efficiently and effectively used to improve achievement.

Secondly, although this study did not intend to explore the effects of different types of feedback in learning, it examined a basic issue – the provision (or not) of feedback specifically in a computer-based learning environment that used varied visuals. That is, this study examined the notion that providing feedback to the responses would enhance learning from the visualized instruction, especially, from the animated visualized instruction. Limited studies have looked at the effect of feedback as a complementary strategy to enhance learning from visuals.

Thirdly, the study examined the use of two varied visual types and instructional strategies in a computer-based learning environment based on theories governing humans’ learning from the perspective of information processing and cognition. It provided theoretically sound and empirical evidence-based instructional design principles, which would aid designers and instructors in many areas especially in their design of scientific and technical instruction because commonly designers in these areas design instruction based on their imagination, human instinct, and personal creativity.
Implications of the Study

The results of the study reinforced and extended previous research on visualized instruction and instructional interventions. A number of implications specifically for instructional design and development employing educational technology may be drawn from the results of the study and the observation of the research when it was conducted:

1. The nature of the learning task and the need of visualizations for understanding of the learning material need to be considered and established before any types of visuals are developed in instructional settings.

The use of visual materials of different types to complement instruction in traditional classrooms and recently flourishing computer-assisted learning environments has become increasingly popular. Visuals designed for CBI especially increase the cost of education and, therefore, their use to improve student achievement needs to be verified and justified. Dwyer (1972) developed a model for the empirical development of visuals and indicated that the need for visuals must exist before incorporating them into the instructional material. That is, visuals typically are used to complement the text material. If students can learn well simply from the text, there is no need to include visuals even if they visually appeal to the students’ affective domain. Carrabello (1985) indicated that a problem with most animated studies that found insignificant differences were due to the fact that animation was not needed to learn the instructional material.

Rieber (1990a) in his review of a series of animation studies suggested certain conditions under which animation can be used effectively to learn specific content.
One of the conditions is to use animation for a learning task that requires students to visualize motion and trajectory. Animation may be unnecessary when carefully designed verbal presentations and static visuals successfully help students form correct mental dynamic images (Rieber, Boyce, & Assad, 1990). In addition, when determining whether to use either static or animated visuals, a pilot study may be needed to determine if learning difficulties occur when learning from static visuals. This will provide justifications for the use of animation to provide attributes that static visuals cannot afford.

2. Other cueing strategies than questions and the type of feedback used in the study may be needed to optimize learning from static and animated visualizations.

Accumulated empirical research findings have established the need for different types of cueing/instructional strategies to facilitate students’ learning from visualized material (Munyofu, Swain, Ausman, Lin, Kidwai, & Dwyer, 2005; Owens & Dwyer, 2005, Rieber, 1990b). Cueing/instructional strategies embedded in visualized material help to effectively cue students’ attention to salient and essential features conveyed in the visuals. The strategies are especially important for students not experienced in learning from visuals or those with low spatial-visual abilities. Dwyer (1972) indicated that the methods of cueing visualized instruction significantly influenced the effectiveness that a particular type of visualization has in facilitating the learning of different educational objectives. Questions and feedback employed in this study were found to be ineffective in appropriately instigating the levels of interaction between visualization and learners to achieve the designated learning objectives. This finding is especially important and relevant to software designers. The relative ease of producing KCR and questions of the type used in the study is
typically tempting to instructional designers of CAI programs. Considering how any type of instructional strategies are costly to develop in CBI, there is little justification to include it in CAI or CBI if it is not effective or has limited effectiveness as suggested from the results of the study.

3. The selection of the instructional material may need to be tailored and congruent to students’ learning needs.

Typical experimental studies utilized a convenience sample and, consequently, the level of mental efforts from participants could not be guaranteed. A convenience sample is typically low in the students’ intrinsic motivation to learn the experimental material. For the sake of obtaining more reliable and accurate findings of the effectiveness of intervention treatments, instructional material may be designed and developed to be congruent with students’ learning needs. As a number of subjects in this study revealed to the researcher during informal encounters, they did not feel motivated to learn even if they had the opportunity to view the animations because the instructional material is irrelevant to their learning. Dwyer (1972) indicated that when determining which type of visual materials will be most effective and efficient to use, visualized content material has to be tailor-made to fit the environment in which it is to be used.

Recommendations for Future Research

The following are a number of recommendations for future research based on the results of the study and the observations of the research when it was conducted. First, questions with or without feedback used to complement visualization was one of the major variables of interest in the study. The importance of feedback in the
instructional process cannot be overemphasized. By understanding the conditions under which different types of feedback are most effective, instructional theories can be refined and empirical evidence can be accumulated (Mory, 1992). In this study, questions, with or without feedback, are mainly used as learning cues to focus students’ attention on essential elements presented in the visualization. Their major purpose is to complement visualized instruction. Feedback, in particular, serves to provide interaction between learners and the learning environment. Consequently, factors concerning learners and the learning environment would have a great impact on the effect of the feedback. The effectiveness of feedback to learning certainly cannot be determined simply by judging from its availability. The results of this study indicated that simply providing textual feedback on the correctness of a submitted response was not effective in facilitating learning from visualized materials. Future studies may consider using feedback that combines graphics and text. This type of feedback may be more appropriate to accompany highly visualized material. In addition, more studies need to be conducted that involve learning tasks and feedback of different levels of complexity while considering other factors such as learners’ cognitive styles, prior knowledge, and the learning environment in which the feedback is used.

Secondly, the motivational factor is always important in determining to what extent an instructional strategy is used to assist learning. In this study, it also may have impacted the learners’ ability to process the feedback and visualization effectively. To ensure an appropriate level of motivation for learning to take place, experimental material may be tailored based on the students’ discipline so that students would devote considerable mental effort to engage in the learning process.
Furthermore, after summarizing a large number of studies on the effect of using visual materials, Dwyer (1972) indicated that the relative effectiveness of visual material depends on several factors: the type of visualization used, the presentation method of the visualized material, student characteristics, and most important of all, techniques used to focus student attention on critical learning cues presented in the visualized material. This study found no effect of questions and feedback in facilitating student learning specifically from animated visualization. Future research may investigate other types of cueing strategies such as advance organizers, narrations, audios, or chunking. In addition, new and emerging technology has been becoming increasingly available to offer more advanced types of instructional strategies that involve sounds, digital images, audio, etc. Feedback certainly can be constructed combining these new advanced features. Future research to study the relative effectiveness of these multi-sensory instructional strategies is consequently warranted.

Finally, limited or no research on visualization has investigated the effect of the time-on-task on learning gains in different visualized instruction given the fact that time has been a factor that accounts for much of the variance in a learning environment. Another experimental study in which the time-on-task is controlled for all participants is obviously warranted. Perhaps forcing participants in a static-only treatment to reread the text or re-view the visuals would produce the same amount of learning effect as animated visuals. Another option will be to allow the animated treatment group to determine if they would review the animations. In this study, animation sequences must be played and viewed before students can move on. Not requiring students to view the animations to move on will contribute to research findings in which all the effects obtained between the static and animated visuals would be attributed to the factors of visuals and motivation shown by students while
learning the materials. In addition, there is no denying that the total active learning time for a particular student will be influenced by other factors such as a student’s characteristics, the resources, skills, and efforts devoted to the session, in addition to the total time allocated. From the perspective of instructional design for enriching a learning environment, research has to gradually focus on how the productivity of settings can influence the amount of active learning time. In other words, research needs to shift its focus on how instructional strategies/techniques can most effectively be used to maximize students’ active learning as reflected in their active learning time and learning achievement. Since the initial significant differences on all criterion posttests observed that favored animated visuals vanished entirely after the time-on-task was controlled, there is a need to hypothesize that additional factors in addition to (or rather than) the time-on-task are in operation that may interact with visual type to affect learning. Future research is needed to resolve the conflicts.
References


Denner, P. R., & Rickards, J. P. (1987). A developmental comparison of the effects of provided and generated questions on text recall. *Contemporary Educational Psychology*, 12, 135-146.


### Appendix A

**Designated Goals, Strategies and Allocated Time (in seconds) of Each Animation Sequence**

<table>
<thead>
<tr>
<th>Unit/Page/Frame No.</th>
<th>Designated goals</th>
<th>Animation Strategies</th>
<th>Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>1/3/3</td>
<td>The auricles have thin walls, while the ventricles have thicker walls.</td>
<td>flashing, directional flow, Tweening</td>
<td>30’23</td>
</tr>
</tbody>
</table>
| 1/4/4               | The layer, which forms the outer wall of a double-walled sac in which the heart is enclosed, is called the pericardium.  
The location of Epicardium.  
The inner portion of a double-walled sac is called the Epicardium, which is attached to the heart muscle.  
Myocardium controls the contraction and relaxation of the heart.  
The location of Endocardium. | zoom in/out, enhancing effect, scaling, tweening, layering | 20’45   |
| 2/1/5               | The superior and inferior vena cavas are the two veins which deposit blood in the right auricle. | flashing, directional flow, tweening | 19’03   |
| 2/2/6               | The location of tendons.                                                         | zoom in/out, directional flow, scrubbing | 27’32   |
| 3/1/7               | The location of pulmonary valve and the pulmonary artery.                        | flashing, highlighting, enhancing effect | 9’29    |
| 3/2/8               | The location of the four pulmonary veins and the mitral valve.  
Returning from the lungs, the blood enters the heart through four pulmonary veins and collects in the left auricle. | zoom in/out, tweening | 29’37   |
| 3/3/9               | The contraction of the left ventricle pumps the blood through the entire body.  
Left ventricle is the largest, strongest, and most muscular section of the heart.  
The aortic valve stops the backward flow of blood to the left ventricle and opens for the forward flow of blood to the aorta.  
The location of aorta. | tweening, directional flow, scrubbing | 28’33   |
Appendix A (continued)

<table>
<thead>
<tr>
<th>Date</th>
<th>Description</th>
<th>Additional Techniques</th>
<th>Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>4/2/11</td>
<td>The right auricle receives its blood through the superior and inferior vena cava, while the left auricle receives its blood through the pulmonary veins.</td>
<td>tweening, scrubbing, directional flow</td>
<td>13’05</td>
</tr>
<tr>
<td>4/3/12</td>
<td>A wave of muscular contraction starts at the top of the heart and passes downward, simultaneously. Both auricles contract at the same time and then relax as the contraction passes down to the ventricles. As the ventricles fill, eddies of the blood float the flaps on both the tricuspid and mitral valves back to a partially closed position.</td>
<td>shape tweening, motion</td>
<td>35’51</td>
</tr>
<tr>
<td>4/5/14</td>
<td>The pulmonary valve, leading from the right ventricle, guards the entrance to the pulmonary artery. The aortic valve, leading from the left ventricle, guards the entrance to the aorta or aortic artery. Prior to ventricle contraction, the semi-lunar valves are closed by back pressure by blood already in the exit arteries. When pressure in the ventricles becomes greater than that in the exit arteries due to ventricle contraction, the semi-lunar valves open.</td>
<td>shape tweening, motion, scrubbing, directional flow</td>
<td>18’37</td>
</tr>
<tr>
<td>4/6/15</td>
<td>Blood flows from the left ventricle into the aorta for distribution throughout the entire body.</td>
<td>enhancing effect, zoom in/out</td>
<td>28’95</td>
</tr>
<tr>
<td>4/7/16</td>
<td>The relaxation of the ventricles lowers the pressure within their chambers and the greater pressure in the arteries close the semi-lunar valves. Pressure within the ventricles is strong enough to maintain closure of the tricuspid and mitral valves against the already increasing auricle pressure.</td>
<td>motion, directional flow, tweening</td>
<td>21’37</td>
</tr>
<tr>
<td>5/1/18</td>
<td>During the diastolic phase the ventricles are relaxing. The ventricles are slowly being filled with blood, due to the full auricles and partially-opened tricuspid and mitral valves.</td>
<td>directional flow, motion, shape tweening</td>
<td>38’65</td>
</tr>
</tbody>
</table>
The systolic or contraction phase, begins when the auricles contract. During the systolic phase, the blood is forced through the tricuspid and mitral valves into the ventricles. The ventricles contract forcing the blood through the semi-lunar valves into the pulmonary and aortic arteries.

<table>
<thead>
<tr>
<th>Date</th>
<th>Description</th>
<th>Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>5/2/19</td>
<td>The systolic or contraction phase, begins when the auricles contract.</td>
<td>36'28</td>
</tr>
<tr>
<td></td>
<td>During the systolic phase, the blood is forced through the tricuspid and</td>
<td></td>
</tr>
<tr>
<td></td>
<td>mitral valves into the ventricles.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>The ventricles contract forcing the blood through the semi-lunar valves</td>
<td></td>
</tr>
<tr>
<td></td>
<td>into the pulmonary and aortic arteries.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>directional flow, motion, scrubbing</td>
<td></td>
</tr>
</tbody>
</table>

Total Time (in seconds) = 366.1
## Appendix B

### Questions Inserted after Selective frames

<table>
<thead>
<tr>
<th>Frame No.</th>
<th>Questions</th>
</tr>
</thead>
</table>
| 3 | Q1: Which chambers are the thickest chambers of the heart?  
A. Ventricles  
B. Auricles  
   Q1: What is the name of the inner portion of the double-walled sac of the heart?  
A. Epicardium  
B. Endocardium  
   Q2: Which membrane is connected to the heart muscle?  
A. Epicardium  
B. Pericardium |
| 4 | Q3: What is the part of the heart that controls the contraction and relaxation of the heart?  
A. Myocardium  
B. Epicardium  
   Q4: What is the name of the inside lining of the heart?  
A. Endocardium  
B. Myocardium |
| 5 | Q5: Blood from the body enters the heart through the  
A. superior and inferior vena cava  
B. pulmonary veins  
   Q1: Where are the tendons located?  
A. Auricles  
B. Ventricles |
| 6 | Q7: What is the name of the valve located between the right ventricle and the pulmonary artery?  
A. Pulmonary valve  
B. Tricuspid valve  
   Q2: Blood is forced away from the heart through the  
A. Pulmonary artery  
B. Pulmonary valve |
| 7 | Q3: What veins are located in the left auricle?  
A. Pulmonary veins  
B. Superior vena cava  
   Q2: Returning from the lungs blood enters the heart through the  
A. Right auricle  
B. Left auricle  
   Q3: What is the name of the valve located between the left auricle and the left ventricle?  
A. Mitral valve  
B. Tricuspid Valve |
<table>
<thead>
<tr>
<th></th>
<th>Question</th>
<th>Answer Options</th>
</tr>
</thead>
<tbody>
<tr>
<td>9</td>
<td>Q1: What is the name of the chamber of the heart that pumps blood to the body?</td>
<td>A. Left ventricle</td>
</tr>
<tr>
<td></td>
<td></td>
<td>B. Right ventricle</td>
</tr>
<tr>
<td></td>
<td>Q2: What is the name of the strongest chamber of the heart?</td>
<td>A. Left ventricle</td>
</tr>
<tr>
<td></td>
<td></td>
<td>B. Left auricle</td>
</tr>
<tr>
<td></td>
<td>Q3: What is the name of the valve located between the aorta and left ventricle?</td>
<td>A. Aortic valve</td>
</tr>
<tr>
<td></td>
<td></td>
<td>B. Tricuspid valve</td>
</tr>
<tr>
<td></td>
<td>Q4: Blood passes from the left ventricle into the aorta must pass through the</td>
<td>A. Aortic valve</td>
</tr>
<tr>
<td></td>
<td></td>
<td>B. Pulmonary valve</td>
</tr>
<tr>
<td></td>
<td>Q5: What artery does aortic valve guard entrance to?</td>
<td>A. Aorta</td>
</tr>
<tr>
<td></td>
<td></td>
<td>B. Pulmonary artery</td>
</tr>
<tr>
<td>11</td>
<td>Q1: Through which vein(s) does the right auricle receive its blood?</td>
<td>A. Pulmonary vein</td>
</tr>
<tr>
<td></td>
<td></td>
<td>B. Superior and inferior vena cavas</td>
</tr>
<tr>
<td></td>
<td>Q2: When the right ventricle contracts forcing the blood out the pulmonary valve, what is the</td>
<td>A. Open</td>
</tr>
<tr>
<td></td>
<td></td>
<td>B. Closed</td>
</tr>
<tr>
<td></td>
<td>Q3: When the heart begins contracting it starts simultaneously with</td>
<td>A. Both auricles contraction</td>
</tr>
<tr>
<td></td>
<td></td>
<td>B. Both ventricles contraction</td>
</tr>
<tr>
<td></td>
<td>Q4: What is the contraction sequence of the heart?</td>
<td>A. Ventricles contract and relax first and then</td>
</tr>
<tr>
<td></td>
<td></td>
<td>auricles contract and relax</td>
</tr>
<tr>
<td></td>
<td></td>
<td>B. Auricles contract and relax first and then</td>
</tr>
<tr>
<td></td>
<td></td>
<td>ventricles contract and relax</td>
</tr>
<tr>
<td>12</td>
<td>Q1: The semi lunar valves-the pulmonary and aortic valves guard the entrance to the</td>
<td>A. pulmonary and aortic arteries</td>
</tr>
<tr>
<td></td>
<td></td>
<td>B. superior and inferior vena cavas</td>
</tr>
<tr>
<td></td>
<td>Q2: What is the position of tricuspid valve when blood passes from the right ventricle into the</td>
<td>A. Open</td>
</tr>
<tr>
<td></td>
<td></td>
<td>B. Closed</td>
</tr>
<tr>
<td>15</td>
<td>Q1: Where does the blood go when the right ventricle contracts?</td>
<td>A. Aorta</td>
</tr>
<tr>
<td></td>
<td></td>
<td>B. Pulmonary artery</td>
</tr>
</tbody>
</table>
Appendix B (continued)

<table>
<thead>
<tr>
<th>Q1</th>
<th>At the point in time when the auricle pressure becomes greater than the ventricle pressure, what is the position of the tricuspid and mitral valves?</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>A. Open</td>
</tr>
<tr>
<td></td>
<td>B. Closed</td>
</tr>
<tr>
<td></td>
<td>C. Begin to open</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Q2</th>
<th>When the ventricles contract forcing the mitral and tricuspid closed, what is the position of the aorta valve?</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>A. Open</td>
</tr>
<tr>
<td></td>
<td>B. Closed</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Q1</th>
<th>During the diastolic phase the ventricles are</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>A. contracting and partially full of blood</td>
</tr>
<tr>
<td></td>
<td>B. relaxing and partially full of blood</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Q1</th>
<th>When both the right and left ventricles contract, where does the blood go?</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>A. Pulmonary and aortic arteries</td>
</tr>
<tr>
<td></td>
<td>B. Mitral and tricuspid valves</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Q2</th>
<th>In which phase does the contraction of the heart occur?</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>A. The systolic phase</td>
</tr>
<tr>
<td></td>
<td>B. The diastolic phase</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Q3</th>
<th>In the first contraction of the systolic phase, the auricles will contract and cause the blood to pass from the auricles to the ventricles. At this stage, what is the position of the mitral valve?</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>A. Open</td>
</tr>
<tr>
<td></td>
<td>B. Closed</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Q4</th>
<th>When the ventricles start to contract, what is the position of the aortic valve?</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>A. Fully open</td>
</tr>
<tr>
<td></td>
<td>B. Partially open</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Q5</th>
<th>When the auricles contract, what is the position of the tricuspid and mitral valves?</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>A. Open</td>
</tr>
<tr>
<td></td>
<td>B. Closed</td>
</tr>
</tbody>
</table>
Appendix C
Evaluation Form for the Animated Visuals

Instructions:

Please review the animation contained in selected frames of the instructional module and evaluate its effectiveness in helping you understand the concepts specified below by putting an X on the 5-point scale with 5 being very effective (positive) and 1 being not very effective (negative). When checking the specific rating, please make sure that each concept evaluated corresponds to the frame where they are presented as indicated on the URL provided.

<table>
<thead>
<tr>
<th>URL</th>
<th>5</th>
<th>4</th>
<th>3</th>
<th>2</th>
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<td><a href="http://cham33.ed.psu.edu/khk122/Humanheart/03b/heart03.html">http://cham33.ed.psu.edu/khk122/Humanheart/03b/heart03.html</a></td>
<td></td>
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</tr>
<tr>
<td>The auricles have thin walls, while the ventricles have thicker walls.</td>
<td></td>
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<td></td>
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</tr>
<tr>
<td><a href="http://cham33.ed.psu.edu/khk122/Humanheart/03b/heart04.html">http://cham33.ed.psu.edu/khk122/Humanheart/03b/heart04.html</a></td>
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</tr>
<tr>
<td>The layer, which forms the outer wall of a double-walled sac in which the heart is enclosed, is called the pericardium.</td>
<td></td>
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</tr>
<tr>
<td>The location of Epicardium.</td>
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<tr>
<td>The inner portion of a double-walled sac, in which the heart is enclosed, is called the Epicardium.</td>
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</tr>
<tr>
<td>Epicardium is attached to the heart muscle.</td>
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<tr>
<td>The heart muscle is called the myocardium.</td>
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</tr>
<tr>
<td>Myocardium controls the contraction and relaxation of the heart.</td>
<td></td>
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<tr>
<td>The location of Endocardium.</td>
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</tr>
<tr>
<td>Endocardium is the name given to the membrane lining inside of the heart wall.</td>
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<tr>
<td><a href="http://cham33.ed.psu.edu/khk122/Humanheart/03b/heart05.html">http://cham33.ed.psu.edu/khk122/Humanheart/03b/heart05.html</a></td>
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<tr>
<td>The superior and inferior vena cava are the two veins which deposit blood in the right auricle.</td>
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<tr>
<td>The location of tendons.</td>
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<td><a href="http://cham33.ed.psu.edu/khk122/Humanheart/03b/heart07.html">http://cham33.ed.psu.edu/khk122/Humanheart/03b/heart07.html</a></td>
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<tr>
<td>The location of the pulmonary valve.</td>
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<tr>
<td>The location of the pulmonary artery.</td>
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</tr>
<tr>
<td><a href="http://cham33.ed.psu.edu/khk122/Humanheart/03b/heart08.html">http://cham33.ed.psu.edu/khk122/Humanheart/03b/heart08.html</a></td>
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<tr>
<td>The location of the four pulmonary veins.</td>
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<td></td>
</tr>
<tr>
<td>Returning from the lungs, the blood enters the heart through four pulmonary veins and collects in the left auricle.</td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>The location of the mitral valve.</td>
<td></td>
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<td></td>
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</tr>
<tr>
<td><a href="http://cham33.ed.psu.edu/khk122/Humanheart/03b/heart09.html">http://cham33.ed.psu.edu/khk122/Humanheart/03b/heart09.html</a></td>
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</tr>
<tr>
<td>The contraction of the left ventricle pumps the blood through the entire body.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Left ventricle is the largest, strongest, and most muscular section of the heart.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>The location of the aortic valve.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>The aortic valve stops the backward flow of blood to the left ventricle and opens for the forward flow of blood to the aorta.</td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>The location of aorta.</td>
<td></td>
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<td></td>
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</table>
Appendix C (continued)

<table>
<thead>
<tr>
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<tbody>
<tr>
<td><a href="http://cham33.ed.psu.edu/khk122/Humanheart/03b/heart11.html">http://cham33.ed.psu.edu/khk122/Humanheart/03b/heart11.html</a></td>
<td>The right auricle receives its blood through the superior and inferior vena cava, while the left auricle receives its blood through the pulmonary veins.</td>
</tr>
<tr>
<td><a href="http://cham33.ed.psu.edu/khk122/Humanheart/03b/heart12.html">http://cham33.ed.psu.edu/khk122/Humanheart/03b/heart12.html</a></td>
<td>A wave of muscular contraction starts at the top of the heart and passes downward, simultaneously, over both sides of the heart. Both auricles contract at the same time and then relax as the contraction passes down to the ventricles. As the ventricles fill, eddies of the blood float the flaps on both the tricuspid and mitral valves back to a partially closed position.</td>
</tr>
<tr>
<td><a href="http://cham33.ed.psu.edu/khk122/Humanheart/03b/heart14.html">http://cham33.ed.psu.edu/khk122/Humanheart/03b/heart14.html</a></td>
<td>The pulmonary valve, leading from the right ventricle, guards the entrance to the pulmonary artery. The aortic valve, leading from the left ventricle, guards the entrance to the aorta or aortic artery. Prior to ventricle contraction, the semi-lunar valves are closed by back pressure provided by blood already in the exit arteries. When pressure in the ventricles becomes greater than that in the exit arteries due to ventricle contraction, the semi-lunar valves open.</td>
</tr>
<tr>
<td><a href="http://cham33.ed.psu.edu/khk122/Humanheart/03b/heart15.html">http://cham33.ed.psu.edu/khk122/Humanheart/03b/heart15.html</a></td>
<td>Blood flows from the left ventricle into the aorta for distribution throughout the entire body.</td>
</tr>
<tr>
<td><a href="http://cham33.ed.psu.edu/khk122/Humanheart/03b/heart16.html">http://cham33.ed.psu.edu/khk122/Humanheart/03b/heart16.html</a></td>
<td>The relaxation of the ventricles lowers the pressure within their chambers and the greater pressure in the arteries close the semi-lunar valves. Pressure within the ventricles is strong enough to maintain closure of the tricuspid and mitral valves against the already increasing auricle pressure.</td>
</tr>
<tr>
<td><a href="http://cham33.ed.psu.edu/khk122/Humanheart/03b/heart18.html">http://cham33.ed.psu.edu/khk122/Humanheart/03b/heart18.html</a></td>
<td>During the diastolic phase the ventricles are relaxing. The ventricles are slowly being filled with blood, due to the full auricles and partially-opened tricuspid and mitral valves.</td>
</tr>
<tr>
<td><a href="http://cham33.ed.psu.edu/khk122/Humanheart/03b/heart19.html">http://cham33.ed.psu.edu/khk122/Humanheart/03b/heart19.html</a></td>
<td>The systolic or contraction phase, begins when the auricles contract. During the systolic phase, the blood is forced through the tricuspid and mitral valves into the ventricles. The ventricles contract forcing the blood through the semi-lunar valves into the pulmonary and aortic arteries.</td>
</tr>
</tbody>
</table>
Appendix D

CBI Module for the Static Visual Treatment

Figure D1. Index page.

Figure D2. Welcome page for static visual treatment.
Figure D3. Demographic survey page for static visual treatment.

Figure D4. Introduction page for static visual treatment.
**Figure D5.** Screenshot of unit 1 page 1 in static visual treatment.

**Figure D6.** Screenshot of unit 1 page 2 in static visual treatment.
Unit 1: The Heart’s Structure

Each half of the heart is divided into an upper chamber and a lower chamber. The upper chambers on each side of the septum are called auricles; the lower chambers are called ventricles. Auricles have thin walls and act as receiving rooms for the blood, while the ventricles having thicker walls act as pumps moving the blood away from the heart. Although there is no direct communication between the right and left sides, both sides function simultaneously.

Figure D7. Screenshot of unit 1, page 3 in static visual treatment.

Unit 1: The Heart’s Structure

The heart contains several layers of membranes and muscle. The first set of membranes enclose the heart in a thin double-walled sac. The layer which forms the outer wall of the sac is called the pericardium. It is composed of a tough, transparent elastic tissue. It protects the heart from rubbing against the walls of the chest. The inner portion of the double-walled sac is called the epicardium. It is attached to the heart muscle.

The heart muscle is called the myocardium; it controls the contraction and relaxation of the heart. The myocardium constitutes by far the greatest volume of the heart and its contraction is responsible for the propulsion of the blood through the body. The muscle varies in thickness; for example, the muscle in the auricle walls is thin when compared to the thickness of the muscle in the ventricle walls.

Finally, the endocardium is the name given to the membrane lining inside of the heart wall.

Figure D8. Screenshot of unit 1, page 4 in static visual treatment.
Figure D9. Screenshot of unit 2, page 1 in static visual treatment.

Figure D10. Screenshot of unit 2, page 2 in static visual treatment.
Figure D11. Screenshot of unit 3, page 1 in static visual treatment.

Figure D12. Screenshot of unit 3, page 2 in static visual treatment.
Figure D13. Screenshot of unit 3, page 3 in static visual treatment.

Figure D14. Screenshot of unit 4, page 1 in static visual treatment.
Both auricles receive blood simultaneously through vein openings which have no valves. The right auricle receives its blood through the superior and inferior vena cavae, while the left auricle receives its blood through the pulmonary veins.

**Figure D15.** Screenshot of unit 4, page 2 in static visual treatment.

A wave of muscular contraction starts at the top of the heart and passes downward, simultaneously, over both sides of the heart, that is, both auricles contract at the same time and then relax as the contraction passes down to the ventricles. When the auricles are caused to contract, they become small and pale and in doing so the blood in their chambers is subjected to increased pressure which forces blood to the ventricles through the opened tricuspid and mitral valves.

As the ventricles fill, eddies of the blood float the flaps on both the tricuspid and mitral valves back to a partially closed position.

**Figure D16.** Screenshot of unit 4, page 3 in static visual treatment.
Figure D17. Screenshot of unit 4, page 4 in static visual treatment.

Figure D18. Screenshot of unit 4, page 5 in static visual treatment.
Figure D19. Screenshot of unit 4, page 6 in static visual treatment.

Figure D20. Screenshot of unit 4, page 7 in static visual treatment.
Figure D21. Screenshot of unit 4, page 8 in static visual treatment.

Unit 4: The Blood Flow through the Heart

As the ventricles relax further, pressure within them rapidly decreases. At the same time blood flowing into the auricles from the veins increases the auricle pressure. Due to the differential pressure between the auricles and ventricles, the tricuspid and mitral valves are forced partially open. The circulation of blood through the heart begins again with the next auricle contraction. Auricle pressure fully opens the tricuspid and mitral valves resulting in a rapid flow of blood into the ventricles.

Back | Next

Figure D22. Screenshot of unit 5, page 1 in static visual treatment.

Unit 5: The Phases of the Heart Cycle

The Cycle of Blood Pressure in the Heart

The cycle of blood pressure in the heart consists of two distinct phases. One of these phases is called the diastolic or relaxation phase.

In the diastolic phase, the heart relaxes between contractions. Blood flows into the heart, filling both auricles. While blood is flowing into the auricles, the arteries still maintain part of the pressure developed by a prior ventricle contraction. This is the time of lowest pressure in the arteries, or what is called the diastolic pressure.

During this phase the ventricles are also relaxing. The ventricles are slowly being filled with blood, due to the full auricles and partially opened tricuspid and mitral valves.

Back | Next
Figure D23. Screenshot of unit 5, page 2 in static visual treatment.

Figure D24. Screenshot of unit 5, page 3 in static visual treatment.
Figure D25. End of content page in static visual treatment.

Figure D26. Thank-you page in static visual treatment.
Appendix E

CBI Module for Animated Visual Treatment

Figure E1. Index page in animated visual treatment.

Figure E2. Welcome page in animated visual treatment.
Figure E3. Demographic survey page in animated visual treatment.

Figure E4. Introduction page in animated visual treatment.
Figure E5. Screenshot of unit 1 page 1 in animated visual treatment.

Figure E6. Screenshot of unit 1 page 2 in animated visual treatment.
Figure E7. Screenshot of unit 1 page 3 in animated visual treatment.

Figure E8. Screenshot of unit 1 page 4 in animated visual treatment.
Figure E9. Screenshot of unit 2 page 1 in animated visual treatment.

Figure E10. Screenshot of unit 2 page 2 in animated visual treatment.
Figure E11. Screenshot of unit 3 page 1 in animated visual treatment.

Figure E12. Screenshot of unit 3 page 2 in animated visual treatment.
Figure E13. Screenshot of unit 3 page 3 in animated visual treatment.

Figure E14. Screenshot of unit 4 page 1 in animated visual treatment.
Figure E15. Screenshot of unit 4 page 2 in animated visual treatment.

Figure E16. Screenshot of unit 4 page 3 in animated visual treatment.
Figure E17. Screenshot of unit 4 page 4 in animated visual treatment.

Figure E18. Screenshot of unit 4 page 5 in animated visual treatment.
Figure E19. Screenshot of unit 4 page 6 in animated visual treatment.

Figure E20. Screenshot of unit 4 page 7 in animated visual treatment.
Figure E21. Screenshot of unit 4 page 8 in animated visual treatment.

Figure E22. Screenshot of unit 5 page 1 in animated visual treatment.
**Figure E23.** Screenshot of unit 5 page 2 in animated visual treatment.

**Figure E24.** Screenshot of unit 5 page 3 in animated visual treatment.
Figure E25. End of content page in animated visual treatment.

Figure E26. Thank-you page in animated visual treatment.
## Appendix F

### Complete Criterion Measures

**Table F1**

*The Drawing Test*

<table>
<thead>
<tr>
<th>The Drawing Test</th>
</tr>
</thead>
<tbody>
<tr>
<td>Subject ID Number:</td>
</tr>
</tbody>
</table>

Instructions:

1. Check if the Subject ID number above is the same as the one on the envelop.
2. Draw a simple line picture of a heart and place the corresponding number of the 20 identified parts (see below) where they should be located on the heart. When you are finished, put this test back into the envelope and hit the button “next” to take the second test.

1. Superior vena cava
2. Aorta
3. Tricuspid valve
4. Pulmonary veins
5. Septum
6. Epicardium
7. Aortic valve
8. Pulmonary valve
9. Inferior vena cava
10. Pulmonary artery
11. Myocardium
12. Endocardium
13. Mitral valve
14. Right auricle
15. Right ventricle
16. Left auricle
17. Left ventricle
18. Apex
19. Tendons
20. Pericardium
Figure F1. Identification test item No. 1.

Figure F2. Identification test item No. 2.
**Figure F3.** Identification test item No. 3.

**Figure F4.** Identification test item No. 4.
Figure F5. Identification test item No. 5.

Figure F6. Identification test item No. 6.
**Figure F7.** Identification test item No. 7.

**Figure F8.** Identification test item No. 8.
Identification Test

Arrow number nine (9) points to the _____.

- Endocardium
- Myocardium
- Pericardium
- Ectoderm
- Septum

Previous  Submit

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Figure F9. Identification test item No. 9.

Identification Test

Arrow number ten (10) points to the _____.

- Endocardium
- Pericardium
- Septum
- Myocardium
- Aortic Valve

Previous  Submit

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Figure F10. Identification test item No. 10.
Figure F11. Identification test item No. 11.

Figure F12. Identification test item No. 12.
Figure F13. Identification test item No. 13.

Figure F14. Identification test item No. 14.
Figure F15. Identification test item No. 15.

Figure F16. Identification test item No. 16.
Figure F17. Identification test item No. 17.

Arrow number seventeen (17) points to the _____
- Superior Vena Cava
- Tricuspid Valve
- Aortic Valve
- Pulmonary Valve
- Mitral Valve

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Figure F18. Identification test item No. 18.

Arrow number eighteen (18) points to the _____
- Right Atricle
- Right Ventricle
- Left Auricle
- Left Ventricle
- Semi-Lunar Chamber

Submit
Figure F19. Identification test item No. 19.

Figure F20. Identification test item No. 20.
Figure F21. Terminology test item No. 1.

Figure F22. Terminology test item No. 2.
Figure F23. Terminology test item No. 3.

Figure F24. Terminology test item No. 4.
Figure F25. Terminology test item No. 5.

Figure F26. Terminology test item No. 6.
**Figure F27.** Terminology test item No. 7.

Vessels that allow the blood to flow from the heart are called the _____.

- Veins
- Arteries
- Apex
- Tendons
- Valves

**Figure F28.** Terminology test item No. 8.

Blood passes from the left ventricle out the aortic valve to the _____.

- Lungs
- Body
- Aorta
- Pulmonary Artery
- Left Atricle

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Figure F29. Terminology test item No. 9.

Figure F30. Terminology test item No. 10.
Figure F31. Terminology test item No. 11.

Figure F32. Terminology test item No. 12.
Figure F33. Terminology test item No. 13.

Figure F34. Terminology test item No. 14.
**Figure F35.** Terminology test item No. 15.

The _____ allow(s) blood to travel in one direction only.

- Septum
- Valves
- Arteries
- Veins
- Tendons

**Figure F36.** Terminology test item No. 16.

The _____ is the common opening between the right auricle and the right ventricle.

- Mitral Valve
- Tricuspid Valve
- Septic Valve
- Pulmonary Valve
- Aortic Valve
Figure F37. Terminology test item No. 17.

Figure F38. Terminology test item No. 18.
Terminology Test

The outside covering of the heart is called the _____.

- Endocardium
- Epicardium
- Pericardium
- Myocardium
- None of these

Previous  Submit

Figure F39. Terminology test item No. 19.

Terminology Test

Immediately before entering the aorta, blood must pass through the _____.

- Left Ventricle
- Mitral Valve
- Lungs
- Superior Vena Cava
- Aortic Valve

Previous  Submit

Figure F40. Terminology test item No. 20.
Figure F41. Comprehension test item No. 1.

Figure F42. Comprehension test item No. 2.
Figure F43. Comprehension test item No. 3.

Comprehension Test

When the blood is being forced out the aorta, it is also being forced out of the _____.

- Pulmonary Veins
- Pulmonary Arteries
- Superior Vena Cava
- Cardiac Artery

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Figure F44. Comprehension test item No. 4.

Comprehension Test

The contraction impulse in the heart starts in _____.

- The Right Auricle
- Both Ventricles Simultaneously
- Both Auricles Simultaneously
- The Atria

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Comprehension Test 5/20

In the diastolic phase the ventricles are _____.

- Contracting, full of blood
- Contracting, partially full of blood
- Relaxing, full of blood
- Relaxing, partially full of blood

Figure F45. Comprehension test item No. 5.

Comprehension Test 6/20

During the first contraction of the systolic phase, in what position will the mitral valve be?

- Beginning to open
- Open
- Beginning to close
- Closed

Figure F46. Comprehension test item No. 6.
**Comprehension Test**  

During the second contraction of the systolic phase, blood is being forced away from the heart through the _____.

- Pulmonary and Aortic Arteries
- Superior and Inferior Vena Cavaes
- Tricuspid and Mitral Valves
- Pulmonary Veins

**Figure F47. Comprehension test item No. 7.**

**Comprehension Test**  

When blood is entering through the vena cavas, it is also entering through the _____.

- Mitral Valve
- Pulmonary Veins
- Pulmonary Artery
- Aorta

**Figure F48. Comprehension test item No. 8.**
Comprehension Test

When the heart contracts, the _____.

- Auricles and ventricles contract simultaneously
- Ventricles contract first, then the auricles
- Right side contracts first, then the left side
- Auricles contract first, then the ventricles

Previous  Submit

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Figure F49. Comprehension test item No. 9.

Comprehension Test

While blood from the body is entering the superior vena cava, blood from the body is also entering through the _____.

- Pulmonary Veins
- Aorta
- Inferior Vena Cava
- Pulmonary Artery

Previous  Submit

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Figure F50. Comprehension test item No. 10.
Figure F51. Comprehension test item No. 11.

Comprehension Test 11/20

When the blood leaves the heart through the pulmonary artery, it is also simultaneously leaving the heart through the _____.

- Tricuspid Valve
- Pulmonary Veins
- Aorta
- Pulmonary Valve

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Figure F52. Comprehension test item No. 12.

Comprehension Test 12/20

When the pressure in the right ventricle is superior to that in the pulmonary artery, in what position is the tricuspid valve?

- Closed
- Open
- Beginning to close
- Confined by pressure from the right auricle

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Figure F53. Comprehension test item No. 13.

Figure F54. Comprehension test item No. 14.
Figure F55. Comprehension test item No. 15.

Figure F56. Comprehension test item No. 16.
**Figure F57. Comprehension test item No. 17.**

During the second contraction of the systolic phase, in what position is the aortic valve?

- Fully open
- Partially open
- Partially closed
- Fully closed

**Figure F58. Comprehension test item No. 18.**

Blood is being forced out the auricles simultaneously as blood is _____.

- Entering only the vena cavas
- Being forced out the pulmonary and aortic valves
- Passing through the tricuspid and mitral valves
- Being forced out through the pulmonary artery
Comprehension Test

If the aortic valve is completely open, the 

- Second contraction of the systolic phase is occurring
- Diastolic phase is occurring
- Tricuspid and mitral valves are completely open
- Blood is rushing into the right and left ventricles

Submit

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Figure F59. Comprehension test item No. 19.

Comprehension Test

When the heart relaxes, the 

- Auricles relax first, then the ventricles
- Right side relaxes first, then the left side
- Left side relaxes first, then the right side
- Ventricles relax first, then the auricles

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Figure F60. Comprehension test item No. 20.
Appendix G

Physiology Prior Knowledge Test

Instructions: Select the answer you feel best completes the sentence.

Question 1. The part of the tooth which contains the hardest substance in the body is the:
   a. root
   b. dentine
   c. cement
   d. enamel

Question 2. The digestion of food occurs principally in the:
   a. stomach
   b. small intestine
   c. mouth
   d. large intestine

Question 3. Contraction of the smooth muscle of the alimentary canal is called:
   a. peristalsis
   b. digestion
   c. absorption
   d. assimilation

Question 4. Worn-out red blood cells are decomposed in the:
   a. heart
   b. lungs
   c. kidneys
   d. liver

Question 5. "Swollen glands” means an enlargement of the:
   a. lymph nodes
   b. heart valves
   c. vena cava
   d. protal vein

Question 6. The chief value of perspiration is that it
   a. eliminates body odors
   b. opens the pores
   c. reduces weight
   d. regulates body temperature

Question 7. Endocrine glands produce:
   a. chyme
   b. endoplasm
   c. hormones
   d. serums
Question 8. The body is stimulated to unusual activity by increased secretion from the:
  a. pancreas  
b. adrenal glands  
c. thyroid gland  
d. thymus gland

Question 9. The spinal cord is made up of:
  a. bone tissue  
b. cartilage tissue  
c. connective tissue  
d. nerve tissue

Question 10. Nerves from the eyes and ears are connected to the:
  a. cerebellum  
b. cerebrum  
c. medulla  
d. spinal cord

Question 11. The chromosome number of the body cells of identical human twins is:
  a. 12  
b. 24  
c. 46  
d. 92

Question 12. The person who can give blood to any other person but can receive only his own type blood has blood type:
  a. A  
b. O  
c. AB  
d. B

Question 13. The ribs are attached to the spine and meet in front of the body at the:
  a. skull  
b. limbs  
c. joints  
d. breastbone

Question 14. The ribs protect the:
  a. stomach  
b. breastbone  
c. spinal Cordially  
d. lungs

Question 15. The hollow interior of the long bones is filled with:
  a. marrow  
b. minerals  
c. red and white corpuscles  
d. haversian canals
Question 16. The windpipe is located -----the esophagus:
   a. in front of
   b. behind
   c. to the left of
   d. to the right of

Question 17. The carbon dioxide-oxygen exchange with the atmosphere occurs in the:
   a. nose
   b. trachea
   c. lungs
   d. bronchi

Question 18. Blood is oxygenated in the capillaries of:
   a. air sacs
   b. heart
   c. muscle
   d. liver

Question 19. During inspiration, the ribs:
   a. do not move
   b. move downward
   c. move inward
   d. move upward

Question 20. The part of the brain that controls respiration is the:
   a. medulla
   b. cerebellum
   c. cerebrum
   d. spinal cord

Question 21. A defense of the body against bacteria is:
   a. hemoglobin
   b. phagocytes
   c. red blood cells
   d. blood platelets

Question 22. The disease hemophilia is associated with
   a. the bone structure
   b. blood clotting
   c. the structure of nervous tissue
   d. the formation of red corpuscles

Question 23. The liquid that bathes every cell and acts as a medium of exchange is:
   a. cell sap
   b. fibrinogen
   c. lymph
   d. fibrin
Question 24. Urine is stored in an organ called the:
   a. diaphragm
   b. kidney
   c. bladder
   d. lungs

Question 25. Secretions of the ductless glands pass:
   a. into tubes or ducts
   b. directly into the blood
   c. directly into the organs where they are used
   d. out of the body

Question 26. Inactivity of the thyroid gland from infancy may produce a condition known as:
   a. diabetes
   b. beriberi
   c. cretinism
   d. Addison’s disease

Question 27. The concentration of sodium and potassium in the blood is controlled by:
   a. adrenin
   b. cortin
   c. insulin
   d. secretin

Question 28. Diabetes is caused by the improper functioning of the:
   a. parathyroids
   b. thyroids
   c. pancreas
   d. adrenals

Question 29. The adult human heart is said to beat approximately---times per minute.
   a. 85
   b. 72
   c. 60
   d. 58

Question 30. Growth and repair of boy tissue involves:
   a. protein
   b. fats
   c. starch
   d. sugar

Question 31. Blood enters the heart through:
   a. arteries
   b. vena cavas
   c. the aortic arch
   d. pulmonary veins
Question 32. Blood leaves the heart through the:
   a. tricuspid valve
   b. aorta
   c. superior vena cava
   d. mitral valve

Question 33. The portion of the heart which divides longitudinally into 2 halves is called the:
   a. myocardium
   b. tendons
   c. pericardium
   d. septum

Question 34. A blood vessel which carries deoxygenated blood is the:
   a. aorta
   b. pulmonary artery
   c. hepatic artery
   d. pulmonary vein

Question 35. The backward flow of blood in the veins is prevented by
   a. muscles
   b. valves
   c. the heart beat
   d. the lymphatics

Question 36. The chamber of the heart which pumps oxygenated blood to all the parts of the body is the:
   a. left auricle
   b. right ventricle
   c. right auricle
   d. left ventricle
Appendix H
Procedures and Results of Pilot Studies

The First pilot study

The sample population involved in the first pilot study was 47 undergraduate students recruited from the Pennsylvania State University in the spring semester of 2004. Students participated for extra class credit. Data were gathered in a one-shot study conducted in a multimedia computer lab. The instructional module used in the pilot study was the same as that used by Static Visuals Alone treatment group in the major study. It was comprised of a 2,000 word text describing the parts and function of the human heart during the diastolic/systolic phases and 20 static visuals. All students were instructed to log on to the website where the instructional module was located. Upon finishing of the instruction module, participants took four criterion posttests measuring their learning and achievement from the instructional module. An item analysis was conducted to identify questions that were difficult. The item difficult index was set at .60, meaning that an item was identified as difficult if more than 60% of the subjects can not respond correctly. The results of the first pilot study suggested that a total of 41 out of 80 items had difficult index lower than .60. These items were identified as areas that students have experienced learning difficulties and were ideal positions that animated visuals and varied instructional strategies may be embedded to improve learning. To be specific, the distribution of difficult items was eleven (12) in the drawing test, five (5) in the identification test, twelve (12) in the terminology test and thirteen (12) in the comprehension test. Table H1 provided a summary of the item difficult index.
Table H1

*Item Difficult Index for the First Pilot Study (N=47)*

<table>
<thead>
<tr>
<th>Item No.</th>
<th>Drawing</th>
<th>Identification</th>
<th>Terminology</th>
<th>Comprehension</th>
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The second pilot study

The first pilot study was replicated with a larger sample size in the fall semester of 2004. The sample population involved in the second study was 70 undergraduate students recruited from the same subject pool as that in the first pilot study. Students participated for extra class credit. The instructional material was the same as that used in the first pilot study. Another item analysis was conducted to identify items that had difficult index level lower than .60. These items were again identified as areas that students have experienced with and
were ideal positions that animated visual and varied instructional strategy can be used to improve learning. The results of the item analysis suggested that a total of 36 out of 80 items have difficult index lower than .60. The distribution of difficult items was seven (7) in the drawing test, three (3) in the identification test; fourteen (14) in the terminology test and twelve (12) in the comprehension test. Table H2 provided a summary of the item difficult index for the second pilot study.

Table H2

*Item Difficult Index for the Second Pilot Study (N=70)*

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<th>Terminology</th>
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Another item analysis combining two pilot studies (N=117) was conducted. The main purpose of this combined item analysis was to identify items that have item difficult index lower than .60 based on a larger sample size. The second purpose was to use the result of the item analysis to develop instructional material to test the effect of the variables of interest, i.e. animated visuals, questions and feedback in this study. Based on the result of the item analysis, the portion of the instructional material that these difficult items addressed was modified to include animated visuals and varied instructional strategies, i.e. questions and feedback. The portion of the instructional material that learners have not experienced difficulty with remained the same, i.e. static visuals were used. The items that were identified as difficult and were improved using animated visuals and varied instructional strategies in this study were summarized in Table G3. In total, 37 items had difficulty level below .60. The distribution of the items was nine (9) in the Drawing test, three (3) in the Identification test, twelve (12) in the Terminology test and thirteen (13) in the Comprehension test. However, since only three items were identified on the Identification Test with item difficulties below .60, indicating that students performed relatively well, no animated visual or instructional strategies were developed to improve achievement in this test. Table H3 provided a summary of the item difficult index combining the first and the second pilot study.
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</table>
VITAE

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