QUESTIONS AND FEEDBACK: EFFECTS OF DIRECT MANIPULATION AND ANIMATION IN FACILITATING STUDENT ACHIEVEMENT ON TESTS MEASURING DIFFERENT EDUCATIONAL OBJECTIVES

A Thesis in

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by

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ABSTRACT

This research investigated the instructional effects of three levels of questioning strategies (no questions, traditional matching questions, and direct manipulation matching questions) and three levels of feedback strategies (no feedback, knowledge of result (KOR) text feedback only, and KOR text plus animation-elaborated feedback). Three research questions were studied in this research: (1) were three levels of questioning strategies equally effective in facilitating student achievement on tests measuring different educational objectives? (2) Were three levels of feedback strategies equally effective in facilitating student achievement on tests measuring different educational objectives? And (3) was there an interaction between the level of questioning strategies and the level of feedback strategies?

Participants were 184 undergraduate students who enrolled in a one hundred level Biological Science course during the fall 2005 semester in a large land grant university in northeastern USA. The students were randomly assigned to five treatment groups: no questions and no feedback control group (T1), traditional matching questions with KOR text feedback (T2), traditional matching questions with KOR text plus animation-elaborated feedback (T3), direct manipulation matching questions with KOR text feedback (T4), and direct manipulation matching questions with KOR text plus animation-elaborated feedback (T5).

The study included an online pretest to determine the students’ prior knowledge, followed by the web-based treatments and three online criterion tests used to assess
student achievement on different learning objectives: (1) identification test, (2) terminology test, and (3) comprehension test.

Two-way multiple analysis of covariance (MANCOVA) was conducted to test the main effects and the interactions between the level of questioning strategies and the level of feedback strategies. Data were analyzed with all test items in each of the three criterion tests as well as the subset of difficult test items practiced with questions and feedback. For research question one, no significant differences in achievement were found among students who received different levels of questions when data were analyzed with all test items, $F (3, 176) = 2.17, p = .094$. However, when data were analyzed with the subset of difficult items, significant differences were found, $F (3, 176) = 3.00, p = .032$. Follow-up univariate pairwise comparisons revealed that students who received traditional matching questions (T2+T3) performed significantly better than students who received no questions (T1) on the terminology test only, $p = .020$. For research questions two, no significant differences in achievement were found among students who received different levels of feedback. For research questions three, no significant interaction was found between the level of questioning strategies and the level of feedback strategies.

Important conclusions included: (1) traditional matching questions were equally effective to direct manipulation matching questions in facilitating factual, conceptual, and rules and principles learning; (2) traditional matching questions were more effective in facilitating conceptual learning on difficult items than no questions; and (3) no feedback, KOR text feedback only, and KOR text plus animation-elaborated feedback were equally effective in facilitating factual, conceptual, and rules and principles learning.
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Chapter 1

INTRODUCTION

Background of the Problem

Since the beginning of the microcomputer revolution in the late 1970s, dramatic changes have taken place in learning and instruction. Advances in technologies have greatly increased the capabilities of desktop computers and made it possible to present computer-based multimedia instruction that includes motion, voice, data, text, graphics, and still images (Moore, Burton, & Myers, 2003). In addition, new software capabilities make it possible and easier for the instructors to create computer-based coursework with graphics, animations, and interactions. As a result, educators and instructional design practitioners are able to provide learners with a wide variety of highly visual and interactive computer-based learning environments (Rieber, 1996).

These opportunities and the widely used computer technologies in teaching and learning are calling for sound computer-based multimedia research to direct practice. Among them, direct manipulation and animation are two fairly important areas for empirical studies because of their growing popularity in Computer-Based Instruction (CBI).
Direct Manipulation

The advances of computer technologies and new software capabilities have made it possible to allow learners to directly manipulate screen objects. Since its emergence, direct manipulation has been widely used as a part of the practice strategy in CBI. When used as a part of the most structured practice activities, direct manipulation has been used as a questioning strategy where learners are required to answer the questions by directly manipulating screen objects. On the other hand, direct manipulation has been used in highly interactive programs such as simulations and games where learners continuously and directly manipulate screen objects. Although manipulation activities have shown positive effects on achievements in several contexts, extensive empirical research has not been conducted to investigate the effectiveness of direct manipulation on learning in CBI (Banna-Ritland & Grabowski, 2002; Haag, 1995).

Animation

Animation is defined as images exhibited in motion (F. M. Dwyer & C. Dwyer, 2003). According to Rieber (1990), animation brings three attributes to instruction: visualization, motion, and trajectory. Based on its attributes, animation has been used to enhance instruction in one of the three functions: attention-gaining, presentation, and practice (Rieber, 1990).

Attention-gaining is an important initial event of R. M. Gagné’s (1985) nine events of instruction. It is an “… obvious, practical, and rational use of animation.” (Rieber, 1990, p. 77). Attention-gaining animations provide additional ways to insure
selective perception where specific features of the presentation are emphasized, stored, and processed in the short-term memory (R. M. Gagné, 1985). Similarly, Hannafin and Peck (1988) suggested that animations can help emphasize important information by providing contrast to the static background. In addition, Levin, Anglin, and Carney (1987) argued that attention-gaining graphics can help make relationships between ideas more apparent by facilitating organization.

Animation can also be used to demonstrate or elaborate a lesson fact, concept, rule, or procedure with or without corresponding text (Rieber, 1990). According to Paivio’s (1971; 1986) dual coding theory, visual information (e.g., animated graphics) will more likely be encoded both visually and verbally into long-term memory when presented simultaneously with verbal information. Reed (1985) described using animation to present information as a “learning-by-viewing approach” (p. 297-298).

Rieber (1990) pointed out that animation is often used as a part of the practice strategies in addition to attention-gaining and elaboration. When used in the most structured practice activities, animations were used as feedback to student answers providing reinforcement to correct answers. On the other hand, animation can be used in highly interactive programs in which animated graphics change continuously over time based on student input (e.g., diSessa, 1982; Lamb, 1982; Papert, 1980; White, 1984).

Park and Hopkins (1993) summarized the findings about the effects of dynamic visual displays and identified five important instructional roles of animation: as an attention guide, as an aid for illustration, as a representation of domain knowledge, as a device model for forming a mental image, and as a visual analogy or reasoning anchor for understanding abstract and symbolic concepts or processes. They further suggested when
one or more of the above five instructional roles are needed for both the characteristics of
the domain knowledge and the students, animation can be most effective (Park &
Hopkins, 1993).

Despite the unique attributes provided by animation and the fact that animation
seems to attract learners’ attention and increase their motivation to learn, it is still unclear
whether animation strategies can facilitate learning and whether it is worth the price. The
research on the effects of animation is not only very limited, but the results of the limited
number of completed research studies are mixed. Moreover, some studies are
methodologically flawed. With the increasing use of visual information in instruction, it
is imperative to determine the most effective animation strategies (Anglin, Vaez, &
Cunningham, 2003).

Statement of the Problem

Questions and feedback have long been considered a very important and effective
instructional strategy. With the development of computer technologies and new software
capabilities, it is now possible to provide various innovative, engaging, and interactive
questioning and feedback strategies in CBI. Many instructional designers and educators
have been using direct manipulation as a questioning strategy and animation as a
feedback strategy, however, the effectiveness of these two instructional strategies on
learning is not yet fully understood.

Direct manipulation questioning strategy allows learners to directly drag and drop
screen objects to answer the questions. The direct manipulation interface gives the learner
the feeling of directness which shortens the distance between the learner’s intentions and
the physical facilities provided by the system, as well as the feeling of engagement
(Hutchins, Hollan, & Norman, 1985). Although it seems that direct manipulation
questioning strategy is very promising and innovative, further research needs to be
conducted to find out its instructional effectiveness on student learning.

As mentioned above, animation, because of its unique attributes, has been used as
a feedback strategy in CBI. Advances in technologies make it possible to enhance the
quality and type of feedback generated in response to learner’s actions by integrating
animation. However, the effectiveness of animation feedback strategy in instruction still
needs to be determined.

**Purpose of the Study**

This research study focused on the individual and combined instructional
effectiveness of two specific instructional strategies: questioning strategies and feedback
strategies. The purpose was to investigate the instructional effects of three levels of
questioning strategies (no questions, traditional matching questions, and direct
manipulation matching questions) and three levels of feedback strategies (no feedback,
knowledge of result (KOR) text feedback only, and KOR text plus animation-elaborated
feedback). The traditional matching questions, direct manipulation matching questions,
and the animation-elaborated feedback were designed based on cognitive processing
requirements of three levels of learning: factual, conceptual, and rules and principles.
It was the objective of this research to provide data to establish the empirical justification for the use of questioning and feedback strategies in the teaching and learning process, and contribute to the knowledge needed in the building of instructional theory.

Research Questions

In this regard, three research questions were explored.

Research Question 1. Were three levels of questioning strategies (no questions, traditional matching questions, and direct manipulation matching questions) equally effective in facilitating student achievement on tests measuring different educational objectives?

Research Question 2. Were three levels of feedback strategies (no feedback, KOR text feedback only, and KOR text plus animation-elaborated feedback) equally effective in facilitating student achievement on tests measuring different educational objectives?

Research Question 3. Was there an interaction between the level of questioning strategies and the level of feedback strategies?
Null Hypotheses

The null hypotheses were as follows:

Ho1: There will be insignificant differences in achievement among students who received no questions, traditional matching questions, or direct manipulation matching questions on tests measuring different educational objectives.

Ho2: There will be insignificant differences in achievement among students who received no feedback, KOR text feedback only, or KOR text plus animation-elaborated feedback on tests measuring different educational objectives.

Ho3: There will be an insignificant interaction between the level of questioning strategies and the level of feedback strategies.

Significance of the Study

Educational Justification

The evolution of learning theories has established the active role of learner in the learning process. The learner is no longer viewed as a passive recipient of instruction. Instead, the learner is considered as an active participant in the learning process who is actively engaged in receiving, processing, and organizing information, and who actively constructs meaning from instruction. Therefore, it poses a continuing challenge for instructional designers to design instructions that facilitate learners’ meaningful interaction with and processing of information (Banna-Ritland & Grabowski, 2002). This
can partly explain the increasing popularity of direct manipulation and animation strategies among instructional design practitioners.

As more instructional designers and educators start to use direct manipulation as a questioning strategy, it is very important for them to know whether it facilitates learning. If it does, which level(s) of learning does it facilitate? And under what conditions does it facilitate learning?

Animation, because of its unique attributes, is often used as a feedback strategy to demonstrate or elaborate a lesson fact, concept, rule or principle. For instructional designers and educators, it is very important to know whether animation-elaborated feedback strategy facilitates learning. If it does, under what circumstances does it facilitate learning? And does it facilitate learning on certain levels of instructional objectives more than other levels of instructional objectives? These are some of the questions needs to be answered.

Furthermore, it is also important for instructional designers and educators to know the combined effectiveness of direct manipulation questioning and animation-elaborated feedback strategies when they are used as a question and feedback strategy.

The results of this study shed light on these questions discussed above and provide information to instructional designers and educators in the decision-making process of using direct manipulation questioning strategy and animation-elaborated feedback strategy in CBI.
Research Justification

In addition to answering a current need in education, this research study also provides important data to establish empirical justification for whether or not to use direct manipulation questioning strategy and animation-elaborated feedback strategy in the teaching and learning process.

Little empirical research exists which examines the instructional effectiveness of direct manipulation questioning strategy. Haag (1995) conducted an experimental study to explore the effects of visual manipulation strategies within CBI on various levels of learning objectives. Four treatment groups were included: static graphics, visual summary with manipulation, learner-manipulation, and computer manipulation. Among them, the visual summary with manipulation and learner-manipulation strategies were used as practice. They were similar to the direct manipulation questioning strategy used in this study. No significant differences were found for the two manipulation strategies in her study. This research extended prior research findings by comparing the direct manipulation questioning strategy with a traditional questioning strategy, i.e., traditional matching questions, and by combining it with animation-elaborated feedback strategy.

Very limited research has been conducted so far on the effectiveness of animation (Anglin et al., 2003; Rieber, 1990; 2000). This lack of empirical research was especially true for the animated attention-gaining and practice strategies (Rieber, 1990). Rieber (1990) pointed out “very little research has been focused on practice strategies…. Little or no work has been done to study the effect of animation as an attention-gaining device” (p.78). Although some research studies have been conducted since then, it is still true that
little research is available on animation’s effectiveness despite its popularity among CBI designers and developers (Rieber, 2000).

In addition, the results of the limited number of animation studies are mixed (Anglin et al., 2003; Park & Hopkins, 1993; Rieber, 1990). These mixed results have caused the debate over the effectiveness of animation in instruction. It was suggested that the reason for the mixed results could be rooted in the methodological issues (Anglin et al., 2003; Park & Hopkins, 1993; Rieber, 1990), therefore, further methodologically-sound research needs to be done to test the effectiveness of animation.

This research extended previous research on animation by examining the effectiveness of animation-elaborated feedback strategy.

**Theoretical and Conceptual Justification**

**Direct Manipulation**

Hutchins et al. (1985) suggested that the advantage of direct manipulation interface is that it gives the learner the feeling of directness which shortens the distance between the learner’s intentions and the physical facilities provided by the system, as well as gives the learner the feeling of engagement. A short distance, they claim, “… means that the translation is simple and straightforward, that thoughts are readily translated into the physical actions required by the system and that the system output is in a form readily interpreted in terms of the goals of interest to the user” (p. 317). By shortening the distance, direct manipulation interface minimizes the learner’s cognitive
mental effort by creating a bridge between the learner’s task and the way that the task can be accomplished via the interface. Engagement gives the learners the feeling that he or she is directly manipulating the objects of interest, a feeling of first-personness (Laurel, 1986) of direct engagement with the objects that they concern (Hutchins et al., 1985).

In this study, the learners were required to identify and build generative relationships for facts, concepts, and rules and principles. For facts, the learners were required to identify and match the concept names with their corresponding graphical parts. For concepts, the learners were required to identify and match the concept attributes with their corresponding concept names. For rules and principles, the learners were required to identify and match the “If…” statements with their corresponding “then…” statements.

The direct manipulation matching questions used in this study allowed the learners to answer the questions by directly dragging and dropping the answers to the questions into corresponding placeholders on a visual frame of the whole heart containing an outline of the primary parts. For facts, the learners were required to drag the concept names and drop them into the placeholders pointing to their corresponding graphical parts. For concepts, the learners were required to drag the concept attributes and drop them into the placeholders under their corresponding concept names. For rules and principles, the learners were required to drag the “If…” statements and drop them into the placeholders above their corresponding “then…” statements. The traditional matching questions, on the other hand, only allowed the learners to answer the questions by clicking on the corresponding radio buttons.
Direct manipulation matching questions required the learners to both covertly and overtly establish the generative relationships while traditional matching questions only required the learners to covertly establish these relationships. It was expected that direct manipulation would minimize the learners’ cognitive mental effort to answer the questions by helping them overtly as well as covertly build these relationships. In addition, it would give the learners a deeper feeling of engagement by asking them to directly interact with the items to be matched. Haag (1995) explained the directness of the direct manipulation interface and suggested it provides “… realistic and intuitive representations so that the interface becomes transparent to the user who feels as if he or she is directly operating in the environment (p. 25). Through direct manipulation, “… the user can participate in novel ways of generatively manipulating and organizing visual information which may mediate the thinking process” (p. 4). Therefore, it was expected that direct manipulation matching questions would better facilitate learning compared to traditional matching questions.

**Animation-Elaborated Feedback**

In this study, animation was used to provide additional informational feedback by demonstrating or elaborating a lesson fact, concept, rule or principle when the learner’s response was correct. For facts, when a concept name was matched correctly with its corresponding graphical part, animation highlighted that graphical part. For concepts, when a concept attribute was matched correctly with its corresponding concept name, animation demonstrated that attribute of the concept. For rules and principles, when an
“If…” statement was matched correctly with its corresponding “then…” statement, animation illustrated the cause-and-effect or correlational relationships between the “If…” and “then…” statements.

It was expected that adding animation-elaborated feedback to KOR text feedback would facilitate learning. More recent learning theories emphasize the information that feedback provides to learners (Kulhavy & Wager, 1993; Rieber, 1996). Cognitive learning theories suggest learning is determined by how meaningful the feedback is to the learners (Rieber, 1996). The KOR text feedback in this study only provided “Correct” or “Wrong” feedback to the learner’s response, it did not provide any additional information to the learner, such as why his or her response was correct. Animation-elaborated feedback, when provided simultaneously with the KOR text feedback when the learner’s response was correct, provided the learner additional information by highlighting the corresponding graphical parts of the concepts, demonstrating the concept attributes of the corresponding concepts, or illustrating the cause-and-effect or correlational relationships between the “If…” and “then…” statements. It not only explained to the learner why his or her choice was correct, but also provided strong visual reinforcement to the correct answer. It was expected to be more meaningful to the learners since it added details to the information being learned. According to E. D. Gagné (1985), the process of adding to the information being learned is called elaboration. She further stated that elaboration facilitates retrieval by providing alternative pathways and extra information to generate answers (E. D. Gagné, 1985). In addition, Lin (2001) suggested that animation, because of its unique dynamic qualities, is more likely to be dually coded “deeper” and “harder” into the long-term memory (p. 20). Therefore, animation-elaborated feedback should
better facilitate the encoding and retrieval processes by providing dynamic visual elaborations.

**Definition of Terms**

**Feedback**

Feedback is “… the event that provides the learner with the confirmation (or verification) that learning has accomplished its purpose.” It is provided to learners “… by observations of the effects of the learner’s own performance” (R. M. Gagné, 1985. p. 75).

**Knowledge of Response (KOR) Feedback**

A form of feedback that simply informs the learner whether a response is correct or wrong (Dempsey, Driscoll, & Swindell, 1993).

**Animation**

Animations are “… artificially generated movements of pictures or graphics in computer displays, resulting in apparent motion” (Park & Gittelman, 1992, p. 27).

**Animation-Elaborated Feedback**

An instructional strategy in which animation is used to provide informational feedback by demonstrating or elaborating a lesson fact, concept, rule or principle when the learner’s response is correct:
• For facts: when a concept name is matched correctly with its corresponding graphical part, animation highlights that graphical part.
• For concepts: when a concept attribute is matched correctly with its corresponding concept name, animation demonstrates that attribute of the concept.
• For rules and principles: when an “If…” statement is matched correctly with its corresponding “then…” statement, animation illustrates the cause-and-effect or correlational relationships between the “If…” and “then…” statements.

**Direct Manipulation Interfaces**

Direct manipulation interfaces refer to systems having the following properties:

1. Continuous representation of the object of interest.
2. Physical actions or labeled button presses instead of complex syntax.
3. Rapid incremental reversible operations whose impact on the object of interest is immediately visible. (Shneiderman, 1982, p. 251)

**Direct Manipulation Strategy**

An instructional strategy in which the learner is asked to directly manipulate (e.g., clicks, drags, and drops) screen objects in order to facilitate learning.
Direct Manipulation Questioning Strategy

An instructional strategy in which the learner is required to answer questions by directly manipulating (e.g., clicks, drags, and drops) screen objects.

Direct Manipulation Matching Questions

An instructional questioning strategy in which the learner is required to correctly identify and match the relationships between the matching items by dragging either concept names, concept attributes, or the “If…” statements and dropping them into the corresponding placeholders on a visual frame of the whole heart containing an outline of the primary parts.

- For facts: the learner is required to correctly identify and match the concept names with their corresponding graphical parts by dragging the concept names and dropping them into the placeholders pointing to their corresponding graphical parts.
- For concepts: the learner is required to correctly identify and match the concept attributes with their corresponding concept names by dragging the concept attributes and dropping them into the placeholders under their corresponding concept names.
- For rules and principles: the learner is required to correctly identify and match the “If…” statements with their corresponding “then…” statements by dragging the “If…” statements and drop them into the placeholders above their corresponding “then…” statements.
Traditional Matching Questions

An instructional strategy in which the learner is required to correctly identify and match the relationships between the matching items by clicking on the corresponding radio buttons.

- For facts: the learner is required to correctly identify and match the concept names with their corresponding graphical parts by clicking on the correct radio button under each concept name.
- For concepts: the learner is required to correctly identify and match the concept attributes with their corresponding concept names by clicking on the correct radio button under each concept attribute.
- For rules and principles: the learner is required to correctly identify and match the “If…” statements with their corresponding “then…” statements by clicking on the correct radio button under each “If…” statement.

Three levels of learning

Attainment of factual, conceptual, and rules and principles knowledge.

Facts, Concepts, and Rules and Principles

- Facts: “…arbitrarily associated pieces of information.”
- Concepts: “…groups of objects, events, or symbols that all share some common characteristics and that are identified by the same name.”
- Rules and principles: “…those cause-and-effect or correlational relationships that are used to interpret events or circumstances.” (Merrill, 1983, p. 287-288)
Information processing is supported by many cognitive theories. It is concerned with how people perceive, encode, and retrieve information. Many early information processing theories (e.g., Atkinson & Shiffrin, 1968; Gagné & Driscoll, 1988; Klatzky, 1980) described the human brain as being similar to a computer, and human learning as being similar to how computers process information. There are three main storage structures in the memory system: sensory register, which registers stimuli in the memory system; short-term memory (STM), which serves as temporary storage; and long-term memory (LTM), where information is permanently stored. Learning occurs when information is input from the environment, and then encoded and transferred from STM to LTM. Therefore, it is important to design instructional strategies which can facilitate the encoding and retrieval processes. Figure 1 presents a basic model of learning and memory which represents the stages of information processing.
Klatzky (1980) indicated information enters the memory system by one or more of the five senses, i.e., sight, hearing, smell, touch, and taste. Each sense has a corresponding sensory register, such as visual register, auditory register, taste register, and so on. Gagné and Driscoll (1988), however, argued that information from the environment is first received by five different types of receptors and then is perceived by the sensory register. Incoming sensory information is retained in the sensory register for a very brief period of time, and then decays and is lost (Atkinson & Shiffrin, 1968; Klatzky, 1980). Only a portion of the information will be attended to and transferred into
STM. Klatzky (1980) suggested that the information is selected through a process called “pattern recognition” (also called “selective perception” by Gagné and Driscoll, 1988) which results in contact between the information in the sensory register and the previous knowledge stored in LTM. The purpose of “pattern recognition” is to convert raw information into something meaningful.

Short-Term Memory

It is also called “short-term store” or “working memory” (Atkinson & Shiffrin, 1968). Compared to sensory register which stores information in a raw, sensory form, STM stores information in a more meaningful way (Klatzky, 1980). Atkinson and Shiffrin (1968) suggested STM receives selected information from both the sensory register and long-term memory. When new information is related to previous knowledge, the previous knowledge will be retrieved back to STM where it will interact with the new information (Gagné & Driscoll, 1988).

Information retained in STM is not only limited but also temporary in duration. Short-term memory can only hold five to nine chunks of information before it is processed in LTM (Miller, 1956). Atkinson and Shiffrin (1968) suggested although information is retained longer in STM than in sensory register, it decays and is lost within as short as 30 seconds. However, the information can be retained and preserved in the STM for longer periods through some control processes such as rehearsal. Rehearsal was defined by Klatzky (1980) as “… the cycling of information through the memory store” (p. 112). He suggested rehearsal can maintain a limited amount of information in STM
Indefinitely. Atkinson and Shiffrin (1968) argued rehearsal helps strengthen the information in LTM by increasing the length of stay in STM and allowing enough time for the coding and other storage processes to operate.

Coding process was defined as “… a select alteration and/or addition to the information in the short-term store as a result of a search of the long-term store” (Atkinson & Shiffrin, 1968, p. 115). They indicated other short-term processes include grouping, organizing, and chunking. One kind of organizing strategy is the grouping of items into small sets with the purpose of memorizing the set as a whole. Chunking strategy was proposed by Miller (1956) who indicates incoming information should be organized into meaningful unit of the desired size in order to best facilitate remembering. A chunk could be words, digits, chess positions, or people’s faces.

Klatzky (1980) categorized rehearsal into maintenance rehearsal which retains the information in STM and elaborative rehearsal (rehearsal encoding) which requires learner to think about the items, interpret them, and relate them to other information in LTM. The latter actually encompasses all the coding, grouping, organizing, and chunking processes referred to by Atkinson and Shiffrin (1968). Klatzky (1980) defines encoding process as “… people act on information to elaborate it and relate it to previous knowledge and the circumstances of its occurrence” (p. 273). Rehearsal encoding proves to be very effective at enhancing the retrieval of information from LTM later. He pointed out that the term organization is underneath all of the encoding processes. Organization was defined as “… the formation of superordinate units from collections of input items” (p. 229). Organization facilitates the encoding process because of the less demand of the storage space when information is organized into units. Hannafin and Rieber (1989) defined
organization as “… the intentional shaping of information into meaningful parts.” They suggested organization facilitates encoding and retrieval processes by providing additional pathways to information. Gagné and Driscoll (1988) concurred with this idea and suggested when information are grouped in certain ways, or classified under previously learned concepts, or are simplified in expressions as principles, greater recall will occur. Driscoll (2005) pointed out that imagery can also facilitate encoding process.

**Long-Term Memory**

Long-term memory is also called “long-term store” (Atkinson & Shiffrin, 1968), which is a fairly permanent unlimited storage for information transferred from STM. The information stored in LTM was critical in the “pattern recognition” process in sensory register since the information is recognized by matching with the previous information in LTM. Klatzky (1980) suggested the better incoming information is meaningfully related to existing prior knowledge in LTM, the more likely it is remembered.

Klatzky (1980) also suggested that LTM is highly organized by knowledge structures and retrieval is not a random, undirected process. Retrieval was defined as “… an active process in which previously encoded information is accessed in a search of memory and evaluated with respect to the retrieval context” (p. 273). Successful retrieval is dependent on both the quality of encoding into LTM and retrieval strategies (Hannafin & Rieber, 1989). Klatzky (1980) considered organization as a process that facilitates both encoding and retrieval. He maintained that retrieval from LTM is facilitated when information is stored as organized units.
Although information is supposed to be permanently stored in LTM, not all the information stored in the LTM can be retrieved. Gagné and Driscoll (1988) stated most theories assume that the failures to retrieve information from LTM are because of the difficulties in locating the information within LTM. Hannafin and Rieber (1989) pointed out failures to retrieve encoded information are attributed to ineffective retrieval strategies rather than simple forgetting. One example could be lack of appropriate cues (Driscoll, 2005; Gagné & Driscoll, 1988). Gagné and Driscoll (1988) suggested the external cues may affect the retrieval process. The external cues may take various forms, such as verbal communications or reminding learners of their previous encoding. Retrieval cues proved to be most effective when they are introduced when learning first occurs. Driscoll (2005) and Klatzky (1980) concurred with them and suggested that retrieval is more likely to happen when appropriate cues are provided in the encoding process, the cues used to facilitate encoding will also serve as the best retrieval cues.

**Instructional Implications of Information Processing Theory**

Information processing theory proposes an explanation of how information is selected, perceived, processed, and retrieved. This process is greatly influenced by the individual factors, such as prior knowledge, expectancies, and presentation factors, such as use of cues, organization of information (Hannafin & Rieber, 1989).

Driscoll (2005) provided four general recommendations for instructional strategies based on the information processing theory. (1) Provide organized instruction. She suggested “… people will try to impose some meaningful structure or organization
on any new information in order to make sense of it” (p. 104), therefore, organized instructions could be provided to help them do this. She pointed out graphic representations are especially effective in enhancing encoding and retrieval. (2) Arrange extensive and variable practice. She suggested variable practice helps learners to attach multiple cues to what they are learning, therefore, they are more likely to recall it later on. (3) Enhance learners’ encoding and memory. She suggested strategies for enhancing encoding and memory include: dual coding information, use of imagery, chunking information, etc. (4) Enhance learners’ self-control of information processing by improving their metacognitive skills.

Various practice strategies have been designed to enhance encoding and retrieval during CBI. For example, embedded questions and feedback (Wager & Wager, 1985) can be used to obtain high levels of association with prior knowledge, and therefore improve the encoding process (Hannafin & Rieber, 1989).

Information Processing Theory and the Current Study

R. M. Gagné (1985) identified nine processes of information processing and relates external instructional events to each process. Using his model of information processing as a framework, Wager and Mory (1993) analyzed the different roles that questions and feedback may serve in learning at each stages of information processing. Questions and feedback provided in this study mainly were expected to serve the functions identified in three stages of information processing in their analysis.
In stage 4, rehearsal to maintain information in STM, questions are used as a rehearsal strategy that maintains information in STM, enables encoding of newly learned material to LTM, and makes information in LTM more accessible (Kuman, 1971). Questions at this stage can help maintain and renew information stored in STM. In addition, they can also help learners organize information into manageable chunks, i.e., meaningful units (Miller, 1956) or propositions (Wager & Mory, 1993). Compared to traditional matching questions, direct manipulation matching questions were expected to better help the learners organize information into meaning units by requiring them to overtly (1) create associations between concept names and their corresponding graphic parts, (2) create associations between concept attributes with their corresponding concept names, and (3) establish connections between the “If…” and “then…” statements for rules and principles. Therefore, direct manipulation matching question was supposed to be a better rehearsal strategy. Feedback in this stage serves to confirm the rehearsal strategies and provide reinforcement to the learners’ responses (Wager & Mory, 1993). Compared to KOR text feedback alone, KOR text plus animation-elaborated feedback was expected to provide a stronger reinforcement by providing extra dynamic visual information that demonstrates or elaborates a lesson fact, concept, rule or principle.

In stage 5, semantic encoding for storage in LTM, questions are used to help learners integrate new knowledge into existing cognitive structures (Wager & Mory, 1993). Direct manipulation matching questions should better facilitate and strengthen rapid encoding by creating a learner-manipulated interface for the learners to directly relate new information to existing knowledge structure, and therefore, build stronger semantic memory for facts, concepts, and rules and principles. Feedback in this stage
validates the integration of new information with existing knowledge, serves as a learning
guidance by demonstrating the processes, and provides elaboration (Wager & Mory, 1993). Compared to KOR text feedback only, KOR text plus animation-elaborated feedback strategy provided additional information of the facts, concepts, and rules and principles by highlighting the corresponding graphical parts of the concepts, demonstrating the attributes of the corresponding concepts, and illustrating the cause-and-effect or correlational relationships between the “If…” and “then…” statements, and therefore, was expected to better facilitate semantic encoding of facts, concepts, rules and principles.

In stage 6, retrieval from LTM to STM, questions are used to activate response organization by providing retrieval cues (Wager & Mory, 1993). As mentioned above, Klatzky (1980) maintained that retrieval from LTM is facilitated when information is stored as organized units. Because direct manipulation matching questions were supposed to better help the learners organize and encode information as facts, concepts, or rules and principles, therefore, it should activate response organization more easily than traditional matching questions, and as a result, better facilitate the retrieval process. The cues provided by direct manipulation matching questions could also serve as the best retrieval cues. Feedback in this process remediates misunderstanding (Wager & Mory, 1993). Compared to KOR text feedback, KOR text plus animation-elaborated feedback strategy was expected to provide a stronger reinforcement to the correct answers by adding extra dynamic visual information.
Table 1 provides a summary of the expected roles of direct manipulation matching questions and animation-elaborated feedback during the three stages of information processing.

Table 1

*Expected Roles of Direct Manipulation Matching Questions and Animation-Elaborated Feedback in the Three Stages of Information Processing*

<table>
<thead>
<tr>
<th>Stages of Information Processing</th>
<th>Expected Roles of Direct Manipulation Matching Questions</th>
<th>Expected Roles of Animation-Elaborated Feedback</th>
</tr>
</thead>
</table>
| Rehearsal to maintain information in STM | • Provides practice on previous learned information  
• Helps learners organize, group, and chunk information into meaningful units | • Provides dynamic visual reinforcement to the learner’s response |
| Semantic encoding for storage in LTM | • Facilitates and strengthens rapid encoding  
• Helps learners integrate new knowledge into existing cognitive structure | • Validates the integration  
• Provides elaborations of facts, concepts, and rules and principles |
| Retrieval from LTM to STM | • Facilitates retrieval  
• Activates response organization  
• Tests for understanding or misunderstanding | • Provides dynamic visual reinforcement to the learner’s response |

**Levels of Processing Theory**

An alternative to the information processing theory is the levels of processing theory proposed by Craik and Lockhart (1972). According to this theory of memory, people process incoming information at a successive series or hierarchy of processing levels (stages) simultaneously based on its characteristics. The series or hierarchy of
processing stages is often called as “depth of processing” where “depth” refers to the
degree of semantic or cognitive analysis. Preliminary stages (shallow processing) are
concerned with processing the information only at its physical or sensory features such as
lines, angles, brightness, pitch, and loudness; while later stages (deeper processing) are
concerned with pattern recognition and analyzing the meaning of the information where
information is first recognized and then further processed by enrichment or elaboration.
Therefore, depth of processing varies along a continuum from a series of sensory stages,
to levels related to matching and pattern recognition, and finally to semantic-associative
stages where information is enriched and elaborated, each at a deeper level than the
previous one. Various factors will determine the depth of processing, such as the amount
of attention to the information, its compatibility with the analyzing structures, and the
available processing time.

One result of the perceptual processing is the memory trace. Both the trace
persistence and retention are functions of depth or processing. The more deeply the
information is processed, the stronger, more elaborate and durable the memory traces are,
the more likely it will be remembered and recalled.

Craik and Lockhart (1986) suggested that deeper levels of processing enhance
recall because of two factors: distinctiveness which suggests a stimulus is different from
other memory trace, and elaboration which involves deeper processing of the meaning of
the information. Distinctiveness helps recall by reducing interference. Deeply processed
information becomes more distinctively represented in memory. Elaboration analyzes and
interprets incoming information and associates it with existing knowledge. Therefore it
creates more potential retrieval pathways.
Levels of Processing Theory and the Current Study

Table 2 explains how direct manipulation questioning strategy and animation-elaborated feedback strategy could facilitate deeper levels of processing.

Table 2
Expected Roles of Direct Manipulation Matching Questions and Animation-Elaborated Feedback in Facilitating Deeper Levels of Information Processing

<table>
<thead>
<tr>
<th>Levels of Processing</th>
<th>Expected Roles of Direct Manipulation Matching Questions and Animation-Elaborated Feedback</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shallow</td>
<td>Direct manipulation matching questions facilitate deeper levels of processing by:</td>
</tr>
<tr>
<td></td>
<td>• facilitating different levels of learning from low to high: from facts, to concepts, to rules and principles</td>
</tr>
<tr>
<td></td>
<td>• building higher levels of learning based on lower levels of learning</td>
</tr>
<tr>
<td></td>
<td>• matching cognitive processing requirements for factual, conceptual, and rules and principles learning by requiring learners to:</td>
</tr>
<tr>
<td></td>
<td>▪ associate concept names with their corresponding graphical parts</td>
</tr>
<tr>
<td></td>
<td>▪ associate concept attributes with their corresponding concept names</td>
</tr>
<tr>
<td></td>
<td>▪ establish connections between the “If…” and “then…” statements</td>
</tr>
<tr>
<td></td>
<td>• helping learners associate new information with existing knowledge</td>
</tr>
<tr>
<td>Deeper</td>
<td>Animation-elaborated feedback facilitates deeper levels of processing by elaborating lesson facts, concepts, and rules and principles:</td>
</tr>
<tr>
<td>Semantic-associative stage</td>
<td>• For facts: highlights the corresponding graphic parts of the concepts</td>
</tr>
<tr>
<td></td>
<td>• For concepts: demonstrates the attributes of the corresponding concepts</td>
</tr>
<tr>
<td></td>
<td>• For rules and principles: illustrates the cause-and-effect or correlational relationships between the “If…” and “then…” statements</td>
</tr>
</tbody>
</table>

Sensory stage

Matching and pattern recognition stage
Dual Coding Theory

Paivio’s (1971; 1986) dual coding theory further explained two separate information processing subsystems in human cognition: a visual system (also called imagery system by Paivio) which processes nonverbal objects and events (visual knowledge) and a verbal system which processes language (verbal knowledge). The two subsystems are structurally and functionally independent yet interconnected for encoding, storage, organization, and retrieval of information. Structurally, they are different from each other in the nature of representational units and the way the units are organized into higher order structures. Functionally, they are independent because they can operate without or in parallel to each other. At the same time, they are functionally interconnected because activities in one system can affect activities in the other.

Dual coding theory also identified three distinctive levels of processing within and between the verbal and visual system: (1) representational, (2) associative, and (3) referential (Paivio, 1986). Representational processing connects the incoming stimuli from the environment to either the verbal or visual system. Associative processing constructs connections within either of the verbal or visual systems, and referential processing builds connections between the verbal and visual systems (Paivio, 1986; Rieber, 1996). Figure 2 presents a schematic depiction of the structure of imagery and nonverbal systems.
Referential processing is especially important to this study because dual coding theory predicts that learning will be enhanced when information is coded both visually and verbally, i.e., dually coded. The chances of retrieval are doubled when information is dually coded because learners have two ways to retrieve the information. Pictures are superior to words in recall because pictures are more likely to be dually coded. Therefore, the chances of retrieval for pictures are doubled (Kobayashi, 1986; Paivio, 1991; Paivio & Caspo, 1973; Rieber, 1996; Rieber, Tzeng, Tribble, & Chu, 1996). Animation, because of its unique dynamic qualities, is more likely to be dually coded “deeper” and “harder”

Figure 2. Schematic depiction of the structure of verbal and nonverbal symbolic system, showing the representational units and their referential (between system) and associative (within system) interconnections as well as connection to input and output systems. Source: from Paivio, A. (1986), Mental representations: A dual coding approach, p. 67. New York: Oxford University Press.
into the long-term memory than static graphics. Therefore, animation should better facilitate the encoding and retrieval processes than static graphics (Lin, 2001, p. 20).

Rieber (1996) suggested that dual coding theory can guide the research with computer-based multimedia learning environments. It is assumed that interactive multimedia will promote different levels of processing depending on the type of presentation used and the instructional purpose. The type of presentation used includes text, graphic, animation, sound, etc. The purpose varies from establishing the scenario, providing feedback between the user’s actions and the effects on the model, to using instructional message to help clarify the relationships of the simulation.

**Dual Coding Theory and the Current Study**

Table 3 summarizes the expected roles of direct manipulation matching questions and animation-elaborated feedback in the three levels of processing.
Generative Learning

Wittrock (1974a; 1974b) proposed generative learning theory. He considered generative learning as a cognitive model of human learning with understanding which integrates research in cognitive development, human learning, human abilities, information processing, and aptitude-treatment interactions. Generative learning is concerned with how learners process information and actively construct meaning from it. It is based on a fundamental assumption that people are more likely to generate perceptions and meanings which are consistent with their prior knowledge. It predicts that learning occurs when learners generate semantic, distinctive, and concrete associations between incoming information and their prior knowledge, which is stored in

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**Table 3**

*Expected Roles of Direct Manipulation Matching Questions and Animation-Elaborated Feedback in Three Levels of Processing*

<table>
<thead>
<tr>
<th>Three Levels of Processing</th>
<th>Expected Roles of Direct Manipulation Matching Questions</th>
<th>Expected Roles of Animation-Elaborated Feedback</th>
</tr>
</thead>
<tbody>
<tr>
<td>Representational processing</td>
<td>Adds an extra form of stimulus to the sensory register — touch</td>
<td>Adds a strong stimulus to the visual register using dynamic visual movement.</td>
</tr>
</tbody>
</table>
| Associative Processing | Requires learners to:  
  - associate concept attributes with corresponding concept names  
  - establish connections between the “If…” and “then…” statements for rules and principles | Elaborates lesson facts, concepts, and rules and principles using animation in combination with the static graphic (outline of the heart). |
| Referential Processing | Makes more direct and obvious connections between text and corresponding static graphics or animations | |
LTM. Therefore, “… learning with understanding is a generative process …” (Wittrock, 1974a, p. 182)

Wittrock and Carter (1975) argued that compared to information processing theory and levels of processing theory, generative learning theory focuses on the psychological variables such as learner’s prior experience, prior learning, and concrete, distinctive associations. Grabowski (2003) maintained that it is the process of generation that distinguishes the generative learning theory from other theories and models of learning.

Wittrock (1985; 1990; 1991; 1992) suggested generative learning is a process of building two types of relationships: (1) relationships that are among the various components of the new incoming information; and (2) relationships that are between the new information and one’s prior knowledge, belief and experience. These two types of relationships were also called by Grabowski (2003) as organizational relationships and integrated relationships.

In generative learning theory, learner is not viewed as a passive recipient of information, but rather seen as an active participant in the learning process who constructs meanings from information in the environment (Grabowski, 2003). Wittrock (1978) suggested “… learners are active, responsible and accountable for their role in generative learning” (p. 15). He later described in detail the role of the learner in generative learning:

… a learner must be “(a) active at generating these relationships; (b) motivated or responsible, in part at least, for exerting the effort required to construct them; (c) attentive to the underlying structure of the information to be learned; and (d)
aware of and making use of the learning strategies and metacognitive processes that will facilitate generating these relationships.” (Wittrock, 1985, p. 124)

Wittrock (1990; 1991) identified four components of generative learning theory: generation, motivation, attention, and memory (students’ knowledge base and preconceptions). Grabowski (2003) presented her understanding of the four components and defined them as processes of generation, motivation, learning, and knowledge creation. These four components attempt to explain learning process through external and internal learning conditions. Wittrock (1990) described generation as a process when “people retrieve information from long-term memory and use their information-processing strategies to generate meaning from the incoming information, to organize it, to code it, and to store it in long-term memory” (p. 349). In a word, generation is a process of relating new information to existing knowledge and experience. In generative learning, learners should be mentally active, should take control and responsibility for constructing relationships and generate meaning. Teaching should direct learner’s voluntary sustained attention to construct meaningful relationships between instruction and learner’s prior knowledge and experience. Teachers also need to understand students’ perceptions of their roles in the learning process. Teaching is a process that leads students to become an active learners and responsible for constructing meaning by building two types of relationships.

Wittrock (1974a; 1991) suggested that instruction that causes learners to generate relationships facilitates long-term recall and understanding. Therefore, it is important to know how and when to facilitate learners’ construction of relations (Wittrock, 1990).
Wittrock and Carter (1975) suggested that when learners’ prior experience provides the context for constructing both distinctive and semantic associations, the greatest recall will occur. They conducted an experimental study to test students’ free recall of a conceptually unrelated hierarchy of words, a randomly arranged, or a properly arranged conceptual hierarchy, with instructions to process the hierarchy generatively or reproductively. Significant differences were found with types of hierarchy as well as types of instructions. The greatest gain in recall occurred for the randomly arranged hierarchy with generative instructions. The results indicated encoding is a “…constructive, semantic and distinctive process” (p. 499). Wittrock (1974a) concluded that generative processing is more effective when the organization was not made explicit to the learners but was in the learners’ repertoires.

Grabowski (2003) pointed out generative learning focuses on selecting appropriate, learner-centered instructional activities for the learner. Based on the two types of learner-generated relationships identified in generative learning theory, she identified two types of generative learning activities which facilitate these two relationships: (1) activities that generate organizational and reorganizational relationships between and among different parts of the external information, and (2) activities that generate integrated relationships between the external information and the learner’s prior knowledge. She pointed out an activity must involve the actual creation of relationships and meaning in order to be classified as generative. Organizational activities include titles, headings, questions, objectives, summaries, graphs, tables, and main ideas. Integrative activities include demonstrations, metaphors, analogies, examples, pictures, applications, interpretations, paraphrases, and inferences (Wittrock, 1990). Grabowski
(2003) added concept maps, diagrams, outlines, and identifying scripts within narratives to the first list, and mnemonics, clarifying, and predicting to the second list, and notetaking, diagrams, and concept maps to both lists. She further categorized these generative learning activities according to different level of mental processing required for each activity.

**Generative Learning Theory and the Current Study**

Table 4 explains how direct manipulation matching questions and animation-elaborated feedback could facilitate building the two types of relationships referred to in generative learning.
### Table 4

*Expected Roles of Direct Manipulation Matching Questions and Animation-Elaborated Feedback in Facilitating Building the Two Types of Relationships in Generative Learning*

<table>
<thead>
<tr>
<th>Two Types of Relationship</th>
<th>Levels of Cognitive Processing</th>
<th>Expected Roles of Direct Manipulation Matching Questions</th>
<th>Expected Roles of Animation-Elaborated Feedback</th>
</tr>
</thead>
<tbody>
<tr>
<td>Organizational Relationship Coding</td>
<td>Requires learners to overtly manipulate screen objects to: • associate concept names with their corresponding graphical parts</td>
<td>Highlights the corresponding graphic parts of the concepts</td>
<td></td>
</tr>
<tr>
<td>Organization</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Conceptualization</td>
<td></td>
<td>• associate concept attributes with their corresponding concept names</td>
<td>Demonstrates the attributes of the corresponding concepts</td>
</tr>
<tr>
<td></td>
<td>• establish connections between the “If…” and “then…” statements for rules and principles</td>
<td>Illustrates cause-and-effect or correlational relationships between the “If…” and “then…” statements</td>
<td></td>
</tr>
<tr>
<td>Integrated Relationship Integration</td>
<td>Requires learners to: • build higher levels of learning based on lower levels of learning • integrate new information into existing information • create meanings of information</td>
<td>Uses animation to reinforce the learner’s response</td>
<td></td>
</tr>
</tbody>
</table>

Direct Manipulation Strategy

Haag (1995) defined manipulation as “overt movement of a concrete or computer-generated object, or the covert maneuvering of imaginal objects in the mind” (p. 8). She categorized manipulation into concrete manipulation, which is the overt physical movement of an object; imagery manipulation, which is the covert maneuvering of an imaginal object in the mind; computer-mediated manipulation, which is the indirect manipulation of visual elements through interface devices such as the mouse or built-in program elements such as buttons; and direct manipulation, which allows learners to directly control the movement and placement of objects on the screen, rather than indirectly interact with the computer or programming elements. It is the same direct manipulation strategy examined in this study.

In the direct manipulation interface, learners use a pointing device such as a mouse to manipulate spatially organized objects on the screen (Whiteside, Wixon, & Jones, 1988). The advantages of direct manipulation interface are obvious. Hutchins et al. (1985) suggested direct manipulation interfaces make learners feel directly engaged with the controlled objects, not with the programs or computers. Haag (1995) explained that “direct manipulation provides the learner with control over the movement and placement of graphical elements using the mouse…. This type of capability of the computer allows for interaction with visuals in an innovative manner” (p. 25). Shneiderman (1982) suggested the following advantages of direct manipulation systems:

1. Novices can learn basic functionality quickly, usually through a demonstration by a more experienced user.
2. Experts can work extremely rapidly to carry out a wide range of tasks, even defining new functions and features.

3. Knowledgeable intermittent users can retain operational concepts.

4. Error messages are rarely needed.

5. Users can see immediately if their actions are furthering their goals, and if not, they can simply change the direction of their activity.

6. Users have reduced anxiety because the system is comprehensible and because actions are so easily reversible. (p. 251)

Despite the advantages of direct manipulation strategy, little research has been conducted to investigate its instructional effectiveness on learning.

Grabowski (2003) suggested that manipulation of objects can be considered as a generative activity because it creates and extends a relationship between the parts of the environment. Haag and Grabowski (1994) investigated the effects of manipulation strategy and found learners in the visual summary with manipulation group performed better than those in learner manipulation or those in the computer manipulation groups in the problem solving test.

Haag (1995) conducted an experimental study and examined the effects of generative and non-generative visual manipulation strategies in CBI. Four treatment groups include: visual summary with manipulation, learner manipulation, computer manipulation, and a control group. She found no main effects for manipulation strategies. The control groups, however, showed highest mean scores.

The above few studies support the use of manipulation strategies to a certain extent. However, none of them examined the instructional effects of direct manipulation
questioning strategy compared to the traditional questioning strategies, such as traditional matching questions. Although the direct manipulation strategy used in Haag’s studies (Haag, 1995; Haag & Grabowski, 1994) is similar to the direct manipulation questioning strategy referred to in this study in terms of direct learner manipulation and using manipulation as a practice strategy, the screen objects that the learners manipulated were different. Haag’s direct manipulation strategy required the learners to manipulate visual screen elements, while this study required the learners to manipulate verbal elements. In addition, Haag’s studies did not consider direct manipulation as a questioning strategy and did not compare direct manipulation questioning strategy with traditional questioning strategy.

Wager and Wager (1985) suggested three general functions that questions serve in learning: (1) to establish and maintain attention, (2) to facilitate encoding, and (3) to provide for rehearsal. It is suggested that the direct manipulation strategy can be used as a questioning strategy to serve one or more of these three functions.

In this study, different types of direct manipulation matching questions were designed to facilitate different levels of learning: for factual learning, the learners were required to correctly identify and match the concept names with their corresponding graphical parts by dragging the concept names and dropping them into the placeholders pointing to their corresponding graphical parts; for conceptual learning, the learners were required to correctly identify and match the concept attributes with their corresponding concept names by dragging the concept attributes and dropping them into the placeholders under their corresponding concept names; for rules and principles learning, the learners were required to correctly identify and match the “If…” statements with their
corresponding “then…” statements by dragging the “If…” statements and drop them into the placeholders above their corresponding “then…” statements.

Animation and Instruction

Previous Animation Studies

The previous research on animations in Computer-Based Instruction (CBI) has showed somewhat mixed results. Rieber (1990) reviewed 13 empirical studies investigating the effects of animation in CBI and found only 5 of them showed significant effects for the animated treatments, while 8 showed insignificant differences. He pointed out that the reason for the mixed results could be “… rooted in general procedural flaws such as poor conceptualization of the research problem or inappropriate implementation of methods” (p. 84). Park and Hopkins (1993) summarized 25 studies investigating the effects of dynamic versus static visual displays. Fourteen of the studies found significant effects for dynamic visual displays. They further suggested the reasons for the inconsistent results “… seem to be related to the different theoretical rationales and methodological approaches used in various studies…” (p. 427).

More recently, Anglin et al. (2003) summarized the results from 42 studies ranging from 1949 to 2000 which included at least one animation treatment and identified significant animation effects in 21 of a total of 45 comparisons. These studies used various animated visual content and covered a wide variety of general content areas. Subjects in these studies range from children to adults. A wide variety of tests were used
to evaluate different learning outcomes. Although the “box score” results indicated that
the use of animated graphics does not facilitate learning, they concurred with Rieber
(1990) and Park and Hopkins (1993) and suggested that methodological issues need to be
considered. Many studies either did not provide a rationale for using animation or did not
indicate that animation was relevant or congruent with the text information presented.

In addition, there are some other experimental studies that were conducted since
2000 which included at least one animation treatment. Some of the studies reported
significant effects for an animation treatment under certain circumstances (Blankenship
& Dansereau, 2000; Catrambone & Seay, 2002), while others reported insignificant
effects for animation treatment (Chanlin, 2001a, 2001b; Koroghlanian & Klein, 2000;
Lowe, 2003). Chanlin (2001b) even reported for novice students, the use of static
graphics was better than animation in procedural learning.

Special attention needs to be given to recent animation studies that used the same
instructional content as this study. Wilson (1998) tested four treatment groups: still
graphics, progressive reveal, animation, and animation and progressive reveal. Haag’s
(1995) study included: a control group, visual summary with manipulation, learner-
manipulation, and computer manipulation group. Lin (2001) used additional instructional
strategies in combination with animation to study the following treatment groups: static
visuals, animated only, animation with advance organizers, and animation with adjunct
questions and feedback. Owens (2002) used three treatment groups: animation, animation
and attention-directing strategies, and animation and visual-elaborating strategies. Zhu
and Grabowski (2006) compared three treatment groups: static graphic, animation used as
an attention-gaining strategy, and animation used as an attention-gaining and elaboration
strategy. The results of these studies showed insignificant differences in student achievement among the treatment groups.

In sum, previous animation research showed mixed results while animation research using the same instructional content as this study suggested insignificant differences for treatments incorporating animation strategies. As suggested above, the reason for the mixed results could be rooted in the methodological issues. However, if the previous animation studies followed correct procedures and utilized sound methodologies, it could be true that animation is significantly effective under certain circumstances. Further research needs to be done to investigate under what circumstances is animation more effective than other instructional strategies as well as under what circumstances is animation equally effective to other instructional strategies.

**Animation-Elaborated Feedback Strategy**

As mentioned above, based on its attributes, animation has been used as an instructional strategy to enhance instruction in one of the three functions: attention-gaining, presentation, and practice (Rieber, 1990). This research study intends to add to the literature by examining the effectiveness of animation-elaborated feedback as a part of the practice strategy.

Feedback is considered as a reinforcer and motivator by behaviorists. More recent learning theories emphasize the information that feedback provides to learners (Kulhavy & Wager, 1993; Rieber, 1996). Cognitive learning theories suggest learning is not determined by the amount of surface interactivity. It is, instead, a function of how
meaningful the feedback is to the learners (Rieber, 1996). Many learning theorists consider informative feedback essential to the reinforcement process (Gagné & Driscoll, 1988). Kulhavy and Wagner (1993) also indicated that feedback has been considered very important to help learners reconstruct their knowledge and support their metacognitive processes. In term of timing of the feedback, Hannafin and Rieber (1989) indicated that immediate feedback, an important characteristic in programmed instruction, is usually provided during CBI interaction. Calariana, Wagner, and Murphy (2000) suggested immediate feedback is slightly better than delayed feedback with more difficult lesson items.

The advancement of multimedia tools allows instructions to integrate a wide variety of verbal and visual information for both presentation and feedback (Rieber, 1995). Rieber (1990) claimed that animation is a powerful way to create a wide variety of practice strategies which has broadened the nature of the interaction between the student and an instructional task significantly. He pointed out that when used in the most structured practice activities, animations were used as feedback to student answers providing reinforcement to correct answers. On the other end, animation can be used in highly interactive programs in which animated graphics change continuously over time based on student input (e.g., diSessa, 1982; Lamb, 1982; Papert, 1980; White, 1984).

A series of research studies have been conducted by Rieber and his colleagues (Rieber, 1996; Rieber et al., 1996) to examine the specific role of real-time graphic feedback and how learners select, process, and interpret real-time feedback provided by animation. He conducted two experimental studies to investigate the effects of animation as feedback strategies in a computer-based simulation (Rieber, 1996). In these two
studies, participants interacted with the computer simulation which modeled the relationship between acceleration and velocity. Participants had control over the acceleration of a ball. Three forms of feedback about the ball’s speed, direction, and position were presented: graphical feedback, textual feedback, and graphical plus textual feedback. He found that participants learned more tacit knowledge when given animated graphical feedback. However, the feedback forms were equally effective for students to learn explicit knowledge. He suggested meaningful representational and associative processing were more likely to be activated exclusively for the visual system when subjects were given graphical versus textual feedback. However, graphical feedback did not facilitate referential processing which is required to improve performance. The reason for that may be because the highly interactive nature of the discovery-based simulation may have interfered with referential processing (Rieber et al., 1996).

Another study (Rieber et al., 1996) supplemented the forms of feedback with embedded elaborations of the content. Results showed significant differences for the use of visual feedback coupled with embedded elaborations in helping subjects gain explicit understanding of science principles. In addition, visual feedback was more effective in helping subjects gain both tacit and explicit learning, which was in contrast to the previous study (Rieber, 1996). Rieber et al. (1996) argued that learners must be given sufficient guidance or time and opportunity for reflection in order for referential processing to take place in a simulation environment.

Rieber’s studies have been focused on using animation as continuous visual feedback in a simulation environment. More research needs to be conducted to
investigate the instructional effects of animation used as a feedback to learners’ responses providing reinforcement in more structured practice activities.

This research intended to focus on this area by investigating the effects of animation-elaborated feedback strategy. Rieber (1990) suggested that animation could be used with or without accompanying text to elaborate a lesson fact, concept, rule, or procedure. In this study, animation-elaborated feedback provided immediate informational feedback by demonstrating or elaborating a lesson fact, concept, rule or principle when learner’s response was correct. Wager and Mory (1993) suggested different types of feedback should be used for different types of learning.

In this study, animation elaborated facts by highlighting the graphical part when a concept name was matched correctly with its corresponding graphical part; animation elaborated concepts by demonstrating the attribute of the concept when a concept attribute was matched correctly with its corresponding concept name; animation elaborated rules and principles by illustrating the cause-and-effect or correlational relationship between the “If…” and “then…” statements when an “If…” statement was matched correctly with its corresponding “then…” statement. It was expected that animation-elaborated feedback would better facilitate the encoding and retrieval processes.

Prior Knowledge

Prior knowledge has been considered the most important single factor influencing learning (Ausubel, 1968). Jonassen and Grabowski (1993) defined prior knowledge and
achievement as the knowledge, skills, or abilities brought by learners to the learning environment before instruction. According to Dwyer (1994), because prior knowledge of lower-level objectives predicts performance in higher-order objectives, it should be included in any study of higher-order learning. Although students were randomly assigned to different treatments, their prior knowledge was still tested to wash out any effects it might have on learning.

Summary

Information processing theory, levels of processing theory, dual coding theory, and generative learning theory provide the fundamental theoretical framework for this study (see Figure 3).

Information processing theory explains how people perceive, encode, and retrieve information. Direct manipulation matching questions and animation-elaborated feedback were expected to better facilitate the rehearsal, encoding and retrieval processes, and therefore, better facilitate learning. Levels of processing theory claims people process incoming information at a successive series or hierarchy of processing levels (stages) simultaneously based on its characteristics. Direct manipulation matching questions and animation-elaborated feedback that match cognitive processing requirement of three levels of learning (factual, conceptual, and rules and principles) were supposed to better facilitate deeper processing of the information from shallow to deep, and from sensory stage, to matching and pattern recognition stage, and to semantic-associative stage. Dual coding theory identified two separate information processing subsystems in human
cognition: a visual system which processes nonverbal objects and events (visual knowledge) and a verbal system which processes language (verbal knowledge). It also identified three distinctive levels of processing within and between the verbal and visual system: (1) representational, (2) associative, and (3) referential (Paivio, 1986). Direct manipulation matching questions and animation-elaborated feedback were believed to better facilitate these three levels of processing and therefore, facilitate learning.

Generative learning theory is concerned with how learners process information and actively construct meaning from it. Direct manipulation matching questions and animation-elaborated feedback should be more likely to help build two types of relationships identified in generative learning theory: organizational and reorganizational relationships between and among different parts of the external information and integrated relationships between the external information and the learner’s prior knowledge. Therefore, they should be more likely to facilitate learning.

The functions of direct manipulation strategy and animation-elaborated feedback are described. Previous research studies related to these two strategies are also reviewed.

Since prior knowledge affects higher order learning, a justification for controlling this variable is made.
Figure 3: Theoretical framework of the present study. Source: from Gagné, R. M. and Driscoll, M. P., Essentials of learning for instruction, 2/e. Published by Allyn and Bacon, Boston, MA. Copyright © 1988 by Pearson Education. Adapted by permission of the publisher.
Chapter 3

METHODS AND PROCEDURES

The purpose of the present study was to investigate the instructional effects of three levels of questioning strategies (no questions, traditional matching questions, and direct manipulation matching questions) and three levels of feedback strategies (no feedback, knowledge of result (KOR) text feedback only, and KOR text plus animation-elaborated feedback) on student achievement on tests measuring different learning objectives.

Participants

Participants were 184 undergraduate students who enrolled in a one hundred level Biological Science (BI SC) course (Human Body) during the fall 2005 semester in a large land grant university in northeastern USA. This was a non-major, biology entry level course, and students in this class were freshmen through seniors from all kinds of majors across campus. The students were invited to participate in the study by the researcher. For their participation, their instructor gave them five extra points towards their final grade for this course.
The self-paced, web-based instruction used in this study was adapted from a color-coded, paper-based booklet developed by Dwyer and Lamberski (1977) about the human heart. This content was chosen because it allows evaluation of different levels of learning objectives. The content contained approximately 1,800 words and was divided into three sections: the parts of the heart, circulation of blood, and cycle of blood pressure. The paper-based booklet consisted of one page of directions and 20 pages of instructions. Page 1 informed the learners of the purpose of the material and directed them to pay attention to both verbal and visual information. Pages 2 to 10 introduced the parts of the heart, pages 11 to 18 described the circulation of blood, and pages 19 to 21 explained the cycle of blood pressure. On each instructional page from page 2 to page 21, instructional text was located in the lower half of the page and a corresponding static graphic was located in the upper half of the page. The central concepts were verbally and visually color-coded: for each central concept mentioned on each page, one of six colors (red, blue, green, purple, brown and gold) was used for the concept name both in the instructional text and the corresponding static graphic, the arrow leading from the concept name to the corresponding graphical part on the heart outline, and the corresponding graphical part itself. The color coding strategy was expected to facilitate the concept learning tasks (Dwyer, 1978).

The paper-based instructional booklet was developed into a web-based instruction with 21 screens: one screen (S1) of directions and twenty screens (S2-S21) of instructions using Macromedia Dreamweaver MX software. Instructional text was moved to the left
side of the screen and the corresponding static graphic was moved to the right side of the screen so that the learners did not have to scroll up and down to study the instruction.

Each colored static graphic in the booklet was scanned individually, edited using Adobe Photoshop 7.0 software, and inserted into each instructional screen. The concept names on each static graphic were changed from all upper cases to title cases to facilitate students reading the content. Because the purpose of this research was to investigate the effects of questioning and feedback strategies on student learning of facts, concepts, and rules and principles instead of the effects of color-coding strategy, therefore, central concept names in the corresponding text were not color-coded. The corresponding static graphics were color-coded because they were directly scanned from the original color-coded booklet.

A total of 10 practice screens (P1-P10) were designed and developed by the researcher using Macromedia Flash MX software for treatments 2, 3, 4 and 5 in order to integrate questioning and feedback strategies into the instructional material: 4 practice screens (P1-P4) were placed after the first content section (the Parts of the Heart); 3 practice screens (P5-P7) were placed after the second content section (Circulation of Blood); and 3 practice screens (P8-P10) were placed after the third content section (Cycle of Blood Pressure).

**Item Analysis**

Integration and positioning of the animation strategies were determined by an item analysis that identified where students were having difficulties based on their
performance on the criterion tests from a pilot study conducted with 35 students enrolled in the same Biological Science course in the fall 2005 semester. From the item analysis, 37 of a total of 60 test items were identified in the three criterion tests in which student achievement was less than or equal to 60% correct (5 items in the identification test, 14 items in the terminology test, and 18 items in the comprehension test). The content referred to in the 37 test items was located on 15 instructional computer screens. The results of the item analysis are summarized in Table 5 with difficult items in shaded print.

<table>
<thead>
<tr>
<th>Test Item</th>
<th>Item Difficulty (% Correct)</th>
<th>Instructional Computer Screen #</th>
<th>Test Item</th>
<th>Item Difficulty (% Correct)</th>
<th>Instructional Computer Screen #</th>
<th>Test Item</th>
<th>Item Difficulty (% Correct)</th>
<th>Instructional Computer Screen #</th>
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</table>
Independent Variables

The effects of two independent variables were examined in this study: level of questioning strategies and level of feedback strategies. The three levels of questioning strategies included: no questions, traditional matching questions, and direct manipulation matching questions. The three levels of feedback strategies included: no questions, KOR text feedback, and KOR text plus animation-elaborated feedback.

Instructional Treatments

Five instructional treatments were included in the present study. Treatment 1 contained one directions screen and twenty instructional screens. No questions or feedback practices were presented.

Treatments 2, 3, 4, and 5 contained additional 10 practice screens which included questioning and feedback strategies to help the students practice on the content referred to by the subset of difficult test items.

The number of the practice screens was decided based on the characteristics of the content items referred to by the subset of difficult test items. Because the identification test was to assess factual learning; the terminology test was to assess conceptual learning; and the comprehension test was to assess rules and principles learning (Dwyer, 1978), the content referred to by the 5 difficult test items in the identification test was mainly facts; the content referred to by the 14 difficult test items in the terminology test was mainly concepts; and the content referred to the by 18 difficult test items in the comprehension
test was mainly rules and principles. When designing the practices, the researcher tried to place practices for the same types of content items on the same screen.

A total of 10 practice screens (P1-P10) were placed after each of the three content sections. Four practice screens (P1-P4) were placed after the first content section (the Parts of the Heart), among which, 1 screen (P1) was to facilitate students learning difficult facts and 3 screens (P2-P4) were to facilitate students learning difficult concepts presented in that section. Three practice screens (P5-P7) were placed after the second content section (Circulation of Blood) to facilitate students learning difficult rules and principles presented in that section, except for screen P5 which also included practice for one concept. Another three practice screens (P8-P10) were placed after the third content section (Cycle of Blood Pressure) to facilitate students learning difficult rules and principles presented in that section, except for screen P9 which also included practice for one concept. Table 6 presents a summary of the difficult items, their item difficulties, their corresponding instructional computer screens, the types of content they referred to, and the corresponding practice screen that the difficult content was practiced. Note that for difficult test item #44, although it was presented in the second content section, it was not practiced until after the third content section for the convenience of design (it was practiced together with difficult test item #49).
Table 6

Difficult Items, Their Item Difficulties, Corresponding Instructional Computer Screen(s), the Type of Content They Referred to, and the Corresponding Practice Screen that the Difficult Content was Practiced

<table>
<thead>
<tr>
<th>Difficult Test Items #</th>
<th>Item Difficulty (% Correct)</th>
<th>Instructional Computer Screen(s)</th>
<th>Type of content Referred to</th>
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<td>#42</td>
<td>46</td>
<td>S14</td>
<td>Rules/Principles</td>
<td>P7</td>
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<td>#43</td>
<td>43</td>
<td>S16</td>
<td>Rules/Principles</td>
<td>P5</td>
</tr>
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<td>#44</td>
<td>37</td>
<td>S13</td>
<td>Rules/Principles</td>
<td>P9</td>
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<td>#45</td>
<td>40</td>
<td>S19</td>
<td>Rules/Principles</td>
<td>P10</td>
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<td>S13 &amp; S20</td>
<td>Rules/Principles</td>
<td>P8</td>
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<td>Rules/Principles</td>
<td>P10</td>
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<td>Rules/Principles</td>
<td>P5</td>
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<td>46</td>
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<td>Rules/Principles</td>
<td>P9</td>
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<td>#50</td>
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<td>S12</td>
<td>Rules/Principles</td>
<td>P5</td>
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<td>S16</td>
<td>Rules/Principles</td>
<td>P5</td>
</tr>
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<td>Rules/Principles</td>
<td>P7</td>
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<td>Rules/Principles</td>
<td>P6</td>
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<td>P7</td>
</tr>
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<td>S14 &amp; S15</td>
<td>Rules/Principles</td>
<td>P7</td>
</tr>
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<td>#56</td>
<td>49</td>
<td>S16 &amp; S20</td>
<td>Rules/Principles</td>
<td>P8</td>
</tr>
<tr>
<td>#57</td>
<td>40</td>
<td>S13 &amp; S20</td>
<td>Rules/Principles</td>
<td>P6</td>
</tr>
<tr>
<td>#58</td>
<td>51</td>
<td>S16 &amp; S20</td>
<td>Rules/Principles</td>
<td>P8</td>
</tr>
<tr>
<td>#59</td>
<td>43</td>
<td>S14, S17 &amp; S19</td>
<td>Rules/Principles</td>
<td>P9</td>
</tr>
<tr>
<td>#60</td>
<td>43</td>
<td>S14, S17 &amp; S19</td>
<td>Rules/Principles</td>
<td>P9</td>
</tr>
</tbody>
</table>
Different types of questioning and feedback strategies were designed and developed to facilitate different levels of learning based on mental processing: for facts, questions and feedback strategies were designed to help build associations between concept names and their corresponding graphical parts; for concepts, questions and feedback strategies were designed to help build associations between concept attributes and their corresponding concept names; and for rules and principles, questions and feedback strategies were designed to help build associations between the “If…” and “then…” statements.

Each treatment is described in detail as follows:

Treatment 1: No Questions and No Feedback (Control Group)

This web-based treatment contained 21 screens: one directions screen and twenty instructional screens with instructional text on the left side and the corresponding static graphic on the right side of each screen. The concept names in the corresponding static graphic, the arrow pointing from the concept names to the corresponding graphical parts on the heart outline, and the corresponding graphical parts themselves were color-coded using the same colors as those used in the original instructional booklet. Two red navigation buttons were located at the bottom of each screen: (1) “Back” and (2) “Next.” No questions and feedback practice were provided. Students clicked through each screen at their own pace using the “Next” button. They could also go back to review previous pages using the “Back” button. See Figure 4.
Treatment 2: Traditional Matching Questions with KOR Text Feedback

Three types of traditional matching questions were embedded in the 10 additional practice screens to facilitate different levels of learning: facts, concepts, and rules and principles. Each is described and exemplified separately.

For Facts

On the practice screen for difficult facts, a list of the concept names of various parts of the heart that were presented in the previous content section was listed on the left side of the screen with radio button choices under each concept name. These concept names were colored with the same colors used in the original instructional booklet. A visual frame of the whole heart containing an outline of the primary parts was presented on the right side of the screen. On the heart graphic, there were several numbered arrows pointing to specific graphical parts. Three navigation buttons were located at the bottom.
of the practice screen: (1) “Back,” (2) “Next,” and (3) “Reset.” The “Next” button was
grayed out so that the students would not be able to click on it until they correctly
answered all the items. See Figure 5.

Directions: Select the answer you feel best identifies the part of the heart indicated by
each numbered arrow. When you have correctly answered all the items, the “NEXT”
button will be activated so that you can proceed to the next screen. Click on the “Reset”
button if you want to practice again.

Figure 5. Example practice screen for facts received by the traditional matching
questions with KOR text feedback group (T2).

Students were required to correctly identify and match the concept names with
their corresponding graphical parts by clicking on the correct radio button under each
concept name. Text feedback was provided in red at the top of the screen between the
concept names and the heart graphic once the student clicked on a radio button. If the
student clicked on the correct radio button, text feedback would be displayed as “Correct”
(see Figure 6). If the wrong radio button was clicked, text feedback would be displayed
as “Wrong.” After the students correctly matched the concept names with their
corresponding graphical parts, the “NEXT” button at the bottom of the screen was activated so that they could proceed to the next screen. At any time, they could click on the “Back” button if they wanted to go back to review the previous screens, or they could click on the “Reset” button if they wanted to start it over or practice again.

![Figure 6](image_url)

*Figure 6.* KOR text feedback provided to the student when his/her answer was correct.

This type of practice was intended to help the learners build associations between concept names and their corresponding graphical parts through covert mental matching and KOR text feedback. It was expected that this practice strategy would help the learners with the identification test.

**For Concepts**

On the practice screens for difficult concepts, a list of the attributes of the concepts that were presented in the previous content section was listed in black on the left
side of the screen with radio button choices under each concept attribute. A visual frame
of the whole heart containing an outline of the primary parts was presented on the right
side of the screen. On the heart graphic, there were several numbered concept names with
arrows pointing to their corresponding graphical parts. These concept names and arrows
were colored with the same colors as those used in the original instructional booklet.
Three navigation buttons were located at the bottom of the practice screen: (1) “Back,”
(2) “Next,” and (3) “Reset.” The “Next” button was grayed out so that the students would
not be able to click on it until they correctly answered all the items. See Figure 7.

Directions: Select the answer you feel best completes the sentence. When you have
correctly answered all the items, the “NEXT” button will be activated so that you can
proceed to the next screen. Click on the “Reset” button if you want to practice again.

---

Figure 7. Example practice screen for concepts received by the traditional matching
questions with KOR text feedback group (T2).

Students were required to correctly identify and match the concept attributes with
their corresponding concept names by clicking on the correct radio button under each
concept attribute. Text feedback was provided in red as either “Correct” or “Wrong” at
the top of the screen between the concept attributes and the heart graphic once the student clicked on a radio button. After the students correctly matched all concept attributes with their corresponding concept names, the “NEXT” button at the bottom of the screen was activated so that they could proceed to the next screen. At any time, they could click on the “Back” button if they wanted to go back to review the previous screens, or they could click on the “Reset” button if they wanted to start it over or practice again.

This type of practice was intended to help the learners build associations between concept attributes and their corresponding concept names through covert mental matching and KOR text feedback. It was expected that this practice strategy would help the learners with the terminology test.

For Rules and Principles

Rules and principles are “If…” and “then…” relationships. On the practice screens for difficult rules and principles, a list of “If…” statements were listed in black on the left side of the screen with radio button choices under each statement. A visual frame of the whole heart containing an outline of the primary parts was presented on the right side of the screen. On the heart graphic, there were several numbered “then…” statements with arrows pointing to the parts they were related. These “then…” statements and arrows were colored with the same colors as those used for the parts they were related to in the original instructional booklet. Three navigation buttons were located at the bottom of the practice screen: (1) “Back,” (2) “Next,” and (3) “Reset.” The “Next” button was grayed out so that the students would not be able to click on it until they correctly answered all the items. See Figure 8.
Students were required to correctly identify and match the “If…” statements with their corresponding “then…” statements by clicking on the correct radio button under each “If…” statement. Text feedback was provided in red as either “Correct” or “Wrong” at the top of the screen between the “If…” statements and the heart graphic once the student clicked on a radio button. After the students correctly matched all “If…” statements with their corresponding “then…” statements, the “NEXT” button at the bottom of the screen was activated so that they could proceed to the next screen. At any time, they could click on the “Back” button if they wanted to go back to review the previous screens, or they could click on the “Reset” button if they wanted to start it over or practice again.

This type of practice was intended to help the learners establish the relationships between the “If…” and “then…” statements through covert mental matching and KOR.
text feedback. It was expected that this practice strategy would help the learners with the comprehension test.

_Treatment 3: Traditional Matching Questions with KOR Text Plus Animation-Elaborated Feedback_

This treatment was the same as treatment 2 except that when the correct radio button was clicked, in addition to the text feedback which was displayed in red as “Correct,” one of the three types of animation-elaborated feedback was also displayed simultaneously to facilitate different levels of learning: facts, concepts, and rules and principles.

_For Facts_

Animation highlighted the corresponding graphical parts of the concepts. For example, when the learner correctly matched Epicardium with its corresponding graphical part by clicking on the correct radio button under the Epicardium text, the graphical part of Epicardium on the heart graphic was highlighted using the same color for the Epicardium text. See Figure 9.
For Concepts

Animation demonstrated the attributes of the corresponding concepts using dynamic visuals. For example, when the learner correctly matched “___ is(are) the chamber(s) with thickest wall(s)” with Ventricles by clicking on the correct radio button under the incomplete sentence, an animation was played to demonstrate the comparative thickness of ventricle walls by highlighting auricles walls first and ventricle walls second. See Figure 10.
For Rules and Principles

Animation illustrated the cause-and-effect or correlational relationships between the “If…” and “then…” statements. For example, when the learner correctly matched “If the auricles contract simultaneously, then ___” with “blood is forced out the tricuspid and mitral valves” by clicking on the correct radio button under the “If…” statement, an animation was played to show blood being forced out the tricuspid and mitral valves after auricles contract simultaneously. See Figure 11.
Figure 11. KOR text plus animation-elaborated feedback provided to the student when s/he correctly matched an “If…” statement with its corresponding “then…” statement.
When the wrong radio button was clicked, text feedback was displayed in red as “Wrong,” but no animation was played.

The practices provided in treatment 3 were intended to facilitate different levels of learning (facts, concepts, and rules and principles) through covert mental matching and KOR text plus animation-elaborated feedback. It was expected that these practice strategies would help the learners with the three criterion tests.

**Treatment 4: Direct Manipulation Matching Questions with KOR Text Feedback**

Three types of direct manipulation matching questions were embedded in the 10 additional practice screens to facilitate different levels of learning: facts, concepts, and rules and principles. Each is described and exemplified separately.

**For Facts**

On the practice screen for difficult facts, a list of concept names of various parts of the heart that were presented in the previous content section was listed on the left side of the screen. These concept names were colored with the same colors as those used in the original instructional booklet. A visual frame of the whole heart containing an outline of the primary parts was presented on the right side of the screen. On the heart graphic, there were several placeholders with arrows pointing to specific graphical parts. Three navigation buttons were located at the bottom of the practice screen: (1) “Back,” (2) “Next,” and (3) “Reset.” The “Next” button was grayed out so that the students would not be able to click on it until they correctly answered all the items. See Figure 12.
Directions: Select the name you feel best identifies the part of the heart indicated by each arrow and drag and drop it into the corresponding placeholder. When you have correctly completed all the items, the “NEXT” button will be activated so that you can proceed to the next screen. Click on the “Reset” button if you want to practice again.

![Image of heart with labeled parts](image)

Figure 12. Example practice screen for facts received by the direct manipulation matching questions with KOR text feedback group (T4).

Students were required to correctly identify, and click and drag the concept names and drop them into the placeholders pointing to their corresponding graphical parts. Text feedback was provided in red at the top of the screen between the concept names and the heart graphic once the student dropped a concept name. If the student dropped the concept name into the right placeholder, text feedback would be displayed as “Correct.” If the name was dropped anywhere else, text feedback would be displayed as “Wrong.” After the students correctly dropped all concept names into the placeholders pointing to their corresponding graphical parts, the “NEXT” button at the bottom of the screen was activated so that they could proceed to the next screen. At any time, they could click on the “Back” button if they wanted to go back to review the previous screens, or they could click on the “Reset” button if they wanted to start it over or practice again.
This type of practice was intended to help the learners build associations between concept names and their corresponding graphical parts through covert mental matching, overt direct manipulation, and KOR text feedback. It was expected that this practice strategy would help the learners with the identification test.

For Concepts

On the practice screens for difficult concepts, a list of the attributes of the concepts that were presented in the previous content section was listed in black on the left side of the screen. A visual frame of the whole heart containing an outline of the primary parts was presented on the right side of the screen. On the heart graphic, there were several concept names with arrows pointing to specific graphical parts. These concept names and arrows were colored with the same colors as those used in the original instructional booklet. There was a placeholder under each concept name. Three navigation buttons were located at the bottom of the practice screen: (1) “Back,” (2) “Next,” and (3) “Reset.” The “Next” button was grayed out so that the students would not be able to click on it until they correctly answered all the items. See Figure 13.
Directions: Identify the statement on the left you feel best describes each term and drag and drop it into the corresponding placeholder. When you have completed all the items, the “NEXT” button will be activated so that you can proceed to the next screen. Click on the “Reset” button if you want to practice again.

Figure 13. Example practice screen for concepts received by the direct manipulation matching questions with KOR text feedback group (T4).
previous screens, or they could click on the “Reset” button if they wanted to start it over or practice again.

This type of practice was intended to help the learners build associations between concept attributes and their corresponding concept names through covert mental matching, overt direct manipulation, and KOR text feedback. It was expected that this practice strategy would help the learners with the terminology test.

For Rules and Principles

On the practice screens for difficult rules and principles, a list of “If…” statements were listed in black on the left side of the screen. A visual frame of the whole heart containing an outline of the primary parts was presented on the right side of the screen. On the heart graphic, there were several “then…” statements with arrows pointing to the parts of the heart to which they were related. These “then…” statements and arrows were colored with the same colors as those used for the parts they were related to in the original instructional booklet. There was a placeholder above each “then…” statement. Three navigation buttons were located at the bottom of the practice screen: (1) “Back,” (2) “Next,” and (3) “Reset.” The “Next” button was grayed out so that the students would not be able to click on it until they correctly answered all the items. See Figure 14.
Directions: Identify the statement on the left you feel best completes the sentence and drag and drop it into the corresponding placeholder. When you have completed all the items, the “NEXT” button will be activated so that you can proceed to the next screen. Click on the “Reset” button if you want to practice again.

![Figure 14. Example practice screen for rules and principles received by the direct manipulation matching questions with KOR text feedback group (T4).]

Students were required to correctly identify, and click and drag the “If…” statements and drop them into the placeholders above their corresponding “then…” statements. Text feedback was provided in red at the top of the screen between the “If…” statements and the heart graphic once the student dropped an “If…” statement. If the student dropped the “If…” statement into the right placeholder, text feedback would be displayed as “Correct.” If the “If…” statement was dropped anywhere else, text feedback would be displayed as “Wrong.” After the students correctly dropped all “If…” statements into the placeholders above their corresponding “then…” statements, the “NEXT” button at the bottom of the screen was activated so that they could proceed to the next screen. At any time, they could click on the “Back” button if they wanted to go back to review the previous screens, or they could click on the “Reset” button if they wanted to start it over or practice again.
This type of practice was intended to help the learners establish the relationships between the “If…” and “then…” statements through covert mental matching, overt direct manipulation, and KOR text feedback. It was expected that this practice strategy would help the learners with the comprehension test.

**Treatment 5: Direct Manipulation Questioning Strategy with KOR Text Plus Animation-Elaborated Feedback**

This treatment was the same as treatment 4 except that when a concept name, a concept attribute, or an “If…” statement was dropped into the right placeholder, in addition to the KOR text feedback which was displayed in red as “Correct,” one of the three types of animation-elaborated feedback was also displayed simultaneously to facilitate different levels of learning: facts, concepts, rules and principles. The animation-elaborated feedback was the same as those in treatment 3:

- For facts: animation highlighted the corresponding graphical parts.
- For concepts: animation demonstrated the attributes of the corresponding concepts.
- For rules and principles: animation illustrated the cause-and-effect or correlational relationships between the “If…” and “then…” statements.

When the item was dropped anywhere else other than the right placeholder, text feedback was displayed in red as “Wrong,” and the item would pop back to its original
position providing negative animation feedback. Then the learners could drag and drop it again.

The practices provided in treatment 5 were intended to facilitate different levels of learning (facts, concepts, and rules and principles) through covert mental matching, overt direct manipulation, and KOR text plus animation-elaborated feedback. It was expected that these practices strategies would help the learners with the three criterion tests.

**Procedures**

Student volunteers recruited from the Biological Science course were asked to sign an approved informed consent form (see Appendix A) before they could participate in the study.

The three-stage study included an online pretest to determine the students’ prior knowledge, followed by the web-based treatments and three online criterion tests. All stages were completed in computer labs. The prior knowledge score was used as a covariate to help analyze and interpret the results.

After taking the online pretest, the students were instructed to go to a specific web site for the web-based treatments according to the treatment groups they were assigned to. Afterwards, the students were instructed to take three criterion tests online: (1) identification test, (2) terminology test, and (3) comprehension test. After they finished all three tests, they were instructed to log off the computer and leave the lab quietly.
Measurement Instruments

Pretest

The pretest developed by Dwyer (1978) consisted of 36 multiple-choice questions on human physiology. The Cronbach’s alpha reliability of the pretest was .45 (n = 184).

Criterion Measures

The three criterion tests used in this study were developed by Dwyer (1978) to measure different learning objectives. Each consists of twenty multiple-choice questions. There was no time limit for test completion. Each test item was worth 1 point for a total of 20 possible points per test.

Identification Test

The identification test measured student ability to identify the names and positions of the parts. Students had to identify the parts of the heart indicated by the numbered arrows on a heart outline drawing. A sample test item follows:

Arrow number one (1) points to the ____

a. Septum  b. Aorta  c. Pulmonary artery  d. Pulmonary vein  e. None of these
**Terminology Test**

The terminology test measured student knowledge of specific facts, terminologies, and definitions. Students answered the multiple-choice questions by selecting the answer that best described different parts of the heart. A sample test item follows:

_____ is (are) the thickest walled chamber (s) of the heart.


**Comprehension Test**

The comprehension test measured student understanding of complex procedures and/or processes. Given the location of the other parts of the hearts at a specific time of its functioning, students located the position of other specified parts of the heart at the same time. An example of a test item follows:

When the tricuspid and mitral valves are forced shut, in what position is the pulmonary valve?

a. Closed  b. Beginning to open  c. Open  d. Beginning to close

**Validity and Reliability**

The validity and reliability of the criterion tests had been tested in many previous research studies. Table 7 presents the internal consistency of Cronbach’s alpha reliability for all 20 items in each of the three criterion tests:
In all the three criterion tests, the test reliabilities were all above 0.8, which is a satisfactory level of reliability (Anastasia & Urbina, 1997).

Table 8 presents the internal consistency of Cronbach’s alpha reliability for the subset of difficult items in each of the three criterion tests:

<table>
<thead>
<tr>
<th>Criterion Tests</th>
<th>Number of Items</th>
<th>Cronbach’s alpha</th>
</tr>
</thead>
<tbody>
<tr>
<td>Identification</td>
<td>5</td>
<td>.62</td>
</tr>
<tr>
<td>Terminology</td>
<td>14</td>
<td>.75</td>
</tr>
<tr>
<td>Comprehension</td>
<td>18</td>
<td>.77</td>
</tr>
</tbody>
</table>

Note. Each criterion test contains 20 test items.

In all the three criterion tests, the test reliabilities were all above 0.6.

**Design and Data Analysis**

The study used an incomplete 3 x 3 factorial design. The two factors included the level of questioning strategies and level of feedback strategies. Figure 15 presents a graphical representation of the research design.
Data were analyzed using SPSS. Multiple analysis of covariance (MANCOVA) was conducted to test for the main effects and the interaction between the level of questioning strategies and level of feedback strategies. A significance level of .05 was set for all statistical tests.

As stated previously, 37 test items were identified through a previous item analysis in which student achievement was less than or equal to 60%. The content referred to in the 37 items was located in 15 instructional computer screens that were then improved with questioning and feedback strategies. It was suggested that the treatment effects might appear only on the test items where the instructions were improved using

Figure 15. Graphical representation of the research design.
questioning and feedback strategies. Therefore, further analysis was done with the subset of difficult test items.

**Summary**

This was an incomplete 3 x3 factorial experimental study. Two independent variables were examined in this study: level of questioning strategies and level of feedback strategies. The three levels of questioning strategies included: no questions, traditional matching questions, and direct manipulation matching questions. The three levels of feedback strategies included: no feedback, KOR text feedback and KOR text plus animation-elaborated feedback. Participants were 184 undergraduate students who enrolled in a one hundred level Biological Science course during the fall 2005 semester in a large land grant university in northeastern USA. The students were randomly assigned to five treatment groups: no questions and no feedback control group (T1), traditional matching questions with KOR text feedback (T2), traditional matching questions with KOR text plus animation-elaborated feedback (T3), direct manipulation matching questions with KOR text feedback (T4), and direct manipulation matching questions with KOR text plus animation-elaborated feedback (T5). The study included an online pretest to determine the students’ prior knowledge, followed by the web-based treatments and three online criterion tests used to assess student achievement in different learning objectives: (1) identification test; (2) terminology test; and (3) comprehension test. MANCOVA was conducted to test the main effects and the interactions between the level of questioning strategies and level of feedback strategies.
Chapter 4

RESULTS OF THE STUDY

Analysis of the Physiology Pretest

The raw scores for the human physiology pretest ranged from 10 to 29, with a median of 20. The mean of the pretest was 20.37, with a standard deviation of 3.40. Scores could range from a low of zero (0) to a high of 36. A one-way analysis of variance (ANOVA) indicated that the five treatments were not significantly different in terms of their prior knowledge, $F (4,179) = 1.12, p = .347$.

Table 9 shows the correlation among the pretest and the three criterion tests. In all cases, the correlations were significant at the 0.01 level.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Prior Knowledge</th>
<th>Identification</th>
<th>Terminology</th>
<th>Comprehension</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prior Knowledge</td>
<td>1.00</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Identification</td>
<td>.29**</td>
<td>1.00</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Terminology</td>
<td>.42**</td>
<td>.77**</td>
<td>1.00</td>
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<tr>
<td>Comprehension</td>
<td>.31**</td>
<td>.69**</td>
<td>.80**</td>
<td>1.00</td>
</tr>
</tbody>
</table>

** Correlation is significant at the 0.01 level (2-tailed).

Note. Each of the criterion tests contains 20 items.
Descriptive Statistics

Descriptive Statistics for the Three Criterion Tests (all items)

Table 10 shows the means and standard deviations for the three criterion tests by treatment for all items in each test.

<table>
<thead>
<tr>
<th>Test by Treatment</th>
<th>n</th>
<th>Mean</th>
<th>S.D.</th>
<th>Low</th>
<th>High</th>
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<tbody>
<tr>
<td>No questions and no feedback control group (T1)</td>
<td></td>
<td></td>
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<tr>
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<td>4.17</td>
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<td></td>
</tr>
<tr>
<td>Identification</td>
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<td>14.69</td>
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<tr>
<td>Terminology</td>
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<td>12.56</td>
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<td>Comprehension</td>
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<td>Traditional matching questions with KOR text plus animation-elaborated feedback (T3)</td>
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<td></td>
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<td>Identification</td>
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<td>13.61</td>
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<td>Terminology</td>
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<td>4.72</td>
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<td>20</td>
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<td>4.33</td>
<td>1</td>
<td>18</td>
</tr>
<tr>
<td>Direct manipulation matching questions with KOR text feedback (T4)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Identification</td>
<td>37</td>
<td>13.76</td>
<td>4.16</td>
<td>5</td>
<td>20</td>
</tr>
<tr>
<td>Terminology</td>
<td>37</td>
<td>10.65</td>
<td>4.13</td>
<td>4</td>
<td>20</td>
</tr>
<tr>
<td>Comprehension</td>
<td>37</td>
<td>9.19</td>
<td>4.21</td>
<td>3</td>
<td>18</td>
</tr>
<tr>
<td>Direct manipulation matching questions with KOR text plus animation-elaborated feedback (T5)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Identification</td>
<td>38</td>
<td>12.84</td>
<td>5.29</td>
<td>3</td>
<td>20</td>
</tr>
<tr>
<td>Terminology</td>
<td>38</td>
<td>10.50</td>
<td>4.68</td>
<td>2</td>
<td>20</td>
</tr>
<tr>
<td>Comprehension</td>
<td>38</td>
<td>9.37</td>
<td>4.72</td>
<td>1</td>
<td>18</td>
</tr>
</tbody>
</table>

Note. Each of the criterion test scores could range from a low of 0 to a high of 20.

Descriptively, Table 10 shows that students in the traditional matching questions with KOR text feedback treatment (T2) had the highest mean score among the five treatment groups for all three criterion tests.
Table 11 presents the means and standard deviations for the three criterion tests examined by question level and feedback level.

### Table 11

**Means and Standard Deviations for the Three Criterion Tests by Question Level and Feedback Level (All Items)**

<table>
<thead>
<tr>
<th>Test</th>
<th>Question Level</th>
<th>Feedback Level</th>
<th>Mean</th>
<th>S. D.</th>
<th>n</th>
</tr>
</thead>
<tbody>
<tr>
<td>Identification</td>
<td>All question levels</td>
<td>No feedback (T1)</td>
<td>13.03</td>
<td>4.53</td>
<td>37</td>
</tr>
<tr>
<td></td>
<td></td>
<td>KOR text feedback (T2+T4)</td>
<td>14.22</td>
<td>4.61</td>
<td>73</td>
</tr>
<tr>
<td></td>
<td></td>
<td>KOR text plus animation-elaborated feedback (T3+T5)</td>
<td>13.22</td>
<td>4.89</td>
<td>74</td>
</tr>
<tr>
<td></td>
<td></td>
<td>All feedback levels (T1+T2+T3+T4+T5)</td>
<td>13.58</td>
<td>4.72</td>
<td>184</td>
</tr>
<tr>
<td></td>
<td>No question</td>
<td>No feedback (T1)</td>
<td>13.03</td>
<td>4.53</td>
<td>37</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Total</td>
<td>13.03</td>
<td>4.53</td>
<td>37</td>
</tr>
<tr>
<td></td>
<td>Traditional matching questions</td>
<td>KOR text feedback (T2)</td>
<td>14.69</td>
<td>5.05</td>
<td>36</td>
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<tr>
<td></td>
<td></td>
<td>KOR text plus animation-elaborated feedback (T3)</td>
<td>13.61</td>
<td>4.47</td>
<td>36</td>
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<tr>
<td></td>
<td></td>
<td>Total</td>
<td>14.15</td>
<td>4.77</td>
<td>72</td>
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<tr>
<td></td>
<td>Direct manipulation matching questions</td>
<td>KOR text feedback (T4)</td>
<td>13.76</td>
<td>4.16</td>
<td>37</td>
</tr>
<tr>
<td></td>
<td></td>
<td>KOR text plus animation-elaborated feedback (T5)</td>
<td>12.84</td>
<td>5.29</td>
<td>38</td>
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<tr>
<td></td>
<td></td>
<td>Total</td>
<td>13.29</td>
<td>4.76</td>
<td>75</td>
</tr>
<tr>
<td>Terminology</td>
<td>All question levels</td>
<td>No feedback (T1)</td>
<td>10.22</td>
<td>4.32</td>
<td>37</td>
</tr>
<tr>
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<td></td>
<td>KOR text feedback (T2+T4)</td>
<td>11.59</td>
<td>4.54</td>
<td>73</td>
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<td>KOR text plus animation-elaborated feedback (T3+T5)</td>
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<td>4.68</td>
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<tr>
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<td>All feedback levels (T1+T2+T3+T4+T5)</td>
<td>11.01</td>
<td>4.56</td>
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<tr>
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<td>No question</td>
<td>No feedback (T1)</td>
<td>10.22</td>
<td>4.32</td>
<td>37</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Total</td>
<td>10.22</td>
<td>4.32</td>
<td>37</td>
</tr>
<tr>
<td></td>
<td>Traditional matching questions</td>
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<tr>
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<td></td>
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<td>36</td>
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<tr>
<td></td>
<td></td>
<td>Total</td>
<td>11.86</td>
<td>4.78</td>
<td>72</td>
</tr>
<tr>
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<td>Direct manipulation matching questions</td>
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<td>10.65</td>
<td>4.13</td>
<td>37</td>
</tr>
<tr>
<td></td>
<td></td>
<td>KOR text plus animation-elaborated feedback (T5)</td>
<td>10.50</td>
<td>4.68</td>
<td>38</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Total</td>
<td>10.57</td>
<td>4.38</td>
<td>75</td>
</tr>
<tr>
<td>Comprehension</td>
<td>All question levels</td>
<td>No feedback (T1)</td>
<td>10.14</td>
<td>4.17</td>
<td>37</td>
</tr>
<tr>
<td></td>
<td></td>
<td>KOR text feedback (T2+T4)</td>
<td>10.52</td>
<td>4.53</td>
<td>73</td>
</tr>
<tr>
<td></td>
<td></td>
<td>KOR text plus animation-elaborated feedback (T3+T5)</td>
<td>9.86</td>
<td>4.53</td>
<td>74</td>
</tr>
<tr>
<td></td>
<td></td>
<td>All feedback levels (T1+T2+T3+T4+T5)</td>
<td>10.18</td>
<td>4.45</td>
<td>184</td>
</tr>
<tr>
<td></td>
<td>No question</td>
<td>No feedback (T1)</td>
<td>10.14</td>
<td>4.17</td>
<td>37</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Total</td>
<td>10.14</td>
<td>4.17</td>
<td>37</td>
</tr>
<tr>
<td></td>
<td>Traditional matching questions</td>
<td>KOR text feedback (T2)</td>
<td>11.89</td>
<td>4.49</td>
<td>36</td>
</tr>
<tr>
<td></td>
<td></td>
<td>KOR text plus animation-elaborated feedback (T3)</td>
<td>10.39</td>
<td>4.33</td>
<td>36</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Total</td>
<td>11.14</td>
<td>4.45</td>
<td>72</td>
</tr>
<tr>
<td></td>
<td>Direct manipulation matching questions</td>
<td>KOR text feedback (T4)</td>
<td>9.19</td>
<td>4.21</td>
<td>37</td>
</tr>
<tr>
<td></td>
<td></td>
<td>KOR text plus animation-elaborated feedback (T5)</td>
<td>9.37</td>
<td>4.72</td>
<td>38</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Total</td>
<td>9.28</td>
<td>4.44</td>
<td>75</td>
</tr>
</tbody>
</table>

*Note.* Each of the criterion test scores could range from a low of 0 to a high of 20.
Descriptively, Table 11 shows that regardless of question level, students who received KOR text feedback (T2+T4) had higher mean scores than students who received no feedback (T1) or KOR text plus animation-elaborated feedback (T3+T5) on all three criterion tests. The mean scores of students who received KOR text plus animation-elaborated feedback (T3+T5) were higher than students who received no feedback (T1) on the identification test and terminology tests, but were lower on the comprehension test. Regardless of feedback level, students who received traditional matching questions (T2+T3) had higher mean scores than students who received no questions (T1) or direct manipulation matching questions (T4+T5) on all three criterion tests. The mean scores of students who received direct manipulation matching questions (T4+T5) were higher than students who received no questions (T1) on the identification and terminology tests, but were lower on the comprehension test.

Descriptive Statistics for the Subset of Difficult Items

As stated previously, 5 items in the identification test, 14 items in the terminology test, and 18 items in the comprehension test out of a total of 20 items per test in the three criterion tests were identified as difficult items through a previous item analysis in which student achievement was less than or equal to 60% correct. Questioning and feedback strategies were then used to improve those difficult items. It was suggested that the treatment effects might appear only on the test items where the instructions were
improved using questioning and feedback strategies. Therefore, further analysis was done with the subset of difficult test items in each test.

Table 12 shows the means and standard deviations for the three criterion tests by treatment for the subset of difficult items in each test.

### Table 12

**Means and Standard Deviations for the Three Criterion Tests by Treatment (Subset of Difficult Items)**

<table>
<thead>
<tr>
<th>Test by Treatment</th>
<th>Number of Items</th>
<th>n</th>
<th>Mean</th>
<th>S.D.</th>
<th>Range</th>
<th>Low</th>
<th>High</th>
</tr>
</thead>
<tbody>
<tr>
<td>No questions and no feedback control group (T1)</td>
<td>Identification 5</td>
<td>37</td>
<td>2.59</td>
<td>1.50</td>
<td>0</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Terminology 14</td>
<td>37</td>
<td>6.35</td>
<td>3.15</td>
<td>0</td>
<td>12</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Comprehension 18</td>
<td>37</td>
<td>8.73</td>
<td>3.64</td>
<td>3</td>
<td>17</td>
<td></td>
</tr>
<tr>
<td>Traditional matching questions with KOR text feedback (T2)</td>
<td>Identification 5</td>
<td>36</td>
<td>3.36</td>
<td>1.66</td>
<td>0</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Terminology 14</td>
<td>36</td>
<td>8.36</td>
<td>3.45</td>
<td>2</td>
<td>13</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Comprehension 18</td>
<td>36</td>
<td>10.44</td>
<td>4.01</td>
<td>3</td>
<td>17</td>
<td></td>
</tr>
<tr>
<td>Traditional matching questions with KOR text plus animation-elaborated feedback (T3)</td>
<td>Identification 5</td>
<td>36</td>
<td>2.83</td>
<td>1.58</td>
<td>0</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Terminology 14</td>
<td>36</td>
<td>7.56</td>
<td>3.34</td>
<td>1</td>
<td>14</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Comprehension 18</td>
<td>36</td>
<td>9.08</td>
<td>3.93</td>
<td>1</td>
<td>16</td>
<td></td>
</tr>
<tr>
<td>Direct manipulation matching questions with KOR text feedback (T4)</td>
<td>Identification 5</td>
<td>37</td>
<td>3.14</td>
<td>1.32</td>
<td>0</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Terminology 14</td>
<td>37</td>
<td>6.86</td>
<td>2.90</td>
<td>2</td>
<td>14</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Comprehension 18</td>
<td>37</td>
<td>8.05</td>
<td>3.86</td>
<td>2</td>
<td>17</td>
<td></td>
</tr>
<tr>
<td>Direct manipulation matching questions with KOR text plus animation-elaborated feedback (T5)</td>
<td>Identification 5</td>
<td>38</td>
<td>2.89</td>
<td>1.61</td>
<td>0</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Terminology 14</td>
<td>38</td>
<td>6.61</td>
<td>3.57</td>
<td>0</td>
<td>14</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Comprehension 18</td>
<td>38</td>
<td>8.16</td>
<td>4.27</td>
<td>0</td>
<td>16</td>
<td></td>
</tr>
</tbody>
</table>

**Note.** The theoretical score for each criterion test was:
Identification: 0 through 5
Terminology: 0 through 14
Comprehension: 0 through 18
Descriptively, Table 12 shows that students in the traditional matching questions with KOR text feedback treatment (T2) had the highest mean score among the five treatment groups across the three criterion tests for the subset of difficult test items.

Table 13 presents the means and standard deviations for the three criterion tests examined by question level and feedback level for the subset of difficult test items in each criterion test.
Table 13

Means and Standard Deviations for the Three Criterion Tests by Question Level and Feedback Level (Subset of Difficult Items)

<table>
<thead>
<tr>
<th>Test</th>
<th>Question Level</th>
<th>Feedback Level</th>
<th>Mean</th>
<th>S. D.</th>
<th>n</th>
</tr>
</thead>
<tbody>
<tr>
<td>Identification (5 Items)</td>
<td>All question levels</td>
<td>No feedback (T1)</td>
<td>2.59</td>
<td>1.50</td>
<td>37</td>
</tr>
<tr>
<td></td>
<td></td>
<td>KOR text feedback (T2+T4)</td>
<td>3.25</td>
<td>1.49</td>
<td>73</td>
</tr>
<tr>
<td></td>
<td></td>
<td>KOR text plus animation-elaborated feedback (T3+T5)</td>
<td>2.86</td>
<td>1.58</td>
<td>74</td>
</tr>
<tr>
<td></td>
<td></td>
<td>All feedback levels (T1+T2+T3+T4+T5)</td>
<td>2.96</td>
<td>1.54</td>
<td>184</td>
</tr>
<tr>
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<td>No question</td>
<td>No feedback (T1)</td>
<td>2.59</td>
<td>1.50</td>
<td>37</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Total</td>
<td>2.59</td>
<td>1.50</td>
<td>37</td>
</tr>
<tr>
<td></td>
<td>Traditional matching questions</td>
<td>KOR text feedback (T2)</td>
<td>3.36</td>
<td>1.66</td>
<td>36</td>
</tr>
<tr>
<td></td>
<td></td>
<td>KOR text plus animation-elaborated feedback (T3)</td>
<td>2.83</td>
<td>1.58</td>
<td>36</td>
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<tr>
<td></td>
<td></td>
<td>Total</td>
<td>3.10</td>
<td>1.63</td>
<td>72</td>
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<tr>
<td></td>
<td>Direct manipulation matching questions</td>
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<td>3.14</td>
<td>1.32</td>
<td>37</td>
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<tr>
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<td></td>
<td>KOR text plus animation-elaborated feedback (T5)</td>
<td>2.89</td>
<td>1.61</td>
<td>38</td>
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<tr>
<td></td>
<td></td>
<td>Total</td>
<td>3.01</td>
<td>1.47</td>
<td>75</td>
</tr>
<tr>
<td>Terminology (14 Items)</td>
<td>All question levels</td>
<td>No feedback (T1)</td>
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<td>3.15</td>
<td>37</td>
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<td>KOR text feedback (T2+T4)</td>
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<td>KOR text plus animation-elaborated feedback (T3+T5)</td>
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<td>3.47</td>
<td>74</td>
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<td>All feedback levels (T1+T2+T3+T4+T5)</td>
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<td>3.33</td>
<td>184</td>
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<td>No question</td>
<td>No feedback (T1)</td>
<td>6.35</td>
<td>3.15</td>
<td>37</td>
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<td></td>
<td>Total</td>
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<td>3.15</td>
<td>37</td>
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<tr>
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<td>Traditional matching questions</td>
<td>KOR text feedback (T2)</td>
<td>8.36</td>
<td>3.45</td>
<td>36</td>
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<td></td>
<td>KOR text plus animation-elaborated feedback (T3)</td>
<td>7.56</td>
<td>3.34</td>
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<td></td>
<td>Total</td>
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<tr>
<td></td>
<td>Direct manipulation matching questions</td>
<td>KOR text feedback (T4)</td>
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<td>2.90</td>
<td>37</td>
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<td></td>
<td>KOR text plus animation-elaborated feedback (T5)</td>
<td>6.61</td>
<td>3.57</td>
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<td></td>
<td>Total</td>
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<td>3.24</td>
<td>75</td>
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<tr>
<td>Comprehension (18 Items)</td>
<td>All question levels</td>
<td>No feedback (T1)</td>
<td>8.73</td>
<td>3.64</td>
<td>37</td>
</tr>
<tr>
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<td>KOR text feedback (T2+T4)</td>
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<td>4.09</td>
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<td>4.10</td>
<td>74</td>
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<tr>
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<td></td>
<td>All feedback levels (T1+T2+T3+T4+T5)</td>
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<td>No feedback (T1)</td>
<td>8.73</td>
<td>3.64</td>
<td>37</td>
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<td>KOR text feedback (T2)</td>
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<td></td>
<td>KOR text plus animation-elaborated feedback (T3)</td>
<td>9.08</td>
<td>3.93</td>
<td>36</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Total</td>
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<td>4.00</td>
<td>72</td>
</tr>
<tr>
<td></td>
<td>Direct manipulation matching questions</td>
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<td>8.05</td>
<td>3.86</td>
<td>37</td>
</tr>
<tr>
<td></td>
<td></td>
<td>KOR text plus animation-elaborated feedback (T5)</td>
<td>8.16</td>
<td>4.27</td>
<td>38</td>
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<tr>
<td></td>
<td></td>
<td>Total</td>
<td>8.11</td>
<td>4.04</td>
<td>75</td>
</tr>
</tbody>
</table>

Note. The theoretical score for each criterion test was: Identification: 0 through 5 Terminology: 0 through 14 Comprehension: 0 through 18
Descriptively, Table 13 shows that regardless of question level, students who received KOR text feedback (T2 +T4) had higher mean scores than students who received no feedback (T1) or KOR text plus animation-elaborated feedback (T3+T5) on all three criterion tests. The mean scores of students who received KOR text plus animation-elaborated feedback (T3+T5) were higher than students who received no feedback (T1) on the identification test and terminology tests, but lower on the comprehension test. Regardless of feedback level, students who received traditional matching questions (T2+T3) had higher mean scores than students who received no questions (T1) or direct manipulation matching questions (T4+T5) on all three criterion tests. Between the other two question levels, the mean scores of students who received direct manipulation matching questions (T4+T5) were higher than students who received no questions (T1) on the identification and terminology tests, but were lower on the comprehension test.

Overall, descriptive statistics for the difficult test items in each criterion test showed the same trends as those for all test items in each test.

**Group Comparisons**

One way MANCOVAs were conducted to find out if there were any statistically significant differences in student achievement among the five treatment groups for all items as well as the subset of difficult items in the three criterion tests.
**Analysis with All Items**

Two prerequisites, equality of variances and the correlations between the dependent variables, were checked before MANCOVA was used. The Levene’s test for equal variance assumption revealed the variance was statistically equal at the .05 alpha level. Table 14 shows the correlation among the three criterion tests. In all cases, the correlations were significant at the 0.01 significance level.

<table>
<thead>
<tr>
<th>Variable (Test)</th>
<th>Identification</th>
<th>Terminology</th>
<th>Comprehension</th>
</tr>
</thead>
<tbody>
<tr>
<td>Identification</td>
<td>1.00</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Terminology</td>
<td>.77**</td>
<td>1.00</td>
<td></td>
</tr>
<tr>
<td>Comprehension</td>
<td>.69**</td>
<td>.80**</td>
<td>1.00</td>
</tr>
</tbody>
</table>

**Correlation is significant at the 0.01 level (2-tailed)**

*Note.* Each of the criterion tests contains 20 items.

Table 15 shows the overall one-way MANCOVA results using Pallai’s Trace F.

<table>
<thead>
<tr>
<th>Source</th>
<th>Pillai’s Trace</th>
<th>F</th>
<th>Sig</th>
<th>Partial Eta Squared</th>
<th>Observed Power</th>
</tr>
</thead>
<tbody>
<tr>
<td>Covariate Prior Knowledge</td>
<td>.18</td>
<td>12.57</td>
<td>.000</td>
<td>.18</td>
<td>1.00</td>
</tr>
<tr>
<td>Group</td>
<td>.08</td>
<td>1.24</td>
<td>.251</td>
<td>.03</td>
<td>.71</td>
</tr>
</tbody>
</table>

*Note.* Each of the criterion tests contains 20 items.

The overall MANCOVA Pillai’s Trace F value was not statistically significant at the .05 alpha level when controlling for prior knowledge as measured by score on the physiology test, F = 1.24, p = .251. Therefore, there were no significant differences in student achievement among the five treatment groups.
Analysis with the Subset of Difficult Items

As mentioned above, it was suggested that the treatment effects might appear only on the test items where the instructions were improved using questioning and feedback strategies. Therefore, further analysis was done with only the subset of difficult items in each criterion test.

Two prerequisites, equality of variances and the correlations between the dependent variables, were checked before the MANCOVA was used. The Levene’s test for equal variance assumption revealed the variance was statistically equal at the .05 alpha level. Table 16 shows the correlation among the three criterion tests. In all cases, the correlations were significant at the 0.01 significance level.

<table>
<thead>
<tr>
<th>Variable (Test)</th>
<th>Identification</th>
<th>Terminology</th>
<th>Comprehension</th>
</tr>
</thead>
<tbody>
<tr>
<td>Identification (5 items)</td>
<td>1.00</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Terminology (14 items)</td>
<td>.65**</td>
<td>1.00</td>
<td></td>
</tr>
<tr>
<td>Comprehension (18 items)</td>
<td>.59**</td>
<td>.74**</td>
<td>1.00</td>
</tr>
</tbody>
</table>

**Correlation is significant at the 0.01 level (2-tailed)

Table 17 shows the overall one-way MANCOVA results using Pallai’s Trace F.

<table>
<thead>
<tr>
<th>Source</th>
<th>Pillai’s Trace</th>
<th>F</th>
<th>Sig</th>
<th>Partial Eta Squared</th>
<th>Observed Power</th>
</tr>
</thead>
<tbody>
<tr>
<td>Covariate Prior Knowledge</td>
<td>.17</td>
<td>11.72</td>
<td>.000</td>
<td>.17</td>
<td>1.00</td>
</tr>
<tr>
<td>Group</td>
<td>.11</td>
<td>1.69</td>
<td>.066</td>
<td>.04</td>
<td>.86</td>
</tr>
</tbody>
</table>

*Note. The identification test contains 5 items, the terminology test contains 14 items, and the comprehension test contains 18 items.*
Although the alpha level was approaching marginal significance (Huck, 2004), \( F = 1.69, p = .066 \), the overall MANCOVA Pillai’s Trace F value was not statistically significant at the .05 alpha level when controlling for prior knowledge as measured by score on the physiology test. Therefore, there were no significant differences in student achievement among the five treatment groups.

**Analysis of Null Hypothesis**

Three null hypotheses were raised in this study:

**Ho1:** There will be insignificant differences in achievement among students who received no questions, traditional matching questions, or direct manipulation matching questions on tests measuring different educational objectives.

**Ho2:** There will be insignificant differences in achievement among students who received no feedback, KOR text feedback only, or KOR text plus animation-elaborated feedback on tests measuring different educational objectives.

**Ho3:** There will be an insignificant interaction between the level of questioning strategies and level of feedback strategies.

In order to test the three null hypothesis, the following analyses were conducted with all test items as well as the subset of difficult test items in each of the three criterion tests examined by question level and feedback level: 1) two-way MANCOVAs; 2) follow-up tests of the between-subjects effects; and 3) pairwise comparisons for question level.
**Analysis with All Items**

Table 18 shows the overall two-way MANCOVA results using Pallai’s Trace F.

### Table 18

*Two-Way Factorial MANCOVA Overall Test Results (n=184, All Items)*

<table>
<thead>
<tr>
<th>Source</th>
<th>Pillai’s Trace</th>
<th>F</th>
<th>Sig</th>
<th>Partial Eta Squared</th>
<th>Observed Power</th>
</tr>
</thead>
<tbody>
<tr>
<td>Covariate Prior Knowledge</td>
<td>.18</td>
<td>12.57</td>
<td>.000</td>
<td>.18</td>
<td>1.00</td>
</tr>
<tr>
<td>Question Level</td>
<td>.04</td>
<td>2.17</td>
<td>.094</td>
<td>.04</td>
<td>.54</td>
</tr>
<tr>
<td>Feedback Level</td>
<td>.01</td>
<td>.66</td>
<td>.579</td>
<td>.01</td>
<td>.19</td>
</tr>
<tr>
<td>Question Level by Feedback Level</td>
<td>.01</td>
<td>.57</td>
<td>.635</td>
<td>.01</td>
<td>.17</td>
</tr>
</tbody>
</table>

*Note.* Each of the criterion tests contains 20 items.

The overall MANCOVA Pillai’s Trace F value was not statistically significant at the .05 alpha level when controlling for prior knowledge as measured by score on the physiology test. However, the alpha level for question level was approaching marginal significance, F (3,176) = 2.17, *p* = .094 (Huck, 2004, P. 155).

Following Huck’s recommendation regarding marginal significance, subsequent exploratory analysis was conducted to further examine the differences. The results of the exploratory follow-up analysis using ANCOVA are presented in Table 19.
Follow-up tests of between-subjects effects presented in Table 19 found significant differences in achievement among students who received different levels of questions on the comprehension test only, $F = 5.66, p = .018$. To further identify where the differences were, follow-up pairwise comparisons were examined. Table 20 presents the adjusted means and standard errors for question level, and Table 21 presents the follow-up univariate pairwise comparison results for question level on the comprehension test.

<table>
<thead>
<tr>
<th>Source</th>
<th>Dependent Variable</th>
<th>F</th>
<th>Sig</th>
<th>Partial Eta Squared</th>
<th>Observed Power</th>
</tr>
</thead>
<tbody>
<tr>
<td>Covariate Prior Knowledge</td>
<td>Identification</td>
<td>17.15</td>
<td>.000</td>
<td>.09</td>
<td>.99</td>
</tr>
<tr>
<td></td>
<td>Terminology</td>
<td>37.38</td>
<td>.000</td>
<td>.17</td>
<td>1.00</td>
</tr>
<tr>
<td></td>
<td>Comprehension</td>
<td>17.39</td>
<td>.000</td>
<td>.09</td>
<td>.99</td>
</tr>
<tr>
<td>Question Level</td>
<td>Identification</td>
<td>.71</td>
<td>.399</td>
<td>.00</td>
<td>.13</td>
</tr>
<tr>
<td></td>
<td>Terminology</td>
<td>2.09</td>
<td>.150</td>
<td>.01</td>
<td>.30</td>
</tr>
<tr>
<td></td>
<td>Comprehension</td>
<td>5.66</td>
<td>.018</td>
<td>.03</td>
<td>.66</td>
</tr>
<tr>
<td>Feedback Level</td>
<td>Identification</td>
<td>1.93</td>
<td>.167</td>
<td>.01</td>
<td>.28</td>
</tr>
<tr>
<td></td>
<td>Terminology</td>
<td>1.44</td>
<td>.232</td>
<td>.01</td>
<td>.22</td>
</tr>
<tr>
<td></td>
<td>Comprehension</td>
<td>1.00</td>
<td>.318</td>
<td>.01</td>
<td>.17</td>
</tr>
<tr>
<td>Question Level by Feedback Level</td>
<td>Identification</td>
<td>.18</td>
<td>.672</td>
<td>.00</td>
<td>.07</td>
</tr>
<tr>
<td></td>
<td>Terminology</td>
<td>.01</td>
<td>.913</td>
<td>.00</td>
<td>.05</td>
</tr>
<tr>
<td></td>
<td>Comprehension</td>
<td>.44</td>
<td>.510</td>
<td>.00</td>
<td>.10</td>
</tr>
</tbody>
</table>

*Note.* Each of the criterion tests contains 20 items.
Pairwise comparisons results in Table 21 showed the differences among students who received different question levels on the comprehension test was not statistically significant at the .05 alpha level when controlling for prior knowledge as measured by score on the physiology test. However, it is important to point out that the differences of performance between the students who received traditional matching questions (T2+T3,
Mean = 11.14) and those who received direct manipulation matching questions (T4+T5, Mean = 9.28) was approaching marginal significance on the comprehension test according to Huck (2004), \( p = .055 \).

**Analysis with the Subset of Difficult Items**

As reported previously, it was suggested that the treatment effects might appear only on the test items where the instructions were improved using questioning and feedback strategies. Therefore, further analysis was done with only the difficult items in each criterion test.

Table 22 shows the overall two-way MANCOVA results using Pallai’s Trace F.

<table>
<thead>
<tr>
<th>Source</th>
<th>Pillais Trace</th>
<th>F</th>
<th>Sig</th>
<th>Partial Eta Squared</th>
<th>Observed Power</th>
</tr>
</thead>
<tbody>
<tr>
<td>Covariate Prior Knowledge</td>
<td>.17</td>
<td>11.72</td>
<td>.000</td>
<td>.17</td>
<td>1.00</td>
</tr>
<tr>
<td>Question Level</td>
<td>.05</td>
<td>3.00</td>
<td>.032</td>
<td>.05</td>
<td>.70</td>
</tr>
<tr>
<td>Feedback Level</td>
<td>.01</td>
<td>.85</td>
<td>.468</td>
<td>.01</td>
<td>.23</td>
</tr>
<tr>
<td>Question Level by Feedback Level</td>
<td>.01</td>
<td>.46</td>
<td>.709</td>
<td>.01</td>
<td>.14</td>
</tr>
</tbody>
</table>

*Note.* The identification test contains 5 items, the terminology test contains 14 items, and the comprehension test contains 18 items.

The overall MANCOVA results presented in Table 22 showed significant differences in achievement among students who received different levels of questions, \( F(3,176) = 3.00, p = .032 \). Follow-up tests of between-subjects effects were then examined. Table 23 shows the results of the follow-up tests.
Follow-up tests of between-subjects effects presented in Table 23 found significant differences in achievement among students who received different levels of questions on both the terminology test (F = 4.12, \( p = .044 \)) and the comprehension test (F = 5.57, \( p = .019 \)). To further identify where the differences were, follow-up pairwise comparisons were examined. Table 24 presents the adjusted means and standard errors by question level, and Table 25 presents the follow-up univariate pairwise comparison results for question level on the terminology and comprehension tests.
Table 24

*Adjusted Means and Standard Errors by Question Level (n=184, Subset of Difficult Items)*

<table>
<thead>
<tr>
<th>Test by Question Level</th>
<th>Adjusted Mean</th>
<th>Standard Error</th>
<th>95% Confidence Interval</th>
</tr>
</thead>
<tbody>
<tr>
<td>Identification Test (5 Items)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No questions (control)</td>
<td>2.56</td>
<td>.25</td>
<td>2.07-3.04</td>
</tr>
<tr>
<td>Traditional matching questions</td>
<td>3.08</td>
<td>.18</td>
<td>2.73-3.43</td>
</tr>
<tr>
<td>Direct manipulation matching questions</td>
<td>3.05</td>
<td>.17</td>
<td>2.71-3.40</td>
</tr>
<tr>
<td>Terminology Test (14 Items)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No questions (control)</td>
<td>6.21</td>
<td>.50</td>
<td>5.23-7.19</td>
</tr>
<tr>
<td>Traditional matching questions</td>
<td>7.89</td>
<td>.36</td>
<td>7.19-8.59</td>
</tr>
<tr>
<td>Direct manipulation matching questions</td>
<td>6.88</td>
<td>.35</td>
<td>6.19-7.57</td>
</tr>
<tr>
<td>Comprehension Test (18 Items)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No questions (control)</td>
<td>8.62</td>
<td>.63</td>
<td>7.38-9.85</td>
</tr>
<tr>
<td>Traditional matching questions</td>
<td>9.71</td>
<td>.45</td>
<td>8.82-10.59</td>
</tr>
<tr>
<td>Direct manipulation matching questions</td>
<td>8.22</td>
<td>.44</td>
<td>7.35-9.09</td>
</tr>
</tbody>
</table>

*Note.* Each item was worth 1 point. Thus scores could range from 0-5 for identification test, 0-14 for the terminology test, and 0-18 for the comprehension test.

---

Table 25

*Follow-Up Univariate Pairwise Comparison Results by Question Level on the Terminology and Comprehension Tests (n=184, Subset of Difficult Items)*

<table>
<thead>
<tr>
<th>Dependent Variable</th>
<th>Question Level</th>
<th>Question Level</th>
<th>Mean Diff.</th>
<th>Standard Error</th>
<th>Sig.</th>
<th>95% Confidence Interval for Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Terminology (14 Items)</td>
<td>No questions (control)</td>
<td>Traditional matching questions</td>
<td>-1.68</td>
<td>.61</td>
<td>.020</td>
<td>-3.15 — -0.20</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Direct manipulation matching questions</td>
<td>-0.66</td>
<td>.61</td>
<td>.829</td>
<td>-2.13 — .81</td>
</tr>
<tr>
<td></td>
<td>Traditional matching questions</td>
<td>Direct manipulation matching questions</td>
<td>1.01</td>
<td>.50</td>
<td>.132</td>
<td>-.19 — 2.22</td>
</tr>
<tr>
<td>Comprehension (18 Items)</td>
<td>No questions (control)</td>
<td>Traditional matching questions</td>
<td>-1.09</td>
<td>.77</td>
<td>.475</td>
<td>-2.95 — .77</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Direct manipulation matching questions</td>
<td>.39</td>
<td>.77</td>
<td>1.000</td>
<td>-1.46 — 2.25</td>
</tr>
<tr>
<td></td>
<td>Traditional matching questions</td>
<td>Direct manipulation matching questions</td>
<td>1.49</td>
<td>.63</td>
<td>.058</td>
<td>-.04 — 3.01</td>
</tr>
</tbody>
</table>

*Note.* Each item was worth 1 point. Thus scores could range from 0-14 for the terminology test, and 0-18 for the comprehension test.
Pairwise comparisons results in Table 25 revealed that students who received traditional matching questions (T2+T3, Mean = 7.96) performed significantly better than students who received no questions (T1, Mean = 6.35) on the terminology test only, $p = .020$. The pairwise comparisons showed the differences among students who received different question levels on the comprehension test was not statistically significant at the .05 alpha level when controlling for prior knowledge as measured by score on the physiology test. However, the differences of performance between the students who received traditional matching questions (T2+T3, Mean = 9.76) and those who received direct manipulation matching questions (T4+T5, Mean = 8.11) was approaching marginal significance on the comprehension test according to Huck (2004), $p = .058$.

These results of the above analysis with all items as well as only the subset of difficult items in each criterion test were used to test the three null hypotheses.

**Null Hypothesis One**

$H_01$: There will be insignificant differences in achievement among students who received no questions (control), traditional matching questions, or direct manipulation matching questions on tests measuring different educational objectives.

The results of Pillai’s Trace indicated that there were no significant differences in achievement among students who received different levels of questions when data were analyzed using all test items in each criterion test, $F (3,176) = 2.17, p = .094$ (see Table 18). Although Huck (2004) suggests that this alpha level was approaching marginal significance, the overall MANCOVA Pillai’s Trace F value was not statistically
significant at the .05 level when controlling for prior knowledge as measured by score on the physiology test. Therefore, null hypothesis one was retained based on the prior established significance level of .05.

However, further analysis with only the subset of difficult items in each criterion test found significant differences in achievement among students who received different levels of questions, $F(3,176) = 3.00, p = .032$ (see Table 22). Follow-up tests of between-subjects effects found significant differences in achievement among students who received different levels of questions on both the terminology test ($F = 4.12, p = .044$) and the comprehension test ($F = 5.57, p = .019$) (see Table 23). Follow-up pairwise comparisons revealed that students who received traditional matching questions (T2+T3, Mean = 7.96) performed significantly better than students who received no questions (T1, Mean = 6.35) on the terminology test only, $p = .020$ (see Table 25). Therefore, null hypothesis one was rejected based on the analysis with only the difficult test items in each criterion test.

**Null Hypothesis Two**

Ho2: There will be insignificant differences in achievement among students who received no feedback (control), KOR text feedback only, or KOR text plus animation-elaborated feedback on tests measuring different educational objectives.

The results of Pillai’s Trace showed that there were no significant differences in achievement among students who received different levels of feedback when data were
analyzed using all test items in each criterion test, $F (3,176) = .66, p = .579$ (see Table 18).

Further analysis with only the difficult items in each criterion test also found no significant differences in achievement among students who received different levels of feedback, $F (3,176) = .85, p = .468$ (see Table 22).

Therefore, null hypothesis two was retained.

**Null Hypothesis Three**

Ho3: There will be an insignificant interaction between the level of questioning strategies and level of feedback strategies.

The results of Pillai’s Trace showed there was no significant interaction between the level of questioning strategies and level of feedback strategies when data were analyzed using all test items in each criterion test, $F (3,176) = .57, p = .635$ (see Table 18).

Further analysis with only the difficult items in each criterion test also found no significant interaction between the level of questioning strategies and level of feedback strategies, $F (3,176) = .46, p = .709$ (see Table 22).

Therefore, null hypothesis three was retained.
Interaction Profile Plots

Figure 16, Figure 17, and Figure 18 present the interaction profile plots for all three criterion tests using all test items in each criterion test.

---

**Estimated Marginal Means of Identification Test (20 Items)**

*Figure 16.* Estimated marginal means of the identification test (20 items).
**Estimated Marginal Means of Terminology Test (20 Items)**

*Figure 17.* Estimated marginal means of the terminology test (20 items).
Figure 18. Estimated marginal means of the comprehension test (20 items).
Figure 19, Figure 20, and Figure 21 present the profile plots for the three criterion tests using only the difficult items in each criterion test.

Estimated Marginal Means of Identification Test (5 Items)

Non-estimable means are not plotted

*Figure 19*. Estimated marginal means of the identification test (5 items).
Figure 20. Estimated marginal means of the terminology test (14 items).
Estimated Marginal Means of Comprehension Test (18 Items)

Figure 21. Estimated marginal means of the comprehension test (18 items).
Summary

Data were analyzed for all test items as well as for the subset of difficult items practiced using questioning and feedback strategies in each of the three criterion tests.

Descriptively, traditional matching questions with KOR text feedback treatment (T2) had the highest mean score among the five treatment groups when data were analyzed using all items as well as the subset of difficult items. Similar trends were also found with all items as well as the subset of difficult items when descriptive statistics were examined by question level and feedback level: regardless of question level, students who received KOR text feedback (T2+T4) had higher mean scores than students who received the other feedback levels on all three criterion tests. Between the other two feedback levels, students who received KOR text plus animation-elaborated feedback (T3+T5) displayed higher mean scores than those who received no feedback (T1) on the identification and terminology tests, but lower mean scores on the comprehension test. Regardless of feedback level, students who received traditional matching questions (T2+T3) had higher mean scores than students who received other question levels on all three criterion tests. Between the other two question levels, students who received direct manipulation matching questions (T4+T5) displayed higher mean scores than those who received no questions (T1) on the identification and terminology tests, but lower mean scores on the comprehension test.

To test the three null hypotheses, three types of analysis were conducted with all test items as well as the subset of difficult items in each criterion test examined by
question level and feedback level: 1) two-way MANCOVAs; 2) follow-up tests of the between-subjects effects; and 3) pairwise comparisons for question level.

For null hypothesis one, the results of Pillai’s Trace indicated that there were no significant differences in achievement among students who received different levels of questions when data were analyzed using all test items in each criterion test, \( F (3,176) = 2.17, p = .094 \) (see Table 18). Therefore, null hypothesis one was retained based on the analysis with all test items. However, further analysis with only the subset of difficult items in each criterion test found significant differences in achievement among students who received different levels of questions, \( F (3,176) = 3.00, p = .032 \) (see Table 22). Follow-up univariate pairwise comparisons revealed that students who received traditional matching questions (T2+T3, Mean = 7.96) performed significantly better than students who received no questions (T1, Mean = 6.35) on the terminology test only, \( p = .020 \) (see Table 25). Therefore, null hypothesis one was rejected based on the analysis with the difficult items.

For null hypothesis two, the results of Pillai’s Trace using all test items in each criterion test showed that there were no significant differences in achievement among students who received different levels of feedback, \( F (3,176) = .66, p = .579 \) (see Table 18). Further analysis with only the subset of difficult items in each criterion test also found no significant differences in achievement among students who received different levels of feedback, \( F (3,176) = .85, p = .468 \) (see Table 22). Therefore, null hypothesis two was retained for both analyses.

For null hypothesis three, the results of Pillai’s Trace using all test items in each criterion test showed there was no significant interaction between the level of questioning
strategies and level of feedback strategies, $F (3,176) = .57, p = .635$ (see Table 18).

Further analysis with only the subset of difficult items in each criterion test also found no significant interaction between the level of questioning strategies and level of feedback strategies, $F (3,176) = .46, p = .709$ (see Table 22).

Therefore, null hypothesis three was retained for both analyses.

Table 26 summarizes the results of the present study.
Table 26

Summary of the Results of the Present Study

<table>
<thead>
<tr>
<th>Items</th>
<th>Results of Data Analysis</th>
<th>Criterion Test</th>
<th>Levels of Learning</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Ho1:</strong> There will be insignificant differences in achievement among students who received no questions (control), traditional matching questions, or direct manipulation matching questions on tests measuring different educational objectives.</td>
<td>Difference between traditional matching questions (T2+T3, Mean = 11.14) and direct manipulation matching questions (T2+T4, Mean = 9.28) was approaching marginal significance, ( p = .055 )</td>
<td>Comprehension</td>
<td>Rules and Principles</td>
</tr>
<tr>
<td>All Items</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Subset of Difficult Items</td>
<td>Traditional matching questions (T2+T3, Mean = 7.96) &gt; No questions (T1, Mean = 6.35), ( p = .020 )</td>
<td>Terminology</td>
<td>Concepts</td>
</tr>
<tr>
<td></td>
<td>Difference between traditional matching questions (T2+T3, Mean = 9.76) and direct manipulation matching questions (T4+T5, Mean = 8.11) was approaching marginal significance, ( p = .058 )</td>
<td>Comprehension</td>
<td>Rules and Principles</td>
</tr>
<tr>
<td><strong>Ho2:</strong> There will be insignificant differences in achievement among students who received no feedback (control), KOR text feedback only, or KOR text plus animation-elaborated feedback on tests measuring different educational objectives.</td>
<td>No significant differences, ( F(3,176) = .66, p = .579 )</td>
<td>Identification</td>
<td>Facts Concepts</td>
</tr>
<tr>
<td>All Items</td>
<td></td>
<td>Terminology</td>
<td>Rules and Principles</td>
</tr>
<tr>
<td>Subset of Difficult Items</td>
<td>No significant differences, ( F(3,176) = .85, p = .468 )</td>
<td>Comprehension</td>
<td></td>
</tr>
<tr>
<td><strong>Ho3:</strong> There will be an insignificant interaction between the level of questioning strategies and level of feedback strategies.</td>
<td>No significant interactions, ( F(3,176) = .57, p = .635 )</td>
<td>Identification</td>
<td>Facts Concepts</td>
</tr>
<tr>
<td>All Items</td>
<td></td>
<td>Terminology</td>
<td>Rules and Principles</td>
</tr>
<tr>
<td>Subset of Difficult Items</td>
<td>No significant interactions, ( F(3,176) = .46, p = .709 )</td>
<td>Comprehension</td>
<td></td>
</tr>
</tbody>
</table>
Chapter 5

DISCUSSIONS AND CONCLUSIONS

This study investigated the effects of questioning and feedback strategies in facilitating student achievement on tests measuring different levels of educational objectives. Three levels of questioning strategies (no questions, traditional matching questions, and direct manipulation matching questions) and three levels of feedback strategies (no feedback, KOR text feedback only, KOR text plus animation-elaborated feedback) were studied.

This chapter provides a general discussion based on relevant literature and the overall findings of the experimental study, followed by conclusions. Implications for instructional designers, recommendations for future research, and limitations of the study are also presented.

Summary of Overall Findings

Three research questions were studied in this research: (1) were three levels of questioning strategies (no questions, traditional matching questions, and direct manipulation matching questions) equally effective in facilitating student achievement on tests measuring different educational objectives? (2) Were three levels of feedback strategies (no feedback, KOR text feedback only, and KOR text plus animation-elaborated feedback) equally effective in facilitating student achievement on tests
measuring different educational objectives? And (3) was there an interaction between the level of questioning strategies and level of feedback strategies?

Descriptively, similar trends were found when data were analyzed with all test items as well as the subset of difficult items. Regardless of question level, students who received KOR text feedback (T2+T4) had higher mean scores than students who received no feedback (T1) or KOR plus animation-elaborated feedback (T3+T5) on all three criterion tests. Regardless of feedback level, students who received traditional matching questions (T2+T3) had higher mean scores than students who received no questions (T1) or direct manipulation matching questions (T4+T5) on all three criterion tests.

Two-way MANCOVAs and follow-up tests of between-subjects effects with all test items as well as the subset of difficult test items found the following results: for research question one, there were no significant differences among students who received different question levels when data were analyzed with all test items. However, further analysis with the subset of difficult items found that students who received traditional matching questions (T2+T3) performed significantly better than students who received no questions (T1) on the terminology test only, \( p = .020 \). For research question two, data analysis with all items as well as the subset of difficult items found no significant differences in achievement among students who received different levels of feedback. For research question three, data analysis with all items as well as the subset of difficult items found no significant interaction between the level of questioning strategies and level of feedback strategies.
Discussion of the Findings

*Effects of Different Levels of Questions*

Research question one was raised to find out whether no questions, traditional matching questions, and direct manipulation matching questions were equally effective in facilitating student achievement on different criterion tests.

The use of direct manipulation matching questions was supported by several fundamental learning theories: information processing theory, levels of processing theory, dual coding theory, and generative learning theory. It was expected that it would be easier for the students to construct generative relationships if they were able to directly manipulate (drag and drop) the answers to the questions because they could both covertly and overtly establish these relationships. Comparatively, it would be more difficult for students who received traditional matching questions to do so because they could only covertly establish these relationships. Therefore, students who received direct manipulation matching questions were expected to perform better than students who received traditional matching questions. Lastly, students in the control group who received no questions would perform the poorest since they did not receive any practice.

The results of the study were contradictory to the theories found in the literature. However, the results partially accorded with those reported by Haag (1995) who found that there were no significant differences among students who actively manipulated visuals, those who passively viewed the manipulation of visuals, and those who interacted with static images in terms of student performance on six posttest measures. Moreover, she found that the students in the control treatment performed better than those
who interacted with the manipulation strategies for most criterion measures shown by higher mean scores.

Following are the detailed discussions of the results regarding the effects of different question levels found in the current study.

**Traditional Matching Questions vs. Direct Manipulation Matching Questions**

The results found that traditional matching questions (T2+T3) and direct manipulation matching questions (T4+T5) were equally effective in facilitating student achievement in all criterion tests when data were analyzed using all test items as well as the subset of difficult items. The main reason might be because both matching questioning strategies may have matched the cognitive processing requirements. They were functionally the same, but structurally different.

Deeper understanding may be obtained by examining more closely how the students interacted with the two questioning strategies. Both the traditional matching questions and the direct manipulation matching questions required students to covertly identify and build generative relationships for facts, concepts, and rules and principles. For facts, the students were required to identify and match the concept names with their corresponding graphical parts. For concepts, the students were required to identify and match the concept attributes with their corresponding concept names. For rules and principles, the students were required to identify and match the “If…” statements with their corresponding “then…” statements. The only difference between the two questioning strategies was the way that students answered the questions. Students who
received traditional matching questions (T2+T3) were required to covertly identify the relationships between the matching items and choose the correct answers by clicking on the corresponding radio buttons. Students who received direct manipulation matching questions (T4+T5) were also required to covertly identify the relationships first, but instead of passively clicking on the corresponding radio buttons, they were required to overtly drag the correct answers and drop them into the corresponding placeholders. Although the physical connections between and among the visual and textual information were formed, the physical manipulation itself did not help the students further process the information at a deeper level, nor did it help them build the generative relationships as expected. Students might have already covertly built those relationships because the physical manipulation itself did not require further cognitive processing of the information.

The results of this study indicated that covertly building generative relationships was as effective as both covertly and overtly building these relationships for factual, conceptual, and rules and principles learning. The overtly building relationships provided by direct manipulation matching questions did not help nor interfere with students’ constructing the generative relationships for factual, conceptual, and rules and principles learning.

Furthermore, the results found that students who received traditional matching questions (T2+T3) showed higher mean scores than those who received direct manipulation matching questions (T4+T5) on all three criterion tests when data were analyzed using all test items as well as the subset of difficult items. Although the differences were not statistically significant at the .05 alpha level, but according to Huck
(2004), the difference between the two questioning strategies was approaching marginal significance on the comprehension test. The trends showed in the mean scores may be explained by the following reasons:

*Firstly, compared to the traditional matching questions, direct manipulation matching questions is a “… novel, unconventional, demanding and possibly a distracting generative strategy for students” (Haag, 1995, p. 86).* Haag (1995) suggested that because manipulation strategy is novel, unconventional, demanding, and possibly distracting, students may need to be trained to become familiar with this type of instructional strategy and their instructional purposes in order to benefit from it. Similarly, Hooper, Sales, and Rysavy (1994) suggested that in order for the students to use generative learning strategies effectively, they need to practice using these strategies.

This may be especially true when students who received direct manipulation matching questions (T4+T5) interacted with the matching questions in such a novel fashion as required in this study. Students who received direct manipulation matching questions were required to correctly identify and match the relationships between the matching items by dragging either concept names, concept attributes, or the “If…” statements and dropping them into corresponding placeholders on a visual frame of the whole heart containing an outline of the primary parts. For facts, they were required to correctly identify and match the concept names with their corresponding graphical parts by dragging the concept names and dropping them into the placeholders pointing to their corresponding graphical parts. For concepts, they were required to correctly identify and match the concept attributes with their corresponding concept names by dragging the concept attributes and dropping them into the placeholders under their corresponding
concept names. For rules and principles, they were required to correctly identify and
match the “If…” statements with their corresponding “then…” statements by dragging
the “If…” statements and drop them into the placeholders above their corresponding
“then…” statements.

Compared to the traditional matching questions, this type of questioning strategy
was a novel and unconventional strategy. Students probably had never seen these types of
matching questions before, therefore, they most likely did not understand the purpose of
this questioning strategy. In addition, they were not given any instructions as to how to
use this questioning strategy to better help them build generative relationships, nor were
they given any opportunities to practice with this strategy. Therefore, they might have felt
confused and had to spend some time trying to figure out what they were supposed to do
instead of concentrating on constructing generative relationships. As a result, instead of
directing the students’ attention toward constructing relationships, the direct manipulation
questioning strategy might have delayed students from focusing on and constructing the
generative relationships until they figured out what they were supposed to do.

Comparatively, students were more familiar with the traditional matching
questions. Students who received traditional matching questions (T2+T3) were required
to correctly identify and match the relationship between the matching items by clicking
on the corresponding radio buttons. Students were more familiar with the way that the
matching questions were presented and the way to answer those questions. Therefore,
they could quickly focus their attentions on building the generative relationships and
finding the correct answers. Haag (1995) further explained this in detail:
With increased exposure, students perhaps become more visually literate in acquiring information and constructing meaning from this static visual presentation of information. Consequently, learners may tend to rely upon these established and well-honed strategies for learning, rather than attempting to cognitively interact with unfamiliar methods of manipulating visual information. (p. 87)

Compared to the traditional matching questions, the direct manipulation matching questions also seemed very demanding and possibly distracting because students were required to physically manipulate the information while constructing generative relationships between the visual and textual information (Haag, 1995). According to Paivio’s (1971; 1986) dual coding theory, the chances of retrieval are doubled when information is dually coded because learners have two ways to retrieve the information. It was expected that direct manipulation matching questions would facilitate learning by adding an extra form of stimulus to the sensory register, touch, to facilitate associative processing and referential processing. Therefore, the chances of retrieval would be increased since information was coded visually, verbally, and kinesthetically. However, the results of the study did not support the effectiveness of the direct manipulation matching questions. On the contrary, the results suggested that the extra form of stimulus, touch, might have increased the students’ cognitive load of processing the incoming visual and verbal information to the extent that it might have distracted them from concentrating on building the generative relationships covertly. The results were contradictory to the suggestions made by Hutchins et al. (1985) that direct manipulation
interface minimizes the learner’s cognitive mental effort by creating a bridge between the
learner’s task and the way that the task can be accomplished via the interface.

Secondly, the manipulation or generative reorganization of information might
have made the recall of specific facts and concepts more difficult for some learners. This
argument was corroborated by the results reported by Perrig (1988) and Haag (1995).
Perrig (1988) found that motor activities improved performance in recognition of location
or spatial relationship but did not improve the recall of conceptual information. The
results of Haag’s (1995) study supported Perrig’s research and found manipulation
strategies groups showed the lowest mean scores on the identification and drawing tests
which required the students to identify and reproduce the correct locations of the parts of
the heart. She suggested that the manipulation required in these treatments may have
failed to activate the necessary processing of the textual and visual information and even
made the recall of specific facts and concepts more difficult. The results found in this
study accorded with those reported in previous literature.

Thirdly, students with higher prior knowledge or familiarity with the content will
benefit more from a conventional instructional strategy (Haag, 1995). All 184 student
volunteers in this study were from a Biological Science course: Human Body. They
might have had some prior experience with the heart content. Snow and Lohman (1984)
suggested that conventional methods are more effective for learners with higher prior
knowledge. Mayer (1984) found when learners are familiar with the instructional content
or when learners have developed appropriate learning strategies, additional instructional
strategies are less likely to be effective. Haag (1995) accorded with these previous
findings and suggested that students with higher prior knowledge or are familiar with the
content will benefit more from a conventional instructional strategy instead of manipulation strategy. The findings of this study corroborated with the findings in the literature evidenced by the higher mean scores of the traditional matching questions over direct manipulation matching questions on all three criterion tests, although the differences were not statistically significant.

**Questioning Strategies Groups vs. No Questions Control Group**

Additional results indicated that students who received no questions (T1) performed equally well to those who received traditional matching questions (T2+T3) and those who received direct manipulation questions (T4+T5) on all three criterion tests when data were analyzed with all test items and on the identification and comprehension tests when data were analyzed with the subset of difficult items. However, students who received traditional matching questions (T2+T3) performed significantly better than those who received no questions (T1) on the terminology test when data were analyzed with the subset of difficult items. These results may be explained by the following reasons.

*First of all, the participants might have been very interested in the heart content, and therefore, might have been highly motivated to learn.* As mentioned above, all 184 student volunteers in this study were from a Biological Science course: Human Body. Although this was a non-major biology entry level course and students in this class were from all kinds of imaginable majors on campus, students who chose to enroll to this course obviously were very interested in biology, especially human body. Therefore, they might have been motivated to try their best to learn the instructional material. As a result,
students in the no questions control group still performed as well as those students who received either traditional matching questions or direct manipulation matching questions. Secondly, the instructional material itself might be powerful enough that the students did not need additional instructional practice strategies to facilitate their learning. No matter which groups the students were assigned to, they all went through the twenty web-based instructional screens with instructional text on the left and the corresponding static graphic on the right. The differences were that students in treatments 2, 3, 4, and 5 received questions and feedback practices on difficult content, while students in the control group (T1) did not receive any practices. The instructions with instructional text and corresponding static graphics have been established to be powerful enough to aid learning of this instructional material about human heart, which was corroborated in a series of previous experimental studies using the same instructional materials (Haag, 1995; Lin, 2001; Owens, 2002; Wilson, 1998; Zhu & Grabowski, 2006), especially when it was improved with color-coding strategies which was expected to facilitate the concept learning tasks (Dwyer, 1978). The power of this instructional strategy is well supported by the dual coding theory (Paivio, 1971; 1986) and also reported in previous literature. For example, Mayer and Anderson (1992) found that students who possessed low prior knowledge attained a higher degree of learning when verbal and visual information were presented simultaneously. Mayer (1997) found that using the coordinated presentation of explanations in a visual format (illustrations) was effective.

It seemed that the students in this study, with great interests in the instructional material and very powerful web-based instructions, did not need additional practice
strategies to aid their learning. However, the fact that the students who received traditional matching questions (T2+T3) performed better than those who received no questions (T1) on the terminology test when data were analyzed with the subset of difficult items indicated that students did benefit from traditional matching questions on learning difficult concepts.

Effects of Three Levels of Feedback Strategies

Research question two was raised to find out if there were any differences among the three levels of feedback strategies (no feedback, KOR text feedback only, KOR text plus animation-elaborated feedback) in facilitating student achievement on different criterion tests. It was expected that animation-elaborated feedback (T3+T5) would better facilitate the encoding and retrieval processes because it provided immediate and additional informational feedback by demonstrating or elaborating a lesson fact, concept, rule or principle when the learner’s response was correct. Comparatively, KOR text feedback (T2+T4) would be less effective since it simply informed the learner whether a response was correct or wrong (Dempsey et al., 1993). And the control treatment (T1) would be the least effective since no feedback strategies were provided.

The results of this study indicated that the three levels of feedback strategies were equally effective in facilitating student achievement on the three criterion tests. The results concurred with those reported by Rieber and his colleagues (Rieber, 1996; Rieber et al., 1996) that graphical feedback, textual feedback, and graphical plus textual feedback were equally effective for students to learn explicit knowledge. However, the
results were contradictory to what was expected based on the literature. This may be explained by the following reasons.

First of all, compared to KOR text feedback, students were not familiar with the animation-elaborated feedback strategy and might not know how to attend to the relevant cues or details provided by animation. This is especially true when students who received KOR text plus animation-elaborated feedback (T3+T5) interacted with the feedback provided in this study. In this study, animation-elaborated feedback provided immediate informational feedback by demonstrating or elaborating a lesson fact, concept, rule or principle when the learner’s response was correct. For facts, it highlighted the corresponding graphical parts of the concepts. For concepts, it demonstrated the attributes of the corresponding concepts. For rules and principles, it illustrated the cause-and-effect or correlational relationships between the “If…” and “then…” statements.

It was very easy for the students to understand the purpose of the KOR text feedback since it informed them whether or not their responses were correct. The students saw either “Correct” or “Wrong” after their each response, and they understood right away that it was the feedback given to them. For the two KOR text plus animation-elaborated feedback groups (T3+T5), animation-elaborated feedback was played simultaneously with the KOR text feedback: either highlighting the corresponding graphical parts of the concepts, or demonstrating the attributes of the corresponding concepts, or illustrating the cause-and-effect or correlational relationships between the “If…” and “then…” statements depending on what level of learning the student was practicing. However, it might be very hard for the students to understand the purpose of the animation. The students were not informed that they would see animation-elaborated
feedback with the KOR feedback nor were they informed of the purpose of this feedback strategy. In addition, they were not given any directions as to what information they should focus their attentions on, nor were they given any opportunities to practice with this strategy. Therefore, instead of benefiting from this feedback strategy, students might have felt confused. They were probably just passively viewing the animation without knowing what information they should attend to, let alone coding the information into their LTM. As a result, learning was not improved.

The support of this reasoning can be found in previous literature. Dwyer (1978) emphasized the importance of the coding process in facilitating teaching and learning and explained:

… if information has not been adequately coded prior to being transmitted, or if the learners have not been given sufficient directions as to how to code specific type of information, or if learners have not had ample opportunity to develop the basic prerequisites to coding the incoming stimuli, learning will be, at least, less than optimum. (p. 142)

He further suggested that students need to acquire or develop the coding process, rules, or strategy in order to benefit the most from visual presentations.

Rieber (1990) also suggested that “… when learners are novices in the content area, they may not know how to attend to relevant cues or details provided by animation” (p. 82). He further suggested that animated graphics should be coupled with interactive instructional strategy directing learners’ attention to the most important information in the graphic overtly. Rieber (2000) explained this in detail:
Designers and developers forget that they become content experts of the materials they produce. Information contained in an animated sequence, though wonderfully obvious to them, may be totally overlooked by students. Even if students appear to be attending to the surface-level features of an animated display, they still may be unable to draw out, or “read,” the information contained in the animation. The answer may lie in the fact that students are probably not accustomed or trained in interpreting animated information. … students must be sufficiently cued and guided in order to take advantage of the potential learning effects of animation. (p. 174)

The support of this recommendation can be found in several experimental studies (Baek & Layne, 1988; Reed, 1985; Rieber, 1991) as well.

Therefore, additional instructional strategies may be needed for the students to direct their attention to the most important information provided by animation-elaborated feedback. Perhaps, directions should be given to the students informing them that they would receive a “Correct” or “Wrong” feedback as well as an animation feedback which would help them to better understand the content, and that they should pay attention to both types of feedback and use the information provided to better learn the content.

Another possible instructional strategy is to provide students textual information simultaneously with the animation-elaborated feedback, directing them to the most important information in the animation. Mayer and Anderson’s (1991) study suggested that animation was completely ineffective when presented without verbal support. It indicated that students were not able to attend to and further understand the most important information provided by animation without verbal support. The results of the
study accorded with what was found in their study. The KOR text feedback in this study only provided “Correct” or “Wrong” feedback. Only some animation-elaborated feedback contained verbal information. For example, “Auricles have thin walls” and “Ventricles have thicker walls” were displayed when animation demonstrated the attribute of ventricles that they are the chambers with thickest walls (see Figure 10). Other animation-elaborated feedback did not contain any verbal information to direct students’ attentions or help them understand the animation-elaborated feedback (see Figure 11). As a result, students did not benefit from the animation-elaborated feedback.

Secondly, animation-elaborated feedback, when used with text feedback, might distract students’ attentions from building generative relationships instead of facilitating their cognitive processing. Closely examining how the students interacted with the animation-elaborated feedback strategy may provide further insights. Students who received KOR text plus animation-elaborated feedback (T3+T5) were required to covertly establish generative relationships between the matching items, and then either click on the corresponding radio buttons on the left side of the screen underneath each matching item or drag and drop the matching items on the left side of the screen to the corresponding placeholders depends on which group they were in. Once they chose the correct answer, KOR text feedback was displayed at the top of the screen informing them whether their response was right or wrong. Simultaneously, animation-elaborated feedback was played on the right side of the screen, either highlighting the corresponding graphical parts of the concepts, or demonstrating the attributes of the corresponding concepts, or illustrating the cause-and-effect or correlational relationships between the “If…” and “then…” statements. The student’s attention was both drawn to the top of the
screen to the KOR text feedback as well as to the right side of the screen to the animation-elaborated feedback. They could quickly get the information provided by the KOR text feedback, however, they might not have been able to identify the information provided by the animation because of the following reasons: (1) they had to split their attention to both types of information at different locations of the screen; (2) they were not familiar with the animation-elaborated feedback strategy and might not know how to attend to relevant cues or details provided by animation, as explained above; and (3) sometimes, the animation happened so fast that they might not have had enough time to learn anything from it before the animation was finished. Although they could click on the “Reset” button provided on the screen to practice again, general observation by the researcher found few students did that. As a result, the animation-elaborated feedback interfered with students’ cognitive processing of building the generative relationships instead of facilitating this process as evidenced by the lower mean scores of students who received KOR text plus animation-elaborated feedback (T3+T5) compared to those who received KOR text feedback alone (T2+T4) on the three criterion tests, although the differences were not statistically significant. This distraction might have been even worse when students were trying to build the “If…” and “then…” relationships as evidenced by the lower mean scores of the students who received KOR text plus animation-elaborated feedback (T3+T5) compared to those who received no feedback (T1) on the comprehension test, although the differences were not statistically significant.

Thirdly, the characteristics of the participants and the powerful instructional material itself could also help explain the equal effects of the different levels of feedback strategies: (1) all 184 student volunteers in this study were from a Biological Science
course who might have been very interested in the heart content, and therefore, might have been highly motivated to learn; and (2) the instructional material itself might be powerful enough so that the students did not need any extra instructional practice strategy to aid their learning this content.

**Interactions between the Level of Questioning and Feedback Strategies**

Research question three was raised to find out if there was an interaction between the level of questioning strategies and the level of feedback strategies.

The review of the literature supported the advantages of using direct manipulation matching questions and animation-elaborated feedback, therefore, it was expected students who received direct manipulation matching questions (T4+T5) would perform better than those who received traditional matching questions (T2+T3), and students who received KOR text plus animation-elaborated feedback (T3+T5) were expected to perform better than those who received KOR text feedback only (T2+T4). When the questioning strategies were used in combination with the feedback strategies, it was expected that students who received traditional matching questions in combination with KOR text feedback (T2) would perform the worst; while students who received direct manipulation matching questions in combination with animation-elaborated feedback (T5) would perform the best. Table 27 below illustrated the different combinations of questioning and feedback strategies students in each group received.
The order of student achievement in the five treatment groups was expected to be as follows: T5>T4>T2>T1 and T5>T3>T2>T1.

The analysis revealed that statistically, there were no significant differences for student achievements on the three criterion tests among the five treatments groups when data were analyzed with all test items (F = 1.24, $p = .251$) as well as the subset of difficult items (F = 1.69, $p = .066$). The interaction profile plots for all three criterion tests using all test items (see Figures 16-18) as well as the subset of difficult items in each criterion test (see Figures 19-21) did not show any interactions between the question level and the feedback level.

Although the trends of the mean scores were contrary to what was expected, the results corroborated with the expectation that there was no significant interaction between the level of the questioning strategy and the level of feedback strategy.

**Conclusions**

Based on the findings of the study and the detailed discussions of the findings, the following conclusions have been drawn:

<table>
<thead>
<tr>
<th>Traditional matching questions</th>
<th>KOR Text Feedback</th>
<th>KOR Text + Animation-Elaborated Feedback</th>
</tr>
</thead>
<tbody>
<tr>
<td>Direct manipulation questions</td>
<td>T4</td>
<td>T5</td>
</tr>
</tbody>
</table>

Table 27

*Different Questioning and Feedback Strategies Students in Each Group Received*

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*Note. T1: Control group which contained no questions and no feedback.*
1. Traditional matching questions and direct manipulation matching questions
   were equally effective in facilitating student achievement on factual,
   conceptual and rules and principles learning.

2. No questions, traditional matching questions, and direct manipulation
   matching questions were equally effective in facilitating student achievement
   on factual, and rules and principles learning.

3. Compared to no questions, traditional matching questions were more effective
   in facilitating difficult conceptual learning.

4. No feedback, KOR text feedback, and KOR text plus animation-elaborated
   feedback were equally effective in facilitating student achievement in factual,
   conceptual, and rules and principles learning.

5. Instructional text with corresponding static graphics is still a very powerful
   instructional strategy.

6. Students needs to be guided or trained in order to possibly benefit from direct
   manipulation questions.

7. Additional instructional strategy is needed in order to direct learner’s attention
   to the most important information provided by animation (Rieber, 1990,
   2000).

**Implications for Instructional Designers**

Based on the literature, the previous research and findings of the present study,
the following suggestions are provided for instructional designers:
1. *Traditional matching questions vs. direct manipulation matching questions.*
   The results of this study revealed traditional matching questions were equally effective as direct manipulation matching questions in facilitating student achievement on all three criterion tests. Therefore, for factual, conceptual, and rules and principles learning, it does not make any difference in student learning to use either traditional matching questions or direct manipulation matching questions. However, traditional matching questions are more cost-effective since it is more expensive to design direct manipulation matching questions.

2. *Direct manipulation matching questions, traditional matching questions, and no questions.* The results revealed there were no significant differences among these three levels of questioning strategies in facilitating student achievement on the identification and comprehension tests. So for factual and rules and principles learning, using any one of these three questioning strategies and should be equally effective.

3. *Traditional matching questions vs. no questions.* The results showed traditional matching questions were more effective than no questions in facilitating student achievement on difficult items in the terminology test. This result provides support to the process of using traditional matching questions to enhance concepts in the instruction where students are having difficulties.

4. *KOR text plus animation-elaborated feedback, KOR text feedback, and no feedback.* The result of the study indicated there were no significant differences among these three levels of feedback strategies on all three
criterion tests. So for factual, conceptual, and rules and principles learning, using any one of these three feedback strategies should yield similar results.

5. **Concurrent presentation of several forms of feedback.** Instructional designers should be careful when providing students several forms of feedback simultaneously as they might split learner’s attention instead of focusing his or her attention on important information.

6. **Instructional text with corresponding static graphics is still a very powerful instructional strategy.** This is well supported by the dual coding theory (1971; 1986) and several previous studies (Mayer, 1997; Mayer & Anderson, 1992). Therefore, it may not be necessary to use additional instructional strategies to facilitate learning, especially when learners have higher prior knowledge or when learners are familiar with the content.

7. **Provide additional instructional strategies when using direct manipulation matching questions.** If using direct manipulation matching questions, additional instructional strategies may be needed to inform learners of the instructional purpose of these questions, provide learners opportunity to practice with this questioning strategy, and provide learners suggestions on how to interact with this questioning strategy.

8. **Provide additional instructional strategies when using animations.** If using animation strategies, additional instructional strategies may be needed to direct learner’s attention to the most important information provided by the animation. Learners need to be informed of the instructional purposes of this feedback strategy, to have the opportunity to practice with this strategy, and to
be advised on how to interact with this strategy and what kind of information they should attend to.

9. **Instructional strategies to enhance visualized instruction.** In the current study, questioning and feedback strategies were used in conjunction with complementing visualized instruction which itself had been specifically designed to complement the verbal instruction. The results of this study provide insights as to how questioning and feedback strategies make contribution to the process of enhancing visualized instruction.

**Recommendations for Future Research**

Several trends revealed in the current study are calling for continued future research in this area. First of all, students who received traditional matching questions (T2+T3) had marginally significant higher mean scores than those who received direct manipulation matching questions (T4+T5) on the comprehension test when data were analyzed with all items as well as the subset of difficult items.

Another important trend among the mean scores revealed that students who received traditional matching questions (T2+T3) and those who received direct manipulation matching questions (T4+T5) had higher mean scores than students who received no questions (T1) on the identification and terminology tests. Although the differences were not statistically significant except that students who received traditional matching questions (T2+T3) performed significantly better than those who received no questions (T1) on difficult items of the terminology test, the trends showed the tendency
that participants were getting some help from these two questioning strategies that match cognitive requirements of different levels of learning. However, students who received direct manipulation matching questions (T4+T5) had lower mean scores, although not significantly, than those who received no questions (T1) on the comprehension test, which indicated that the direct manipulation matching questions might be more distracting rather than helping students build the “If…” and “then…” relationships for rules and principles.

While not statistically significant, these trends are compelling enough to warrant continued research in this area.

The following recommendations are provided for future research.

1. Rerun the study by providing detailed directions and practice for the direct manipulation matching questions.

2. Rerun the study by providing additional instructional strategies to cue learners to the most important information provided by the animation-elaborated feedback. Chunking (Rieber, 2000) and corresponding instructional text are two possible strategies which may be used to cue learners to the most important information in animation.

3. Rerun the study with a better designed animation-elaborated feedback. In this study, students’ attentions were split between the KOR text feedback and the animation-elaborated feedback. In addition, the animation sometimes happened so fast that the students might not have had enough time to learn anything from it before the animation was finished. These may contribute to the insignificant differences among the feedback strategies found in this study.
Future research may choose to provide KOR text feedback and animation-elaborated feedback separately instead of simultaneously. When providing animation-elaborated feedback, allow learners enough time to process the information.

4. Rerun the study with students from a non-Biological Science course. The fact that all the student volunteers in this study were from a Biological Science course who might have been very interested in biology, and therefore, might have been highly motivated to learn the material may contribute to the insignificant differences results in this study. Therefore, future studies need to be conducted to see if different results will be found with a more general population.

5. Conduct a pilot study before the real study. A pilot study will help to validate the effectiveness of the instructional treatments and the reliability of the criterion tests. Researchers can then make appropriate revisions accordingly before conducting the real study.

6. Investigate the effects of direct manipulation questions and animation-elaborated feedback on higher level learning tasks, such as problem-solving.

7. Investigate the effects of other questioning and feedback strategies and in different combinations. With the development of computer technologies and new software capabilities, it is now possible to provide various innovative, engaging, and interactive questioning and feedback strategies in CBI.
Limitations of the Study

The participants of this study are undergraduate students enrolled in a one hundred level Biological Science course: Human Body. The results of the study are limited to the population of undergraduate students with similar characteristics (e.g., prior knowledge, etc.). Further, this study was delimited to selected questioning and feedback strategies and to the specific levels of learning: factual, conceptual, and rules and principles. Therefore, generalization should be taken cautiously.

Summary

This chapter provides a general discussion based on relevant literature and the overall findings of the experimental study. The findings for each of the research questions and possible reasons for these findings are discussed.

The reason that traditional matching questions and direct manipulation matching questions were equally effective in facilitating student achievement in all criterion tests might be because both of the questioning strategies matched the cognitive processing requirements of different levels of learning. They were functionally the same, but structurally different.

The possible reasons that students who received traditional matching questions (T2+T3) had marginally significant higher mean scores than those who received direct manipulation matching questions (T4+T5) on the comprehension test were as follows:
1. Compared to the traditional matching questions, direct manipulation matching questions is a “... novel, unconventional, demanding and possibly a distracting generative strategy for students” (Haag, 1995, p. 86).

2. The manipulation or generative reorganization of information might have made the recall of specific facts and concepts more difficult for some learners.

3. Students with higher prior knowledge or familiarity with the content will benefit more from a conventional instructional strategy (Haag, 1995).

Students who received no questions (T1) performed equally well to those who received traditional matching questions (T2+T3) and those who received direct manipulation questions (T4+T5) on all three criterion tests when data were analyzed with all test items and on identification and comprehension tests when data were analyzed with the subset of difficult items. These results may be explained by the following reasons:

1. All 184 student volunteers in this study were from a Biological Science course who might have been very interested in the heart content, and therefore, might have been highly motivated to learn.

2. The instructional material itself might be powerful enough.

The three levels of feedback strategies (no feedback, KOR text feedback, and KOR plus animation-elaborated feedback) were equally effective in facilitating student achievement on the three criterion tests. This may be explained by the following reasons:

1. Compared to KOR text feedback, students were not familiar with the animation-elaborated feedback strategy and might not know how to attend to the relevant cues or details provided by animation.
2. Animation-elaborated feedback might distract students’ attentions from building generative relationships instead of facilitating their cognitive processing.

3. The characteristics of the participants and the powerful instructional material itself could also help explain the equal effects of the three levels of feedback strategies.

The results indicated no significant interactions between the level of questioning strategies and the level of feedback strategies.

Important conclusions include:

1. Traditional matching questions and direct manipulation matching questions were equally effective in facilitating student achievement on factual, conceptual and rules and principles learning.

2. No questions, traditional matching questions, and direct manipulation matching questions were equally effective in facilitating student achievement on factual, and rules and principles learning.

3. Compared to no questions, traditional matching questions were more effective in facilitating difficult conceptual learning.

4. No feedback, KOR text feedback, and KOR text plus animation-elaborated feedback were equally effective in facilitating student achievement in factual, conceptual, and rules and principles learning.

5. Instructional text with corresponding static graphics is still a very powerful instructional strategy.
6. Students needs to be guided or trained in order to possibly benefit from direct manipulation questions.

7. Additional instructional strategy is needed in order to direct learner’s attention to the most important information provided by animation (Rieber, 1990, 2000).
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Appendix A

Informed Consent Form

INFORMED CONSENT FORM FOR SOCIAL SCIENCE RESEARCH
The Pennsylvania State University

Title of Project: The Effects of Various Learning Strategies on Students’ Achievement of Different Educational Objectives

Principal Investigator: Li Zhu, 202M Rider II Keller Building, University Park, PA 16802
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Advisor: Dr. Barbara Grabowski, Professor of Education, 315 Keller Building, University Park, PA 16802 (814) 863-7380; blg104@psu.edu

1. Purpose of the Study: The purpose of present research is to find out the effects of various learning strategies in facilitating students’ achievement of different educational objectives.

2. Procedures to be followed: You will take a prior knowledge test first, and then study a web-based instructional script about the human heart, its parts, and functions and then take four tests.

3. Discomforts and Risks: There are no risks in participating in this research beyond those experienced in everyday life.

4. Benefits:
   a. You may gain a greater understanding and appreciation for the wonders of the human heart and how it functions.
   b. The findings of this study will help contribute to the current research and theories on the effects of varied learning strategies on student achievement in different educational objectives.

5. Duration: It will take about 60 minutes to take the prior knowledge test, study the online instructional script and take the four tests.

6. Statement of Confidentiality: The pre and post-tests will be done in ANGEL except the paper-based drawing test; therefore the data will be associated with personal identifiers. But only the person in charge, and her advisor, will know your identity. Your name will be replaced with number code after data is collected. The Penn State’s Office for Research Protections and the Social Science Institutional Review Board may review records related to this project. If this research is published, no information that would identify you will be written.

7. Right to Ask Questions: If you have questions about the research, contact Li Zhu at 883-7023. If you have questions about your rights as a research participant, contact Penn State’s Office for Research Protections at (814) 865-1775.
8. Compensation: Participants will receive 5 extra credit points towards their final grade for the Bi Sci 004 course. You can alternatively choose to get the 5 extra credit points by reading an instructional material provided by the researcher and write a 2-page summary.

9. Voluntary Participation: You do not have to participate in this research. You can end your participation at any time by telling the person in charge. You do not have to answer any questions you do not want to answer.

You must be 18 years of age or older to consent to participate in this research study. If you consent to participate in this research study and to the terms above, please sign your name and indicate the date below.

You will be given a copy of this consent form to keep for your records.

______________________________________  _____________________
Participant Signature     Date

______________________________________  _____________________
Investigator Signature     Date
Appendix B

One Page Directions Screen for Treatment One (Control Group)

DIRECTIONS

You are about to participate in a study which is attempting to investigate the relative effectiveness of different learning strategies on student achievement.

The subject matter deals with the heart, its parts and functions. This instruction contains static color graphics with correspondent texts. Be attentive to both the written and the visual information.

You can advance to the next screen by clicking on the "NEXT" button and go back to the previous screen by clicking the "BACK" button. You may view the instruction as many times as you want.

After you go through this instruction, you will be given a test consisting of several parts. The results of this test will provide us with information assessing the effectiveness of this instruction.

It will be to your advantage to make sure you understand the instructional material on each page before advancing to the next page. There is no time limit in reading this instruction.
Appendix C

One Page Directions Screen for Treatments Two and Four

DIRECTIONS

You are about to participate in a study which is attempting to investigate the relative effectiveness of different learning strategies on student achievement.

The subject matter deals with the heart, its parts and functions. This instruction contains static color graphics with correspondent texts. Be attentive to both the written and the visual information. After several instructional screens, there will be some practice activities. Try your best to complete the items in the practice activities.

You can advance to the next screen by clicking on the "NEXT" button and go back to the previous screen by clicking the "BACK" button. You may view the instruction as many times as you want.

After you go through this instruction, you will be given a test consisting of several parts. The results of this test will provide us with information assessing the effectiveness of this instruction.

It will be to your advantage to make sure you understand the instructional material on each page and before advancing to the next page. There is no time limit in reading this instruction.
Appendix D

One Page Directions Screen for Treatments Three and Five

DIRECTIONS

You are about to participate in a study which is attempting to investigate the relative effectiveness of different learning strategies on student achievement.

The subject matter deals with the heart, its parts and functions. This instruction contains static color graphics and animation with correspondent texts. Be attentive to both the written and the visual information. After several instructional screens, there will be some practice activities. Try your best to complete the items in the practice activities.

You can advance to the next screen by clicking on the "NEXT" button and go back to the previous screen by clicking the "BACK" button. You may view the instruction as many times as you want.

After you go through this instruction, you will be given a test consisting of several parts. The results of this test will provide us with information assessing the effectiveness of this instruction.

It will be to your advantage to make sure you understand the instructional material on each page and before advancing to the next page. There is no time limit in reading this instruction.
In order to better comprehend the following instruction, it will be helpful to visualize a cross-sectional view of a human heart in a position such that you are facing a person. Therefore, the right side of the person’s heart is your visual left, as shown in the above diagram. Likewise, the left side of the person’s heart would be illustrated on the right side in the above diagram.

The human heart is a hollow, bluntly conical, muscular organ. Its pumping action provides the force that circulates the blood through the body. In the average adult, the heart is about five inches long and about two and one half inches thick. A man’s heart weighs about 11 oz. and a woman’s heart weighs about 9 oz.
Screen 3

The heart lies toward the front of the body and is in a slanting position between the lungs, immediately below the breastbone. The wide end points toward the right shoulder. The small end of the heart points downward to the front of the chest and toward the left. The lower portion of the heart is called the apex and is the part that you feel beating.

The human heart is really two pumps combined in a single organ which circulate blood to all parts of the body. The heart is divided longitudinally into two halves by the septum. The two halves may be compared to a block of two houses, which are independent of each other but have a common wall, the septum, between them.
Each half of the heart is divided into an upper chamber and a lower chamber. The upper chamber 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.
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 pericardium. It is composed of a tough, transparent elastic tissue. It protects the heart from rubbing against the lungs and 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 are 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.
Blood enters the heart through veins. Only veins carry blood to the heart. The superior and inferior vena cavae are the two veins which deposit blood in the right auricle; there are no valves at the openings of these veins.

The superior vena cava deposits blood into the right auricle from all body parts above heart level, for example, the head and arms. The inferior vena cava carries blood from parts of the body below heart level, for example, the trunk and legs, depositing blood in the right auricle.

As blood from the body fills the right auricle, some of it begins to flow into the right ventricle immediately, through a common opening.
Screen 7

This common opening, between the right auricle and right ventricle, is called the tricuspid valve. This valve consists of three triangular flaps of thin, strong, fibrous tissue. These flaps permit the flow of blood into the right ventricle, but prevent it from flowing backward into the right auricle because the ends of the flaps are anchored to the floor of the right ventricle by slender tendons.

Thus, blood passes from the right auricle through the tricuspid valve into the right ventricle. As the right ventricle is filled with blood, both ventricles begin to contract created pressure.
While the blood pressure behind the tricuspid valve brings the flaps together and prevents the flow of blood between the right auricle and the right ventricle, the contraction of the right ventricle continues until the blood presses hard enough to open the pulmonary valve.

The pulmonary valve, located between the right ventricle and the pulmonary artery, consists of three flaps like the tricuspid valve. As soon as the right ventricle begins to relax from its contraction, the valve flaps are filled with blood backing up from the pulmonary artery. The flaps are pressed together stopping the blood flow back into the right ventricle. The pulmonary valve only opens when the pressure in the right ventricle is greater than the pressure in the pulmonary artery, forcing the blood into the artery.

In the pulmonary artery the blood is carried away from the heart to both the left and right lungs where it is cleansed and oxygenated.
Returning from the lungs, the blood enters the heart through four pulmonary veins and collects in the left auricle; these vein openings, like the vena cavae, have no valves. The left auricle then contracts when it is full, squeezing blood through the mitral valve into the left ventricle.

The mitral valve, located between the left auricle and the left ventricle, is similar in construction to the tricuspid valve. As the left ventricle contracts simultaneously with its mate, the right ventricle, it forces blood behind the flaps of the valve thereby closing the passageway back to the left auricle. Like the tricuspid valve, the ends of the mitral valve flaps are anchored to the floor of the left ventricle by slender tendons.
The contraction of the left ventricle pumps the blood through the entire body. For this reason it is the largest, strongest, and most muscular section of the heart. When the left ventricle is filled with blood, it contracts resulting in pressure opening the aortic valve. The aortic valve is similar to the other flap like valves; the valve stops the backward flow of blood to the left ventricle and opens for the forward flow of blood to the aorta.

The aorta is the large artery which carries the blood away from the heart back to the various parts of the body.
The Circulation of Blood Through the Heart

The directional flow of blood in the heart is determined by valves which allow the blood to flow in only one direction. These sets of valves are the tricuspid and mitral valves, which control the flow of blood from the auricles to the ventricles, and the pulmonary and aortic valves which control the flow of blood from the ventricles to the arteries.
Both auricles receive blood simultaneously through vein openings which have no valves. The right auricle receives its blood through the superior and inferior vena cava, while the left auricle receives its blood through the pulmonary veins.
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.
The instant that the contraction of the auricles has been completed, the ventricles are stimulated to contract. This contraction increases the pressure in the ventricle chambers forcing the tricuspid and mitral valves completely closed, thereby preventing blood from being forced backwards into the auricles.

The auricles, relaxing from their contraction, receive a continuous blood flow from the vena cava and the veins.
As the ventricles continue to contract, pressure in these chambers force the pulmonary and aortic valves to open. 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.

Both are 3 flapped valves, and are together known as the semi-lunar valves. Prior to ventricle contraction, the 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.
With the semi-lunar valves open, blood flows from the right ventricle into the pulmonary artery on route to the lungs for cleaning and oxygen. Simultaneously, blood flows from the left ventricle into the aorta for distribution throughout the entire body.
Immediately following the pumping of blood into the arteries, the ventricles begin to relax. This relaxation lowers the pressure within their chambers and the greater pressure in the arteries close the semi-lunar valves. Pressure within the ventricles is sufficient, however, to maintain closure of the tricuspid and mitral valves against the already increasing auricle pressure.
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.
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.
The second phase, the systolic or contraction phase, begins when the auricles contract. The blood is forced through the tricuspid and mitral valves into the ventricles. The ventricles then contract forcing the blood through the semi-lunar valves into the pulmonary and aortic arteries.

The blood leaves the ventricles under terrific pressure and surges through the arteries with a force so great that it bulges their elastic walls. At this point, arterial blood pressure is greatest; we refer to this pressure as the systolic pressure.
The heart begins to relax again. The semi-lunar valves are closed; blood flows into the auricles from the veins, and the tricuspid and mitral valves are forced partially open.

The diastolic phase begins, and the cycle of blood pressure starts again.

- **End of instructional materials** -
  Review the instructional materials until you feel you have mastered the concepts presented.

- **Ask for Testing Materials** -
  When you are finished, raise your hand to receive the testing materials from the researcher. Once you start the test, you can not review the instruction any more.

  Note: do not close any window yet!
Appendix F
Ten Practice Screens for Treatments Two and Three

Practice 1

Directions: Select the answer you feel best identifies the part of the heart indicated by each numbered arrow. When you have correctly answered all the items, the "NEXT" button will be activated so that you can proceed to the next screen. Click on the "Reset" button if you want to practice again.

Mitral Valve
01 02 03 04 05

Tricuspid Valve
01 02 03 04 05

Epicardium
01 02 03 04 05

Myocardium
01 02 03 04 05

Pericardium
01 02 03 04 05
Practice 2

Directions: Select the answer you feel best completes the sentence. When you have correctly answered all the items, the "NEXT" button will be activated so that you can proceed to the next screen. Click on the "Reset" button if you want to practice again.

_____ is (are) the chamber(s) with thickest wall(s).
01 02 03 04

_____ is also called the heart muscle, and it controls the contraction and relaxation of the heart.
01 02 03 04

_____ is the layer that forms the outer wall of the double-walled membranes.
01 02 03 04

_____ is the inner portion of the double-walled membranes and it is attached to the heart muscle.
01 02 03 04
**Practice 3**

**Directions:** Select the answer you feel best completes the sentence. When you have correctly answered all the items, the "NEXT" button will be activated so that you can proceed to the next screen. Click on the "Reset" button if you want to practice again.

1. _____ are the veins that deposit blood from the lungs into the left auricle.
   - 1
   - 2
   - 3

2. _____ are the vessels that carry blood away from the heart.
   - 1
   - 2
   - 3

3. _____ are the veins that deposit blood from the body into the right auricle.
   - 1
   - 2
   - 3
Practice 4

Directions: Select the answer you feel best completes the sentence. When you have correctly answered all the items, the "NEXT" button will be activated so that you can proceed to the next screen. Click on the "Reset" button if you want to practice again.

_____ is the largest, strongest, and most muscular section of the heart and pumps the blood through the entire body.
  01  02  03

_____ carries the blood from the right ventricle through pulmonary valve away from the heart back to both lungs.
  01  02  03

_____ carries the blood from the left ventricle through aortic valve away from the heart back to the body.
  01  02  03
Practice 5

Directions: Select the answer you feel best completes the sentence. When you have correctly answered all the items, the "NEXT" button will be activated so that you can proceed to the next screen. Click on the "Reset" button if you want to practice again.

___ are located at the entrance to the pulmonary and aortic arteries.
01 02 03

If blood from the body is passing through the superior and inferior vena cava simultaneously, then ___
01 02 03

If the blood is passing through the pulmonary arteries, then ___
01 02 03

1 it is also passing through aorta.
2 Semi-lunar Valves
3 it is also passing through pulmonary veins.
Practice 6

Directions: Select the answer you feel best completes the sentence. When you have correctly answered all the items, the "NEXT" button will be activated so that you can proceed to the next screen. Click on the "Reset" button if you want to practice again.

If the auricles contract simultaneously, then _____
○ 1 ○ 2

If the ventricles contract simultaneously, then _____
○ 1 ○ 2

1. Blood is forced out the pulmonary and aortic valves.
2. Blood is forced out the tricuspid and mitral valves.
Practice 7

Directions: Select the answer you feel best completes the sentence. When you have correctly answered all the items, the "NEXT" button will be activated so that you can proceed to the next screen. Click on the "Reset" button if you want to practice again.

If the blood in the aorta is exerting a superior pressure on the aortic valve, then ____
○ 1 ○ 2 ○ 3

If the tricuspid and mitral valves are forced shut, then ____
○ 1 ○ 2 ○ 3

If the pressure in the right ventricle is superior to that in the pulmonary artery and blood is being forced out of the right ventricle, then ____
○ 1 ○ 2 ○ 3

1. the pulmonary and aortic valves are open.
2. the tricuspid valve is closed.
3. the mitral valve is beginning to open.
Practice 8

Directions: Select the answer you feel best completes the sentence. When you have correctly answered all the items, the "NEXT" button will be activated so that you can proceed to the next screen. Click on the "Reset" button if you want to practice again.

If it is during the first contraction of the systolic phase, then ____
 ○ 1  ○ 2

If it is during the second contraction of the systolic phase, then ____
 ○ 1  ○ 2

1. pulmonary and aortic valves are fully open.
2. tricuspid and mitral valves are fully open.
Practice 9

Directions: Select the answer you feel best completes the sentence. When you have correctly answered all the items, the "NEXT" button will be activated so that you can proceed to the next screen. Click on the "Reset" button if you want to practice again.

If it is during the diastolic phase, then
○ 1 ○ 2

If it is during the systolic phase, then
○ 1 ○ 2

1. the auricles contract first simultaneously, then the ventricles contract.

2. the ventricles relax after auricles.
Practice 10

Directions: Select the answer you feel best completes the sentence. When you have correctly answered all the items, the "NEXT" button will be activated so that you can proceed to the next screen. Click on the "Reset" button if you want to practice again.

If it is during the systolic phase, then_____
⊙1  ⊙2

If it is during the diastolic phase, then_____
⊙1  ⊙2

1 blood is being forced away from the heart through the pulmonary and aortic arteries.

2 the ventricles are relaxing, partially full of blood.
**Appendix G**

**Ten Practice Screens for Treatments Four and Five**

**Practice 1**

**Directions:** Select the name you feel best identifies the part of the heart indicated by each arrow and drag and drop it into the corresponding box. When you have correctly completed all the items, the "NEXT" button will be activated so that you can proceed to the next screen. Click on the "Reset" button if you want to practice again.

- Mitral Valve
- Tricuspid Valve
- Epicardium
- Myocardium
- Pericardium
Practice 2

**Directions:** Identify the statement on the left you feel best describes each term and drag and drop it into the corresponding box. When you have completed all the items, the "NEXT" button will be activated so that you can proceed to the next screen. Click on the "Reset" button if you want to practice again.

- ____ is (are) the chamber(s) with thickest wall(s).

- ____ is also called the heart muscle, and it controls the contraction and relaxation of the heart.

- ____ is the layer that forms the outer wall of the double-walled membranes.

- ____ is the inner portion of the double-walled membranes and it is attached to the heart muscle.
Practice 3

**Directions:** Identify the statement on the left you feel best describes each term and drag and drop it into the corresponding box. When you have completed all the items, the "NEXT" button will be activated so that you can proceed to the next screen. Click on the "Reset" button if you want to practice again.

____ are the veins that deposit blood from the lungs into the left auricle.

____ are the vessels that carry blood away from the heart.

____ are the veins that deposit blood from the body into the right auricle.

- Pulmonary and Aortic Arteries
- Superior and Inferior Vena Cava
- Pulmonary Veins
Practice 4

Directions: Identify the statement on the left you feel best describes each term and drag and drop it into the corresponding box. When you have completed all the items, the "NEXT" button will be activated so that you can proceed to the next screen. Click on the "Reset" button if you want to practice again.

_____ is the largest, strongest, and most muscular section of the heart and pumps the blood through the entire body.

_____ carries the blood from the right ventricle through pulmonary valve away from the heart back to both lungs.

_____ carries the blood from the left ventricle through aortic valve away from the heart back to the body.
Practice 5

Directions: Identify the statement on the left you feel best completes the sentence and drag and drop it into the corresponding box. When you have completed all the items, the "NEXT" button will be activated so that you can proceed to the next screen. Click on the "Reset" button if you want to practice again.

___ is (are) located at the entrance to the pulmonary and aortic arteries

If blood from the body is passing through the superior and inferior vena cava simultaneously, then ___

If the blood is passing through the pulmonary arteries, then ___

it is also passing through aorta.

it is also passing through pulmonary veins.

Semi-lunar Valves
Practice 6

Directions: Identify the statement on the left that you feel best completes the sentence and drag and drop it into the corresponding box. When you have completed all the items, the "NEXT" button will be activated so that you can proceed to the next screen. Click on the "Reset" button if you want to practice again.

If the auricles contract simultaneously, then_____

If the ventricles contract simultaneously, then_____

blood is forced out the pulmonary and aortic valves.

blood is forced out the tricuspid and mitral valves.
Practice 7

Directions: Identify the statement on the left you feel best completes the sentence and drag and drop it into the corresponding box. When you have completed all the items, the "NEXT" button will be activated so that you can proceed to the next screen. Click on the "Reset" button if you want to practice again.

If the blood in the aorta is exerting a superior pressure on the aortic valve, then_____

If the tricuspid and mitral valves are forced shut, then_____

If the pressure in the right ventricle is superior to that in the pulmonary artery and blood is being forced out of the right ventricle, then_____

the pulmonary and aortic valves are open.

the tricuspid valve is closed.

the mitral valve is beginning to open.
Practice 8

Directions: Identify the statement on the left you feel best completes the sentence and drag and drop it into the corresponding box. When you have completed all the items, the "NEXT" button will be activated so that you can proceed to the next screen. Click on the "Reset" button if you want to practice again.

If it is during the first contraction of the systolic phase, then _____

If it is during the second contraction of the systolic phase, then _____

pulmonary and aortic valves are fully open.

tricuspid and mitral valves are fully open.
Practice 9

Directions: Identify the statement on the left you feel best completes the sentence and drag and drop it into the corresponding box. When you have completed all the items, the "NEXT" button will be activated so that you can proceed to the next screen. Click on the "Reset" button if you want to practice again.

If it is during the diastolic phase, then ____

If it is during the systolic phase, then ____

- the auricles contract first simultaneously, then the ventricles contract.
- the ventricles relax after auricles.
**Practice 10**

**Directions:** Identify the statement on the left you feel best completes the sentence and drag and drop it into the corresponding box. When you have completed all the items, the "NEXT" button will be activated so that you can proceed to the next screen. Click on the "Reset" button if you want to practice again.

If it is during the systolic phase, then_____

If it is during the diastolic phase, then_____

- Blood is being forced away from the heart through the pulmonary and aortic arteries.
- The ventricles are relaxing, partially full of blood.
Appendix H

Physiology Pretest

Directions:

1. You can take the pretest only once. There is no time limit in this pretest. Take it using your best knowledge.
2. In the following 36 multiple-choice questions, select the answer which you feel best completes the sentence. Only one choice may be selected.
3. After you finish the pretest, click "Submit" button to submit your answers.

Research Study Pretest

1. The part of the tooth which contains the hardest substance in the body is the
   - A. root
   - B. dentine
   - C. cement
   - D. enamel

2. The digestion of food occurs principally in the
   - A. stomach
   - B. small intestine
   - C. mouth
   - D. large intestine

3. Contraction of the smooth muscle of the alimentary canal is called
   - A. peristalsis
   - B. digestion
   - C. absorption
   - D. assimilation

4. Worn-out red blood cells are decomposed in the
   - A. heart
   - B. lungs
   - C. kidneys
   - D. liver
5. "Swollen" glands means an enlargement of the
   - A. lymph nodes
   - B. heart valves
   - C. vena cava
   - D. portal vein

6. The chief value of perspiration is that it
   - A. eliminated body odors
   - B. opens the pores
   - C. reduces weight
   - D. regulates body temperature

7. Endocrine glands produce
   - A. enzyme
   - B. endoplasm
   - C. hormones
   - D. serums

8. The body is stimulated to usual activity by increase secretion from the
   - A. pancreas
   - B. adrenal glands
   - C. thyroid gland
   - D. thymus gland

9. The spinal cord is made up of
   - A. bone tissue
   - B. cartilage tissue
   - C. connective tissue
   - D. nerve tissue

10. Nerves from the eyes and ear are connected to the
    - A. cerebellum
    - B. cerebrum
    - C. medulla
    - D. spinal cord

11. The chromosome number of the body cells of identical human twins is
    - A. 12
    - B. 24
    - C. 46
12. The person who can give blood to another person but can receive only his own type of blood has blood type

☐ A. A
☐ B. O
☐ C. AB
☐ D. B

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

14. The ribs protects the

☐ A. stomach
☐ B. breastbone
☐ C. spinal cord
☐ D. lungs

15. The hollow interior of the long bones is filled with

☐ A. marrow
☐ B. minerals
☐ C. red and white corpuscles
☐ D. Haversian canals

16. The windpipe is located ______ the esophagus

☐ A. in front of
☐ B. behind
☐ C. to the left of
☐ D. to the right of

17. The carbon dioxide-oxygen exchange with the atmosphere occurs in the

☐ A. nose
☐ B. trachea
☐ C. lungs
☐ D. bronchi
18. Blood is oxygenated in the capillaries of the
   ☐ A. air sacs
   ☐ B. heart
   ☐ C. muscle
   ☐ D. liver

19. During inspiration, the ribs
   ☐ A. do not move
   ☐ B. move downward
   ☐ C. move inward
   ☐ D. move upward

20. The part of the brain that controls respiration is the
   ☐ A. medulla
   ☐ B. cerebellum
   ☐ C. cerebrum
   ☐ D. spinal cord

21. A defense of the body against bacteria is
   ☐ A. haemoglobin
   ☐ B. phagocytes
   ☐ C. red blood cells
   ☐ D. blood platelets

22. The disease haemophilia is associated with
   ☐ A. the bone structure
   ☐ B. blood clotting
   ☐ C. the structure of nervous tissue
   ☐ D. the formation of red corpuscles

23. The liquid that bathes every cell and acts as a medium of exchange is
   ☐ A. cell sap
   ☐ B. fibrinogen
   ☐ C. lymph
   ☐ D. fibrin

24. Urine is stored in an organ called
   ☐ A. diaphragm
   ☐ B. kidney
   ☐ C. bladder
25. Secretions of the ductless glands pass
   - A. into tubes or ducts
   - B. directly into the blood stream
   - C. directly into the organs where they are used
   - D. out of the body

26. Inactivity of the thyroid gland from infancy may produce a condition known as
   - A. diabetes
   - B. beriberi
   - C. cretinism
   - D. Addison's disease

27. The concentration of sodium and potassium in the blood is controlled by
   - A. adrenin
   - B. cortin
   - C. insulin
   - D. secretin

28. Diabetes is caused by the improper functioning of the
   - A. parathyroids
   - B. thyroids
   - C. pancreas
   - D. adrenals

29. The adult human heart is said to beat approximately ____ times a minute
   - A. 85
   - B. 72
   - C. 60
   - D. 58

30. Growth and repair of body tissue involves
   - A. protein
   - B. fats
   - C. starch
   - D. sugar
31. Blood enters the heart through
   - A. arteries
   - B. vena cava
   - C. the aortic arch
   - D. pulmonary veins

32. Blood leaves the heart through the
   - A. tricuspid valve
   - B. aorta
   - C. superior vena cava
   - D. mitral valve

33. The portion of the heart which divides it longitudinally into 2 halves is called the
   - A. myocardium
   - B. tendons
   - C. pericardium
   - D. septum

34. A blood vessel which carries deoxygenated blood is the
   - A. aorta
   - B. pulmonary artery
   - C. hepatic artery
   - D. pulmonary vein

35. The backward flow of blood in the veins is prevented by
   - A. muscles
   - B. valves
   - C. the heart beat
   - D. lymphatics

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 I

Identification Test

Directions:

1. There is no time limit in this test.

2. Select the answer you feel best identifies the part of the heart indicated by the numbered arrows and mark the corresponding radio button. When finished with the test, click the "Submit" button to submit your answers.

Note: the graphics for all the questions in this test are the same. It's just for your convenience so that it's put in front of every question.

Identification Test

1. Arrow number one (1) points to the

   ☐ A.  Septum
   ☐ B.  Aorta
   ☐ C.  Pulmonary Artery
   ☐ D.  Pulmonary Vein
   ☐ E.  None of these
2. Arrow number two (2) points to the
☐ A. Superior Vena Cava
☐ B. Inferior Vena Cava
☐ C. Pulmonary Artery
☐ D. Tricuspid Valve
☐ E. Aorta

3. Arrow number three (3) points to the
☐ A. Right Ventricle
☐ B. Right Auricle
☐ C. Left Ventricle
☐ D. Left Auricle
☐ E. Heart Muscle
4. Arrow number four (4) points to the
   - A. Pulmonary Valve
   - B. Pulmonary Vein
   - C. Aortic Valve
   - D. Tricuspid Valve
   - E. Mitral Valve

5. Arrow number five (5) points to the
   - A. Aorta
   - B. Pulmonary Artery
   - C. Superior Vena Cava
   - D. Inferior Vena Cava
   - E. Pulmonary Vein
6. Arrow number six (6) points to the
   A. Aortic Valve
   B. Pulmonary Valve
   C. Mitral Valve
   D. Tricuspid Valve
   E. Semi-Lunar Valve

7. Arrow number seven (7) points to the
   A. Left Ventricle
   B. Right Ventricle
   C. Right Auricle
   D. Left Auricle
   E. Vascular Space
8. Arrow number eight (8) points to the
   - A. Myocardium
   - B. Ectoderm
   - C. Pericardium
   - D. Endocardium
   - E. Epicardium

9. Arrow number nine (9) points to the
   - A. Endocardium
   - B. Myocardium
   - C. Pericardium
   - D. Ectoderm
   - E. Septum
10. Arrow number ten (10) points to the

◇ A. Endocardium
◇ B. Pericardium
◇ C. Septum
◇ D. Myocardium
◇ E. Aortic Base

11. Arrow number eleven (11) points to the

◇ A. Epicardium
◇ B. Pericardium
◇ C. Endocardium
◇ D. Myocardium
◇ E. None of These
12. Arrow number twelve (12) points to the
   - A. Pericardium
   - B. Myocardium
   - C. Endocardium
   - D. Endoderm
   - E. Apex

13. Arrow number thirteen (13) points to the
   - A. Pericardium
   - B. Endocardium
   - C. Ectocardium
   - D. Endoderm
   - E. Myocardium
14. Arrow number fourteen (14) points to the
   - A. Right Ventricle
   - B. Left Ventricle
   - C. Left Auricle
   - D. Right Auricle
   - E. Apex

15. Arrow number fifteen (15) points to the
   - A. Pulmonary Veins
   - B. Tendons
   - C. Aortas
   - D. Pericardium
   - E. None of These
16. Arrow number sixteen (16) points to the

- A. Venic Valve
- B. Pulmonary Valve
- C. Tricuspid Valve
- D. Mitral Valve
- E. Aortic Valve

17. Arrow number seventeen (17) points to the

- A. Superior Vena Cava
- B. Tricuspid Valve
- C. Aortic Valve
- D. Pulmonary Valve
- E. Mitral Valve
18. Arrow number eighteen (18) points to the
   - A. Right Auricle
   - B. Right Ventricle
   - C. Left Auricle
   - D. Left Ventricle
   - E. Semi-Lunar Chamber

19. Arrow number nineteen (19) points to the
   - A. Inferior Vena Cava
   - B. Superior Vena Cava
   - C. Aortas
   - D. Pulmonary Veins
   - E. Pulmonary Arteries
20. Arrow number twenty (20) points to the

- A. Inferior Vena Cava
- B. Aorta
- C. Pulmonary Artery
- D. Septum
- E. Superior Vena Cava
Appendix J

Terminology Test

Directions:

1. There is no time limit in this test.

2. Select the answer you feel best completes the sentence and mark the corresponding radio button. When finished with this test, click the "Submit" button to submit your answers.

1. _____ is(are) the thickest walled chamber(s) of the heart.
   - A. Auricles
   - B. Myocardium
   - C. Ventricles
   - D. Pericardium
   - E. Endocardium

2. The contraction of the heart occurs during the ______ phase.
   - A. Systolic
   - B. Sympathetic
   - C. Diastolic
   - D. Parasympathetic
   - E. Sympatric

3. Lowest blood pressure in the arteries occurs during the _____ phase.
   - A. Sympatric
   - B. Sympathetic
   - C. Diastolic
   - D. Systolic
   - E. Parasympathetic

4. Blood from the right ventricle goes to the lungs through the _____.
   - A. Tricuspid Valve
   - B. Aortic Artery
   - C. Pulmonary Artery
   - D. Pulmonary Veins
5. The ______ is(are) the strongest section(s) of the heart.
   - A. Left Ventricle
   - B. Aorta
   - C. Septum
   - D. Right Ventricle
   - E. Tendons

6. When blood returns to the heart from the lungs, it enters the _____.
   - A. Left Auricle
   - B. Pulmonary Valve
   - C. Left Ventricle
   - D. Right Ventricle
   - E. Pulmonary Artery

7. Vessels that allow the blood to flow from the heart are called the _____.
   - A. Veins
   - B. Arteries
   - C. Apex
   - D. Tendons
   - E. Valves

8. Blood passes from the left ventricle out the aortic valve to the _____.
   - A. Lungs
   - B. Body
   - C. Aorta
   - D. Pulmonary Artery
   - E. Left Auricle

9. The chamber of the heart which pumps oxygenated blood to all parts of the body is the _____.
   - A. Right Auricle
   - B. Left Auricle
   - C. Aorta
   - D. Left Ventricle
   - E. Right Ventricle

10. The _____ is another name for the part of the heart called the heart muscle.
    - A. Apex
    - B. Epicardium
    - C. Endocardium
11. _____ is(are) the part(s) of the heart which controls its contraction and relaxation.
   - A. Myocardium
   - B. Endocardium
   - C. Ventricles
   - D. Auricles
   - E. Septum

12. The _____ is the name given to the inside lining of the heart wall.
   - A. Epicardium
   - B. Endocardium
   - C. Pericardium
   - D. Myocardium
   - E. Septum

13. Blood from the body enters the heart through the _____.
   - A. Aortic Artery
   - B. Pulmonary Veins
   - C. Pulmonary Artery
   - D. Superior and Inferior Vena Cava
   - E. Superior Vena Cava Only

14. The membrane which borders on the inside lining of the pericardium and is connected to the heart muscle is called the ________.
   - A. Extomim
   - B. Epicardium
   - C. Endocardium
   - D. Myocardium
   - E. Ectocardium

15. The _____ allow(s) blood to travel in one direction only.
   - A. Septum
   - B. Valves
   - C. Arteries
   - D. Veins
   - E. Tendons
16. The _______ is the common opening between the right auricle and the right ventricle.

☐ A. Mitral Valve
☐ B. Tricuspid Valve
☐ C. Septic Valve
☐ D. Pulmonary Valve
☐ E. Aortic Valve

17. The _______ is the triangular flapped valve between the left auricle and the left ventricle.

☐ A. Aortic Valve
☐ B. Pulmonary Valve
☐ C. Septic Valve
☐ D. Tricuspid Valve
☐ E. Mitral Valve

18. The semi-lunar valves are located at the entrance to the ________.

☐ A. Pulmonary Veins
☐ B. Superior and Inferior Vena Cavas
☐ C. Pulmonary and Aortic Arteries
☐ D. Mitral and Tricuspid Valves
☐ E. Ventricles

19. The outside covering of the heart is called the ________.

☐ A. Endocardium
☐ B. Epicardium
☐ C. Pericardium
☐ D. Myocardium
☐ E. None of These

20. Immediately before entering the aorta, blood must pass through the ________.

☐ A. Left Ventricle
☐ B. Mitral Valve
☐ C. Lungs
☐ D. Superior Vena Cava
☐ E. Aortic Valve
Appendix K

Comprehension Test

Directions:

1. There is no time limit in this test. 2. Select the answer you feel best answers the question and mark the corresponding radio button. When finished with this test, click the "Submit" button to submit your answers.

Comprehension Test

1. Which valve is most like the tricuspid in function?
   - A. Pulmonary
   - B. Aortic
   - C. Mitral
   - D. Superior Vena Cava

2. When blood is being forced out the right ventricle, in which position is the tricuspid valve?
   - A. Beginning to open
   - B. Beginning to close
   - C. Open
   - D. Closed

3. When the blood is being forced out the aorta, it is also being forced out of the
   - A. Pulmonary Veins
   - B. Pulmonary Arteries
   - C. Superior Vena Cava
   - D. Cardiac Artery

4. The contraction impulse in the heart starts in
   - A. The Right Auricle
   - B. Both Ventrices simultaneously
   - C. Both Auricles simultaneously
   - D. The Arteries

5. In the diastolic phase the ventricles are
   - A. Contracting, full of blood
   - B. Contracting, partially full of blood
   - C. Relaxing, full of blood
6. During the first contraction of the systolic phase, in what position will the mitral valve be?

- A. Beginning to open
- B. Open
- C. Beginning to close
- D. Closed

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

- A. Pulmonary and Aortic Arteries
- B. Superior and Inferior Vena Cavas
- C. Tricuspid and Mitral Valves
- D. Pulmonary Veins

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

- A. Mitral Valve
- B. Pulmonary Veins
- C. Pulmonary Artery
- D. Aorta

9. When the heart contracts, the

- A. Auricles & Ventricles contract simultaneously
- B. Ventricles contract first, then the Auricles
- C. Right side contracts first, then the left side
- D. Auricles contract first, then the Ventricles

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

- A. Pulmonary Veins
- B. Aorta
- C. Inferior Vena Cava
- D. Pulmonary Artery

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

- A. Tricuspid Valve
- B. Pulmonary Veins
- C. Aorta
- D. Pulmonary Valve
12. When the pressure in the right ventricle is superior to that in the pulmonary artery, in what position is the tricuspid valve?

☐ A. Closed
☐ B. Open
☐ C. Beginning to Close
☐ D. Confined by pressure from the Right Auricle

13. When the ventricles contract, blood is forced out the

☐ A. Superior and Inferior Vena Cavas
☐ B. Pulmonary Veins
☐ C. Tricuspid and Mitral Valves
☐ D. Pulmonary and Aortic Valves

14. Blood leaving the heart through the aorta had left the heart previously through the

☐ A. Vena Cavas
☐ B. Pulmonary Veins
☐ C. Pulmonary Artery
☐ D. Tricuspid and Mitral Valves

15. When the blood in the aorta is exerting a superior pressure on the aortic valve, what is the position of the mitral valve?

☐ A. Closed
☐ B. Open
☐ C. Beginning to open
☐ D. Confined by pressure from the Right Ventricle

16. When the tricuspid and mitral valves are forced shut, in what position is the pulmonary valve?

☐ A. Closed
☐ B. Beginning to open
☐ C. Open
☐ D. Beginning to close

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

☐ A. Fully open
☐ B. Partially open
☐ C. Partially closed
☐ D. Fully closed

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

☐ A. Entering only the Vena Cavas
☐ B. Being forced out the Pulmonary and Aortic Valves
C. Passing through the Tricuspid & Mitral Valves
D. Being forced out through the Pulmonary Artery

19. If the aortic valve is completely open, the

A. Second contraction of the Systolic phase is occurring
B. Diastolic phase is occurring
C. Tricuspid & Mitral Valves are completely open
D. Blood is rushing into the Right & Left Ventricles

20. When the heart relaxes, the

A. Auricles relax first, then the Ventricles
B. Right side relaxes first, then the left side
C. Left side relaxes first, then the right side
D. Ventricles relax first, then the Auricles
VITA

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