THE EFFECT OF VARIED CONCEPT MAPS AND SELF-DIRECTED LEARNING ABILITY ON STUDENTS’ HYPERMEDIA LEARNING

A Dissertation in

Instructional Systems

by

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ABSTRACT

The purpose of this study was to examine the instructional effectiveness of varied concept maps in measuring different learning objectives for students with different levels of self-directed learning abilities in a hypertext environment.

This study adopted a randomized-based experimental design. A two (high and low levels of self-directed learning ability) by four (instructional treatments with or without concept maps) factorial research model was built. The independent variables were concept map and self-directed learning; the dependent variables were the three criterion tests (identification, terminology, and comprehension test) measuring participants’ hypermedia learning performances. Multivariate Analysis of Variance (MANOVA), a primary statistical technique, was used in this experimental study.

Undergraduate students (n=126) voluntarily participated in this study. Based on the median score of the SDLRS measurement, student participants were divided into two levels (high or low) of self-directed learning. Through stratified sampling, participants in each group were randomly assigned into four instructional treatments: Treatment 1 (Control 1: text-only), Treatment 2 (Control 2: static images), Treatment 3 (traditional concept maps), and Treatment 4 (visualized-based concept maps).

Through data analysis, this study yielded eight findings:

2. Different concept maps would not influence students’ self-directed learning abilities since no significant interaction existed between instructional strategy (concept maps) and self-directed learning.

3. Visualized-based concept maps were significantly better than traditional concept maps for identification and terminology tests.

4. Traditional concept maps would not significantly support student learning.

5. Static images (visuals) significantly improved students’ learning performances.

6. Participants’ background information, as extraneous variables, would not influence the results of this study.

7. Visual instruction was students’ preference. Both visualized-based concept maps and static visual effectively supported student learning.

8. Based on Guglielmino’s standard, students’ self-directed learning abilities tend to be low level in this study.
# TABLE OF CONTENTS

LIST OF TABLES ........................................................................................................ vii  
LIST OF FIGURES ...................................................................................................... viii  
ACKNOWLEDGEMENTS ............................................................................................... ix  
Chapter 1  INTRODUCTION ......................................................................................... 1  
  Background Information ......................................................................................... 1  
  Problem Identification ............................................................................................ 3  
  Purpose of Study .................................................................................................... 5  
  Research Questions ............................................................................................... 6  
  Research Hypotheses ............................................................................................ 7  
  Project Significance .............................................................................................. 8  
  Definition of Terminology .................................................................................... 9  
  Summary .............................................................................................................. 12  
Chapter 2  REVIEW OF THE LITERATURE ................................................................. 13  
  Cognitive Information Processing ........................................................................ 13  
    Cognitive Learning ............................................................................................. 13  
    Information Processing Theory ......................................................................... 14  
  Scaffolding in an Online Environment ................................................................ 16  
    The Concept of Scaffolding .............................................................................. 16  
    Different Types of Scaffolds ............................................................................. 17  
  Self-Directed Learning .......................................................................................... 18  
    The Concept of Self-Directed Learning .............................................................. 18  
    Characteristics of a Self-directed Learner ......................................................... 20  
    Self-directed Learning and Academic Performance ......................................... 21  
    Instruments for Measuring Self-directed Learning .......................................... 22  
  Concept Mapping .................................................................................................. 24  
    The Meaning of Concept Mapping .................................................................. 24  
    The Effect of Concept Mapping on Learning .................................................... 25  
    The Trend of Research-Based Studies ................................................................ 26  
    Related Studies ................................................................................................ 28  
  Theoretical Justification ....................................................................................... 30  
  Summary .............................................................................................................. 32  
Chapter 3  RESEARCH METHODS ............................................................................ 34  
  Instrumentation ................................................................................................... 34  
    Instructional Material ....................................................................................... 34  
    Self-directed Learning Measurement ................................................................ 35  
    Criterion Tests .................................................................................................. 36  
  Research Design ................................................................................................... 37  
    The Structure of Experimental Design .............................................................. 37  
    Instructional Treatments ................................................................................... 38  
  Pilot Study 1 ........................................................................................................ 44  
  Pilot Study 2 ........................................................................................................ 46  
  Major Study ......................................................................................................... 49
### Chapter 4  RESULTS OF THE RESEARCH

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Research Participants</td>
<td>55</td>
</tr>
<tr>
<td>Background Information</td>
<td>55</td>
</tr>
<tr>
<td>Stratified Sampling</td>
<td>56</td>
</tr>
<tr>
<td>Analysis of SDLRS Pretest</td>
<td>57</td>
</tr>
<tr>
<td>Independent T-test</td>
<td>57</td>
</tr>
<tr>
<td>Reliability Analysis</td>
<td>58</td>
</tr>
<tr>
<td>Comparison with Guglielmino’s Normal Distribution</td>
<td>59</td>
</tr>
<tr>
<td>Analysis of Criterion Posttest</td>
<td>60</td>
</tr>
<tr>
<td>Reliability Analysis</td>
<td>60</td>
</tr>
<tr>
<td>Descriptive Statistics</td>
<td>60</td>
</tr>
<tr>
<td>MANOVA Analysis</td>
<td>63</td>
</tr>
<tr>
<td>Statistical Assumption Check</td>
<td>63</td>
</tr>
<tr>
<td>Results of MANOVA</td>
<td>65</td>
</tr>
<tr>
<td>Test of Null Hypotheses</td>
<td>68</td>
</tr>
<tr>
<td>Test of Null Hypothesis 1</td>
<td>68</td>
</tr>
<tr>
<td>Test of Null Hypothesis 2</td>
<td>70</td>
</tr>
<tr>
<td>Test of Null Hypothesis 3</td>
<td>70</td>
</tr>
<tr>
<td>Additional Findings</td>
<td>71</td>
</tr>
<tr>
<td>Additional Finding 1 (Participants’ Experiences)</td>
<td>71</td>
</tr>
<tr>
<td>Additional Finding 2 (Composite Test)</td>
<td>72</td>
</tr>
<tr>
<td>Additional Finding 3 (Gender &amp; Major)</td>
<td>74</td>
</tr>
<tr>
<td>Additional Finding 4 (Item Analysis)</td>
<td>78</td>
</tr>
<tr>
<td>Summary</td>
<td>82</td>
</tr>
</tbody>
</table>

### Chapter 5  DISCUSSION AND CONCLUSIONS

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Summary of the Major Study</td>
<td>84</td>
</tr>
<tr>
<td>Discussion</td>
<td>85</td>
</tr>
<tr>
<td>Conclusions</td>
<td>92</td>
</tr>
<tr>
<td>Limitations</td>
<td>94</td>
</tr>
<tr>
<td>Recommendations for Future Research</td>
<td>95</td>
</tr>
</tbody>
</table>

REFERENCES ........................................................................... 97

| Appendix A (PRETEST MEASUREMENT)                                       | 107  |
| APPENDIX B (POSTTEST MEASUREMENT)                                      | 109  |
| APPENDIX C (INSTRUCTIONAL MATERIAL)                                     | 115  |
| APPENDIX D (INFORMED CONSENT FORM)                                     | 120  |
| APPENDIX E (INSTRUCTIONAL TREATMENT1)                                  | 123  |
| APPENDIX F (INSTRUCTIONAL TREATMENT2)                                  | 134  |
| APPENDIX G (INSTRUCTIONAL TREATMENT3)                                  | 145  |
| APPENDIX H (INSTRUCTIONAL TREATMENT4)                                  | 156  |
LIST OF TABLES

Table 1-1 This Study’s Experimental Study ................................................................. 8
Table 2-1 Related Empirical Studies ......................................................................... 21
Table 2-2 Summary of Chapter2 ............................................................................. 33
Table 3-1 Item Analysis for Pilot Study 1 ................................................................. 45
Table 3-2 Results of T-Test ..................................................................................... 47
Table 3-3 Item Analysis for Pilot Study2 ................................................................. 48
Table 3-4 Actions to Extraneous Factors Affecting Internal Validity .................... 51
Table 4-1 Participants’ Background Information ..................................................... 55
Table 4-2 Distribution of Participants in Treatment Groups .................................... 57
Table 4-3 Assumption Check for T-test (n=126) ....................................................... 57
Table 4-4 Results of Independent-sample T-test ..................................................... 58
Table 4-5 Reliability Analysis of SDLRS ................................................................. 58
Table 4-6 Reliability Analysis for Three Criterion Posttest (n=126) ...................... 60
Table 4-7 Overall Summary for Each Posttest (n=126) ......................................... 61
Table 4-8 Summary of High/Low Group on Each Posttest .................................... 61
Table 4-9 Summary of Instructional Treatment for Each Posttest ......................... 61
Table 4-10 Summary of Instructional Treatment for High-Level Group on Each Posttest 63
Table 4-11 Summary of Instructional Treatment for Low-level Group on Each Posttest 63
Table 4-12 Pearson’s Correlation among Each Posttest ........................................ 64
Table 4-13 Skewness and Kurtosis of Dependent Variables .................................. 64
Table 4-14 Box’s Test of Equality of Covariance Matrices .................................... 65
Table 4-15 Levene’s Test of Equality of Error Variances ....................................... 65
Table 4-16 Overall Results of MANOVA ............................................................... 65
Table 4-17 Detailed Results of MANOVA ............................................................... 66
Table 4-18 Tukey HDS Analysis of MANOVA ......................................................... 67
Table 4-19 Mean Analysis of Students Having Experience Using Concept Mapping 71
Table 4-20 Instructional Treatment on Composite Test ......................................... 72
Table 4-21 Results of ANOVA ............................................................................... 73
Table 4-22 Scheffe Analysis of ANOVA ................................................................. 73
Table 4-23 Results of MANCOVA on Gender ....................................................... 74
Table 4-24 LDS Mean Comparison of MANCOVA ............................................... 75
Table 4-25 Results of MANCOVA for Curriculum Major ..................................... 76
Table 4-26 LDS Mean Comparison of MANCOVA ............................................... 77
Table 4-27 Item Analysis for Major Study-1 ............................................................. 79
Table 4-28 Item Analysis for Major Study-2 ............................................................. 80
Table 4-29 Item Analysis for Major Study-3 ............................................................. 81
LIST OF FIGURES

Figure 1-1 Example of a traditional concept map .......................................................... 10
Figure 1-2 Example of a visualized-based concept map .............................................. 10
Figure 2-1 Atkinson and Shiffrin’s model of information processing .................... 15
Figure 3-1 SDLRS scores’ normal distribution ....................................................... 35
Figure 3-2 Structure of the experimental design ....................................................... 38
Figure 3-3 Learning units in this dissertation ......................................................... 39
Figure 3-4 Sample screenshot for Treatment1 ....................................................... 40
Figure 3-5 Sample screenshot for Treatment2 ....................................................... 41
Figure 3-6 Instructional description of concept mapping ........................................ 42
Figure 3-7 Sample screenshot for Treatment3 ....................................................... 42
Figure 3-8 Instructional description of visualized-based concept mapping ............ 43
Figure 3-9 Sample screenshot in treatment4 ....................................................... 44
Figure 4-1 Sample population distribution ............................................................. 56
Figure 4-2 Histogram of the SDLRS measurement ............................................... 59
Figure 4-3 Means per treatment for three posttests ............................................... 62
Figure 4-4 Means per treatment for composite test .............................................. 72
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Chapter 1

INTRODUCTION

The goal of this chapter is to explain the purpose and need for this study. Specifically, background information, problem identification, purpose of study, research questions, research hypotheses, project significance, and definition of terminology are topics of discussions.

Background Information

Today, the number of higher educational institutions in the United States offering distance education programs is growing (Carr-Chellman, 2005). This trend toward Web-based education spurs, not only the proliferation of online learners (non-campus students) around the country, but also the growth of on-campus resident students taking online courses (Moore & Kearsley, 2005). Although this learning phenomenon builds on the availability and convenience of Web-based advanced technologies, the core of online teaching and learning still relies on reading electronic text (Davis, 2007).

One of the electronic text reading technologies for online learning environments is hypertext materials. These documents, full of hyperlinks, allow learners to navigate Web pages for knowledge exploration (Jonassen, 1993). In the hypertext environment, however, Astleitner and Leutner (1995) suggested that online learners may face a cognitive overload problem when engaging in knowledge acquisition. For this reason, different kinds of instructional scaffolding should be
used to support online students (Chen & Dwyer, 2003; Davis, 2007) “in more efficiently and effectively processing and internalizing course materials” (Sharma, Oliver & Hannafin, 2007, p. 265).

Concept mapping is a visual-based scaffolding which can assist learners’ comprehension of large amounts of information in various learning situations (Ploynivk, 1997; Dabbagh, 2001; Eppler, 2006; Novak & Canas, 2006). Previous empirical research showed that concept mapping benefits students’ learning outcomes. For example, Novark and Musonda’s (1991) 12-year longitudinal analysis of concept mapping of science learning, and Horton et al.’s (1993) meta-analysis on the effectiveness of concept mapping as an instructional tool in classrooms, all confirm that concept mapping can facilitate students’ meaningful learning in knowledge construction.

In online learning settings, in addition to providing appropriate instructional scaffoldings, learners’ self-directed learning abilities also play an important role (Moore & Kearsley, 2005). In theory, students with high levels of self-directed learning often reach high achievement (Chou & Chen, 2008). In this case, Hanna et al. (2000) believed self-directed learning is a key factor to successful online learning. Likewise, Guglielmino and Guglielmino (2003a) contended, although students’ technical skills are important for e-learning, self-direction is even more vital for successful e-learning environment.

In summary, based on this background information, this dissertation explores the instructional effectiveness of integrating concept mapping into an online hypertext learning environment and the effect of learners’ self-directed learning
abilities on their online learning performances.

**Problem Identification**

By reviewing the existing literature of concept mapping and self-directed learning, potential problems may be summarized as follows:

1. Concept mapping
   (a) A need for integration of concept map into online learning: Of those related studies exploring the effect of concept map on learning, few integrate concept map into hypertext environments. Past studies tended to employ new advanced technologies, such as Web 2.0 technologies (see The Horizon Report, 2007), to support student learning and ignored the benefit of simple instructional design.

   (b) Lack of experimental design: The trend of current studies regarding concept map centers on curriculum integration and students’ knowledge evaluation. This type of research only uses a survey or interview method to obtain the effectiveness of concept maps (see Jacobs-Lawson & Hershey, 2000; Roberts, 1999). The number of experimental-based studies is sparse in this area.

   (c) Problematic in learner-generated concept mapping: Past experimental studies tended to design learner-generated concept mapping as one treatment group. However, several studies reported that students must spend a long time learning creation skills and functions of concept mapping (e.g. Novak, 1991). In an experimental study, allowing participants to construct concept maps in a short period of time poses a danger to research design.

   (d) A need for new type of concept map: Past studies all used traditional concept
maps, which contain text-based diagram boxes and arrow links, to design treatment groups. Novak and Canas (2006) considered new concept map, which combines multimedia with traditional concept mapping, is a future developmental model for exploring the learning effectiveness of concept mapping. Also, Wang (2003) recommended that future experimental studies regarding concept map should account for multimedia elements, such as combining static images with traditional concept mapping.

(e) Quantity of concept map: Two past related studies, which employed Dwyer’s (1978) human heart content to design instructional treatments, only provided 5 big concept maps to support student learning for a 2000-word reading material (see Taricarni, 2002; Wang, 2003). Since each concept map encompasses large amounts of information, learners may face a cognitive overload problem. In addition, concept map may not fully exhibit its potential for assisting learners to comprehend information.

2. Self-directed learning

(a) Lack of a reliable measurement for learning outcomes: Past studies only explored the relationship between students’ self-directed learning abilities and learning performance. Neither did they report the reliability of outcome measurements nor conduct an item analysis for outcome measurements (see Hsu & Shiue, 2005; Stewart, 2007).

(b) Assessment for unclear outcome variables: Built on discussion point 2 (a), in past studies, outcome measurements did not describe what types of cognitive outcome variables, such as comprehension or problem solving, were assessed
Past research only used an umbrella term, academic performance, to cover detailed outcome variables.

(c) Lack of experimental design: When past studies empirically inquired into the relationship between students’ self-directed learning abilities and learning performance in distance education, several problems complicated research design (Chou & Chen, 2008). One of key problems is that past research only used a survey research method to explore the effect of self-directed learning rather than an experimental design.

(d) Weak methodological design: Since past studies did not use an experimental design to explore the effect of self-directed learning, low sample size (e.g. low response rate from surveys) and non-randomization (e.g. focusing on one-course students) may influence the research results (Chou & Chen, 2008).

(e) Lack of other independent variables: Past studies only emphasized the role of self-directed learning and ignored other independent variables (see Morris, 1995; Horng, 1995). For example, different online teaching styles and course structures as independent variables may cause an interactive effect with self-directed learning.

**Purpose of Study**

The purpose of this experimental study is to examine the effectiveness of different types of concept maps in measuring different learning objectives for students with different levels of self-directed learning abilities in an hypertext environment. Guglielmino’s (1977) Self-Directed Learning Readiness Scale is the
measurement employed in this dissertation to identify learners’ self-directed learning abilities. Dwyer’s (1978) three objective tests are used to measure learning performance for learners with different concept maps across different learning objectives. Two types of concept maps are used in the online learning context: traditional and visualized-based concept maps. Specifically, the purpose of this study is to:

1. Examine the instructional effectiveness of different types of concept maps in facilitating students’ achievement of different types of learning objectives.
2. Examine whether or not students with different self-directed learning abilities (high and low) achieve differently for different learning objectives.
3. Examine whether or not an interaction exists between types of concept maps and learners’ self-directed learning abilities.

**Research Questions**

Based on the research purpose, this dissertation addresses the following research questions:

1. Do significant differences exist in achievement among students receiving different concept maps?
2. Do students with different self-directed learning abilities (high and low level) achieve differently for different learning objectives?
3. Does a significant interaction exist between types of concept maps and learners’ self-directed learning abilities?
**Research Null Hypotheses**

To answer the research questions, the following research hypotheses need to be tested (C₁, C₂, T₁, and T₂ represent two Control Groups and two Treatment Groups; H and L represent two level of self-directed learning: High and Low):

1. **H₀₁**: No significant differences exist in achievement tests measuring different learning objectives among students receiving different concept maps.
   
   \[ C_1 = C_2 = T_1 = T_2 \]

2. **H₀₂**: No significant differences exist for student achievement of different learning objectives between students identified with H/L level of self-directed learning.
   
   \[ C_{1H} = C_{2H} = T_{1H} = T_{2H} \text{ and } C_{1L} = C_{2L} = T_{1L} = T_{2L} \]

3. **H₀₃**: No significant interaction exists between H/L level of self-directed learning and different concept maps on tests measuring different learning objectives.
   
   \[ C_{1H} = C_{1L}; C_{2H} = C_{2L}; T_{1H} = T_{1L}; T_{2H} = T_{2L} \]

Overall, the research hypothesis is that, with or without instructional scaffoldings in the hypertext environment, students identified as having high levels of self-directed learning may perform better than their counterparts (low levels of self-directed learning). With proper instructional scaffoldings, students identified as having low levels of self-directed learning may enhance their learning performances. Table 1-1 summarizes a main idea described earlier.
Table 1-1 This Study’s Experimental Study

<table>
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<tr>
<th>Treatment</th>
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<th>C₂</th>
<th>T₁</th>
<th>T₂</th>
</tr>
</thead>
<tbody>
<tr>
<td>H (High)</td>
<td>C₁₃</td>
<td>C₂₃</td>
<td>T₁₃</td>
<td>T₂₃</td>
</tr>
<tr>
<td>L (Low)</td>
<td>C₁₄</td>
<td>C₂₄</td>
<td>T₁₄</td>
<td>T₂₄</td>
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Project Significance

Although past studies have confirmed the role of concept map in supporting student learning for non Web-based learning environments (i.e. traditional face-to-face contexts), current research still lacks of empirical data to establish justification for the use of concept map for hypermedia learners. Whether or not concept maps effectively facilitate hypertext learning is worthy of in-depth exploration. In addition, the focus of past studies is on traditional concept maps, and a more current research paradigm needs to seek a varied definition of concept maps to extend the knowledge base in the field of educational technology. Whether different concept maps equally and effectively foster knowledge construction in hypermedia learning settings remains unknown. Implementation of this dissertation will provide concrete evidence for this inquiry.

In theory, a reasonable link exists between self-directed learning and academic success. Whether the learning environment is a traditional classroom or the older style distance learning (e.g. telecommunication), past studies have supported this theoretical statement. However, Chou and Chen (2008) reviewed six empirical
studies exploring the role of self-directed learning on students’ online learning achievements, and reported that the effect of self-directed learning on students’ academic success in Web-based environments is questionable because of poor research design in past studies. Whether or not students with different self-directed learning abilities perform differently in online learning settings is a controversial issue. Implementation of this dissertation will clarify the debate.

**Definition of Terminology**

**Concept Mapping:** Refers to learning scaffolding that supports student learning by using concept maps, which refer to “a representation of meanings or ideational frameworks specific to a domain of knowledge, for a given context of meaning” (Novark, 1990, p.29). In this study, concept mapping is instructor-provided rather than student-generated.

**Traditional Concept Map:** Refers to “a graphical representation where nodes (points or vertices) represent concepts and links (arcs or lines) represent the relationships between concepts. The concepts, and sometimes the links, are labeled on the concept map. The links between the concepts can be one-way, two-way, or non-directional. The concepts and the links may be categorized, and the concept map may show temporal or causal relationships between concepts” (Plotnick, 1997, p.2). Figure 1-1 shows an example of a traditional concept map.
**Visualized-based Concept Map:** Refers to a new type of concept map which combines multimedia elements with a traditional concept map. Figure 1-2 shows an example of a visualized-based concept map, which is developed in this study. When learners move their mouse pointers over a pink oval-shaped box, the visualized-based concept map shows a related image.

**Scaffolding:** Refers to an “adult controlling those elements of the task that are essentially beyond the learner’s capacity, thus permitting him to concentrate upon and complete only those elements that are within his range of competence” (Wood,
Bruner, & Ross, 1976, p. 9). To date, scaffolding no longer restricts interactions between individuals. It has extended to technological tools and instructional techniques, which are often regarded as scaffolds (Puntambekar & Hubscher, 2005). In this dissertation, concept mapping serves as a technological tool for supporting student learning.

**Self-directed Learning:** Refers to adult education experts’ perspectives, in which self-directed learning contains three dimensions: motivation, metacognition, and self-regulation (Long, 2000). Learners with high levels of self-directed learning are active learners who have strong desires for learning, make use of problem-solving skills, have the capacity to engage in independent learning activities, and autonomously manage their own learning (Knowles, 1975; Brockett & Hiemstra, 1991; Candy, 1991; Guglielmino & Guglielmino, 1991; Merriam & Caffarella, 1991; Gibbons, 2002).

**Self-directed Learning Measurement:** Refers to the Self-Directed Learning Readiness Scale, a 58-item 5-point Likert scale, used in this dissertation. Higher scores occurring from using the scale represent higher readiness for self-directed learning (Guglielmino, 1977).

**Hypermedia Learning Material:** Refers to hypertext documents which allow learners to use hyperlinks to navigate web pages at their own paces in the online learning environments.
**Achievement Test:** Refers to academic performance measured by the criterion tests of identification, terminology, and comprehension and a total score of these criterion tests at different levels: factual, conceptual, and principal/procedural.

**Summary**

Hypertext documents (or hypermedia) as main course materials dominate current online learning environments. In this dissertation, concept mapping and self-directed learning are two main focuses, which aim to test the effect on students’ hypermedia learning. Two types of concept maps were developed for this study: traditional and visualized-based concept maps. Guglielmino’s (1977) Self-Directed Learning Readiness Scale was used to identify participants’ self-directed learning abilities. Dwyer’s (1978) three criterion tests were used to measure learners’ hypermedia learning performances. Implementation of this dissertation not only solves existing problems identified in the literature (problem identification), but also provides concrete answers for statements described in the project significance.
Chapter 2

REVIEW OF THE LITERATURE

This chapter summarizes the results of literature review relevant to this study. The scope of the review of the literature covers key theoretical constructs employed in this study, including cognitive information processing, scaffolding in an online environment, self-directed learning, and concept mapping. A theoretical justification of this research ends this chapter.

Cognitive Information Processing

Cognitive Learning

Not until the 1950s did cognitive learning theories reverse the trend that behaviorism dominated for a long time (Bransford, Brown & Cocking, 2000). Cognitivists focus on how people acquire the knowledge in their minds and how knowledge is stored, organized, and retrieved. The major feature of cognitive theory is that prior knowledge can be connected to new information in order to make learning meaningful. From the cognitivists’ perspectives, learners actively construct their understanding and apply knowledge into different situations like problem solving (Pellegrino, Chudowsky & Glaser, 2001). As Jonassen and Land (2000) contended, “…learning is willful, intentional, active, conscious, constructive practice that includes reciprocal intention-action-reflection activities” (p. 5). Therefore, the main point of instruction shifted from a teacher-centered to a student-centered environment. Students are no longer passive information-receivers;
rather, they are active knowledge-constructors.

**Information Processing Theory**

As mentioned earlier, cognitivists’ concerns are about how information people receive can be stored, organized, and retrieved in their minds. Cognitivists’ focus on mental processes and information-reception leads to a well-known theory: information processing theory, whose considerable influence can be seen from the many instructional design books. Indeed, the notable Gagne’s nine events of instruction is constructed on this theory (Richey, 2000).

Based on the information processing theory, educators can explain the internal learning process rather than behavior-observation; that is, the brain deals with and transforms external information. However, the knowledge of this theory is hypothetical. Until now, brain research has not located specific structures in the mind that information processing theory describes (Smith & Ragan, 2005).

The information processing theory can be represented by different models, such as Atkinson and Shiffrin’s Multi-Store Model, Craik and Lockhart’s Level-Processing Model, and Rumelhart and McClelland’s parallel-distributed processing model (Smith & Ragan, 2005). Among these three models, the Multi-Store Model is most widely used for illustrating information processing (Huitt, 2003).

According to Atkinson and Shiffrin’s model as illustrated in Figure 2-1, three important elements in the mind process the information learners receive: (a) sensory register, (b) short-term memory, and (c) long-term memory. The concepts of the
model are: (Atkinson & Shiffrin, 1968; Gagne, 1985; Huitt, 2003; Schunk, 2004; Smith & Ragan, 2005)

![Figure 2-1 Atkinson and Shiffrin’s model of information processing](image)

(Source: Huitt, 2003, p3)

1. Sensory register (or sensory memory) is the first stage of the model. The senses (e.g. vision, hearing, touch, taste, and smell) in the human body receive the information from the situated environment, and then, information transmits to the sensory register in the brain. However, the sensory register only selects the attended information for further consideration. Without this process, the mind would be overwhelmed by too much encountered information.

2. Short-term memory temporarily records the information which passes through the sensory register. The short-term memory has limited size. According to George Miller’s (1956) “Magic Number Seven” study, short-term memory only can hold
five to nine chunks. A chunk could refer to digits, words, chess positions, or people's faces. In addition, the information in short-term memory can be retained for only 5 to 20 seconds. If the information cannot be transferred to long-term memory in this period of time, the information will be lost. In other words, received information will be forgotten in learners’ minds.

3. Long-term memory receives meaningful information from short-term memory. In order to obtain meaningful information, the short-term memory links to prior knowledge already stored in long-term memory. The linking process, encoding information from short-term memory and retrieving information from long-term memory, does not always occur. The process activates by many instructional strategies, such as elaboration or rehearsal. Compared to short-term memory, long-term memory has limitless size and holds information indefinitely.

_Scaffolding in an Online Environment_

_The Concept of Scaffolding_

Scaffolding is an “adult controlling those elements of the task that are essentially beyond the learner’ capacity, thus permitting him to concentrate upon and complete only those elements that are within his range of competence” (Wood, Bruner, & Ross, 1976, p. 9). A theoretical foundation behind scaffolding is Vygotsky’s zone of proximal development which emphasizes the role of social interaction in promoting cognitive development and bridging the gap between what learners actually know and potentially know (Sharma & Hannafin, 2007). To date,
scaffolding no longer restricts interactions between individuals. It has extended to technological tools and instructional techniques, which are often regarded as scaffolds (Puntambekar & Hubscher, 2005). For example, Bell and Linn (2000) employed a technological tool called Knowledge Integration Environment (KIE) to improve students’ reflective thinking and argumentation skills. Zumbach et al. (2006) designed a feedback-based instructional technique to promote a higher-level thinking during online discussions.

**Different Types of Scaffolds**

In online learning settings, Hill and Hannafin (2001) proposed four types of scaffolds: procedural, strategic, metacognitive and conceptual scaffolds, which can be employed to support student learning. Procedural scaffolds assist learners to use online resources and to “clarify requirement and reduce cognitive load” (p. 45). Strategic scaffolds provide learners with alternative approaches to engage online tasks. Metacognitive scaffolds allow learners to “assess what they know and what to do as they learn” (p. 45). Conceptual scaffolds help learners digest online information and facilitate knowledge construction.

In directed distance learning environments (DDLEs), Sharma, Oliver, and Hannafin (2007) defined DDLEs scaffolds as “planned strategies and content structures that assist the learner in more efficiently and effectively processing and internalizing course materials” (p. 265). Basically, DDLEs scaffolds are instructional techniques which aim to improve students’ learning performances in terms of knowledge acquisition.
Saye and Brush (2002) considered two scaffolds to exist in hypermedia learning environments: hard and soft scaffolds. Hard scaffolds are “static supports that can be anticipated and planned in advance based on typical student difficulties with a task” (p. 81). In contrast, soft scaffolds are “dynamic and situational…require teachers to continuously diagnose the understandings of learners and provide timely support based on student responses “(p. 82). These two types of scaffolds must be balanced according to learners’ differences and types of learning (Sharama & Hannafin, 2007).

Hadwin and Winne (2001) distinguished the difference between tacit and explicit scaffolds while creating a software tool called CoNote2. Tacit scaffolds are “tools that are intended to cue students to attend to aspects of their studying without explicitly directing or instructing those studying activities” (p. 322). Oppositely, explicit scaffolds serve as “templates that focused students’ attention by identifying and requiring students to use specific processes” (Sharma & Hannafin, 2007, p. 31).

Self-Directed Learning

The Concept of Self-Directed Learning

The concept of self-directed learning originated in the field of adult education (Roberson, 2005). In the literature, closely related terms include: independent learning, self-planned learning, autonomous learning, self-education, and so forth. (Hiemstra, 1996). Due to the benefits for learning outcomes, school environments and corporate settings strongly emphasize the importance of self-directed learning,
including its value as a required skill needed for work in the 21st century (Murane & Levy, 1996). Likewise, one of the most important tasks for teachers is to enhance students’ self-directed learning abilities (Taylor, 1995).

From adult education experts’ perspectives, self-directed learning contains three dimensions: motivation, metacognition, and self-regulation (Long, 2000). Learners with high levels of self-directed learning are active learners who have strong desires for learning, make use of problem-solving skills, have the capacity to engage in independent learning activities, and autonomously manage their own learning (Knowles, 1975; Brockett & Hiemstra, 1991; Candy, 1991; Guglielmino & Guglielmino, 1991; Merriam & Caffarella, 1991; Gibbons, 2002).

In the literature, self-directed learning had been used as a correlation for students’ academic performances and even as a perfect indicator of predicting academic success in traditional learning settings or non-web-based distance learning (Long, 1991). In this case, Darmayanti (1994) found a positive relationship between self-directed learning and academic success in the traditional classroom setting. A recent study also showed self-directed learning is a strong factor for predicting learners’ academic achievement in non-web-based distance learning (Hsu & Shiue, 2005).

With the growing trend toward online learning, the concept of self-directed learning has received widespread attention again. For this reason, in the book “147 Practical Tips For Teaching On-line Groups: Essentials of Web-based Education,” Hanna et al. (2000) suggested self-directed learning is a key factor to successful online learning. Similarly, Guglielmino and Guglielmino (2003a) contended that
although the students’ technical skills are important for e-learning, self-direction is even more vital in the successful e-learning environment.

**Characteristics of a Self-directed Learner**

The literature described the characteristics of a self-directed learner as many and varied; several characteristics interrelated. The following summarizes the general aspects that appear in the literature (Knowles, 1975; Brockett & Hiemstra, 1991; Candy, 1991; Guglielmino & Guglielmino, 1991; Merriam & Caffarella, 1991; Gibbons, 2002):

1. Independence. Self-directed learners are fully responsible people who can independently analyze, plan, execute, and evaluate their own learning activities.

2. Self-management. Self-directed learners can identify what they need during the learning process, set individualized learning goals, control their own time and effort for learning, and arrange feedbacks of their work.

3. Desire for learning. For the purpose of knowledge acquisition, self-directed learners’ motivations for learning are extremely strong.

4. Problem-solving. In order to achieve the best learning outcomes, self-directed learners make use of existing learning resources and feasible learning strategies to overcome the difficulties which occur in the learning process.

These four characteristics seem to construct a concept which separates self-directed learners from others because self-directed learners will autonomously control their own learning. Despite the autonomous nature of self-directed learners, they need to interact with peers and fellow learners in order to exchange valuable
Self-directed Learning and Academic Performance

In order to fully understand related empirical studies regarding the effect of self-directed learning on academic performance, Table 2-1 summarizes the literature’s findings that occurred in traditional classroom settings and non-web-based contexts.

Table 2-1 Related Empirical Studies

<table>
<thead>
<tr>
<th>Selected Study</th>
<th>Subject</th>
<th>Findings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Savoie (1980)</td>
<td>Nursing students</td>
<td>Positive relationship between self-directed learning and course grade</td>
</tr>
<tr>
<td>Harriman (1990)</td>
<td>Distance education students</td>
<td>Self-directed learning related to achievement</td>
</tr>
<tr>
<td>Anderson (1993)</td>
<td>Social and political science students</td>
<td>Self-directed learning related to academic performance</td>
</tr>
<tr>
<td>Darmayanti (1994)</td>
<td>Distance education students</td>
<td>Positive correlation between self-directed learning and GPA</td>
</tr>
<tr>
<td>Morris (1995)</td>
<td>Business students</td>
<td>Predicting academic success by self-directed learning</td>
</tr>
<tr>
<td>Horng (1995)</td>
<td>Distance education students</td>
<td>Positive relationship between self-directed learning and course grade</td>
</tr>
<tr>
<td>Ogazon (1995)</td>
<td>Business, communication, public administration, and hospitality management students</td>
<td>Self-directed learning is one of the key factors leading to academic success</td>
</tr>
<tr>
<td>Hsu &amp; Shiue (2005)</td>
<td>Distance education students</td>
<td>Predicting academic success by self-directed learning</td>
</tr>
<tr>
<td>Stewart (2007)</td>
<td>Engineering students</td>
<td>Self-directed learning related to learning outcome</td>
</tr>
</tbody>
</table>
From Table 2-1, the findings indicated the link between self-directed learning and academic performance in different disciplines remains unchanged from the past to the present. If this concept can be applied to online environments, online learning administrators might be able to use instructional strategies and activities to enhance a student’s self-directed learning, and further, successful online learning outcomes can be expected. Indeed, Long (2003) suggested that online course facilitators should use diagnostic instruments such as Self-Directed Learning Readiness Scale (discussed later) to identify learners’ abilities for self-directed learning, and then, should implement appropriate instructional strategies.

_Instruments for Measuring Self-directed Learning_

One of the instruments used for measuring self-directed learning, Self-Directed Learning Readiness Scale (SDLRS), was the product of Dr. Guglielmino’s doctoral dissertation. The SDLRS uses a 58-item 5-point Likert scale. Through factor analysis, the scale includes eight factors: openness to learning opportunities, self-concept as an effective learner, initiative and independence in learning, informed acceptance of responsibility for one’s own learning, love of learning, creativity, positive orientation to the future, and ability to use basic study and problem-solving skills. Higher scores occurring from using the scale represent higher readiness for self-directed learning (Guglielmino, 1977).

Since development of the scale by Guglielmino, a number of studies have supported the reliability and validity of the scale (Guglielmino, 1989). According to Guglielmino and Guglielmino (2003b), “This instrument has consistently
demonstrated strong reliability and validity in identifying those who are ready for self-directed learning in its 26-year history” (p.5). However, a recent study conducted by Hoban et al. (2005) conflicts with this statement. They found that the SDLRS can not truly assess medical students’ self-directed learning. They further asserted that other methods for exploring self-directed learning should be considered.

Another instrument for assessing self-directed learning, developed by Dr. Oddi’s doctoral dissertation, is the Oddi Continuing Learning Inventory (OCLI). The OCLI is a 24-item 7-point Likert scale and contains three domains established by factor analysis: proactive/reactive learning drive, cognitive openness/defensiveness, and commitment/aversion to learning. Higher scores in the scale indicate having greater characteristics of a self-directed continuing learner. In this scale, the reliability coefficient also achieves a higher level (more than 0.8) (Oddi, 1984, 1986). However, factor analysis conducted by a recent study suggested that Oddi’s three domains should be extended to four domains. The new four factors created are: learning with others, learner motivation/self-efficacy/autonomy, ability to be self-regulating, and reading avidity (Harvey et al., 2006).

In addition to the two measurements described earlier, a scale, the Bartlett-Kotrlik Inventory of Self Learning, has been newly developed. This measurement is a 49-item 7-point Likert scale and contains 11 factors. According to the developers, social and environment variables, which are not included in the SDLRS or OCLI, were added to the scale. The developers also reported the measurement had high estimates for internal consistency (Bartlett & Kotrlik, 1999).
**Concept Mapping**

*The Meaning of Concept Mapping*

Human beings are visually oriented (Norman, 2004; Dwyer, 2007) and tend to employ various visualization tools to comprehend large amounts of information (Thomas & Cook, 2004). In the education domain, concept mapping is one of visualization-based tools or instructional techniques which support learners’ constructing and representing knowledge (Eppler, 2006).

Concept mapping stems from Ausubel’s assimilation theory of learning which emphasizes the importance of prior knowledge in acquiring new concepts (Novak, 1990). The concept’s developer, Dr. Joseph Novak at the Cornell University, defined concept maps as “a representation of meaning or ideational frameworks specific to a domain of knowledge, for a given context of meaning” (Novak, 1990, p.29). Novak (1990) believed when creating a concept map, learners can systematically integrate prior knowledge in memory with new concepts by organizing verbal (word description) and nonverbal representations (graphics), and in doing so, meaningful learning occurs.

In a concept map, different concepts in two-dimension diagrams are connected by relationship links and arranged in an hierarchical way where general concepts appear at the top level, and a list below contains subordinate concepts (Eppler, 2006). Plotnick (1997) provided an in-depth insight into the operation of a concept map:

“A concept map is a graphical representation where nodes (points or vertices) represent concepts, and links (arcs or lines) represent the relationships between concepts. The concepts, and sometimes the links, are labeled on the concept map. The links between the concepts can be one-way, two-way, or
non-directional. The concepts and the links may be categorized, and the concept map may show temporal or causal relationships between concepts “(p.2).

With increasingly available advanced technologies, traditional hand-drawn concept mapping is gradually being replaced by computer-based concept mapping which allows learners to create concept maps quickly and easily. Today, Inspiration, Mindmap and C-Map are the more popular software programs that corporate trainers and school instructors adopt (Dabbagh, 2001; Eppler, 2006; Novak & Canas, 2006).

Due to the benefit to cognitive development, concept mapping is used for the following purposes: (a) brainstorming creative ideas, (b) designing complex structures, (c) communicating complex ideas, (d) supporting learning process, and (e) assessing understanding or diagnosing misunderstanding (Plotnick, 1997). In addition, concept mapping has been integrated into a variety of curricula in different academic disciplines, including nursing education (All & Havens, 1997), medical education (Torre et al., 2007), teacher education (Zak & Munson, 2008), business education (Simon, 2007), science education (Chang, et al., 2007), engineering education (Upadhyay et al., 2007), liberal arts education (Jacobs-Lawson & Hershey, 2002), distance learning education (Cicognani, 2000), and mathematics education (Roberts, 1999).

**The Effect of Concept Mapping on Learning**

Past empirical research has employed qualitative and quantitative methodologies to confirm the role of concept mapping in facilitating meaningful learning in different knowledge domains (Novak, 1990; Simone, 2007). For example,
through clinical interviews with K-12 students, Novak and Musonda (1991a) explored the effect of concept mapping on students’ science learning over a span of twelve years, and reported that concept mapping significantly fosters students’ cognitive thinking development. Based on the results of 19 empirical studies from 1985 to 1992, Horton et al. (1993) employed a meta-analysis approach to investigate the effectiveness of concept mapping as an instructional tool, and found that concept mapping, integrated into classroom learning, has a positive effect on students’ achievement and attitudes. Therefore, through these two large-scale evaluation studies, apparently, concept mapping, as an instructional technique, strongly influences students’ thinking processes and benefits students’ learning outcomes.

**The Trend of Research-Based Studies**

In the literature, research-based studies of concept mapping can be grouped into four categories: comparison within concept mapping strategies, comparison between concept mapping and other instructional techniques, concept mapping integrated in curriculum teaching and learning, and reports on the literature review of concept mapping. These four types of research are discussed as follows:

1. **Comparison within concept mapping strategies:** In this research category, studies may compare different formats of concept mapping, including instructor-provided versus student completed concept mapping, individual versus group concept mapping, hand-drawn versus computer generated concept mapping, and simple versus enhanced concept mapping. For example, Jo (2001) investigated the effects of two types of concept mapping: instructor-provided
concepts and student-generated concept maps. The results of this study revealed that no insignificant difference existed between those two types. In Smith and Dwyer’s (1995) study, the effect of the two concept mapping strategies, instructor-prepared and learner-generated, was the same.

2. Comparison between concept mapping and other instructional techniques:
   Studies in this category tend to compare the effect of concept mapping with other instructional techniques or learning strategies. For instance, Keng (1996) conducted a comparison study between concept mapping, note-taking, and outlining.

3. Concept mapping integrated in curriculum teaching and learning: A growing trend of research appears in this category where studies integrate a concept mapping strategy into classroom learning, and the studies evaluate students’ understanding of subject knowledge. For example, in Jacobs-Lawson and Hershey’s (2002) study, concept mapping served as an assessment tool to evaluate students’ psychological knowledge in a psychology class. Similarly, Roberts (1999) used concept mapping to measure students’ mathematical knowledge in a statistics class.

4. Reports on the literature review of concept mapping: Studies in this category only report the benefits and applications of concept mapping through literature review. In this case, Simone (2007) reviewed three major uses of concept mapping strategies for postsecondary learning, and proposed the benefits and limitations.

From the above discussion, this dissertation, which falls into the first category,
aims to explore the effect of two concept mapping strategies on students’ online learning, and to find a better approach to foster online reading comprehension.

**Related Studies**

Two empirical studies are closely related to this dissertation. These two studies not only deal with concept mapping strategy, but also use Dwyer’s (1978) heart content to design and develop their treatments. The details are:

1. Taricarni’s (2002) 1 x 5 study.

   In this study, a combination of feedback and concept mapping was an independent variable, and terminology learning and comprehension were dependent variables. One hundred-fifty freshmen at a large northeastern university were randomly assigned to five treatment groups: (a) no concept map generated and no feedback, (b) totally learner generated concept mapping without feedback, (c) totally learner generated concept mapping with feedback, (d) partially learner generated concept mapping with feedback, and (e) partially learner generated concept mapping without feedback. The results of the study showed that: (a) the use of concept mapping was not significantly different from those who did not use concept mapping on criterion test scores, (b) those who did not receive feedback did significantly better than those with feedback on the comprehension test score, (c) those working with partially generated maps with feedback did significantly better on the terminology test score items that matched the learners’ generated items versus those that matched the researcher’s generated ones, and (d) significant differences occurred between science and non-sciences majors.
2. Wang’s (2003) 2x4 study

In this study, a learner’s prior knowledge and concept mapping strategy were independent variables, and different educational achievements were dependent variables. Two hundred-ninety undergraduate students at a large comprehensive state university were randomly assigned into four treatment groups: (a) control (no concept mapping), (b) concept matching mapping, (c) proposition identifying mapping, and (d) student-generated concept mapping. The results of the study showed that: (a) significant differences existed between the three concept mapping treatments and control groups on specific criterion tests, (b) insignificant differences on all criterion tests occurred among the three concept mapping strategies, (c) low prior knowledge students in three concept mapping groups performed better than the control group on specific criterion tests, (d) high prior knowledge students in concept matching mapping performed better than the control group on specific criterion tests, and (e) no significant interaction existed between levels of prior knowledge and the three concept mapping treatments on all criterion tests.

Although using the same instructional material, this study differs with the previous two studies in four ways:

1. Independent variable: One of independent variables in this study is students’ self-directed learning ability. In Dwyer’s program of systematic evaluation, no studies use self-directed learning as an independent variable in designing treatment groups (See Dwyer, 2007).

2. Type of concept maps: The concept maps used in this study are researcher-generated rather than learner-generated. Several studies reported that
students should spend a long time learning creation skills for concept mapping (Novak, 1991b; Wang, 2003). In an experimental study, allowing participants to construct concept maps in a short of period time poses a danger to the research design.

3. Concept mapping strategy: Past studies all used traditional concept mapping, which contains text-based diagram boxes and arrow links, to design treatment groups. The researcher in this dissertation perceives that traditional concept mapping only transforms specific text reading into main idea summaries. Thus, in addition to providing a traditional concept mapping to one of the treatment groups, this dissertation also creates an innovative concept mapping, which combines static images with text-based diagram boxes and arrow links, for one treatment group.

4. Quantity of concept map: The previous two studies discussed earlier only provided 5 big concept maps to support students learning for a 2000-word reading material. The researcher in this dissertation perceives that few concept maps may not exhibit scaffoldings’ potential benefits. In this dissertation, therefore, 19 concept maps are provided to treatment groups.

**Theoretical Justification**

Based on information processing theory, when learners read online hypertext materials, the visual sense of the sensory register intentionally selects attended information for short-term memory. Subsequently, a linking process between short-term memory and long-term memory plays an important role in facilitating
students’ knowledge acquisition in terms of online reading. For this reason, this
dissertation attempts to employ two concept mapping strategies to make the linking
process function well in learners’ minds (Novak, 2008); that is, meaningful learning
and long-term transfer of learning can be achieved.

Today, online learning settings contain many hypertext documents in which
hyperlinks allow learners to navigate web pages with the purpose of knowledge
exploration (Jonassen, 1993; Davis, 2007). However, Astleitner and Leutner (1995)
argued learning in such a text-based environment often leads to goal distraction,
spatial disorientation, and cognitive overload. Therefore, in order to solve these
problems, Chen and Dwyer (2003) suggested that different kinds of instructional
strategies, which derive from a theoretical knowledge base, should be used to
support student learning in online hypertext environments. Of those strategies, based
on early discussion, scaffolding can be regarded as a theory-based instructional
method (Puntambekar & Hubscher, 2005). The researcher in this dissertation
perceives that concept mapping strategies serve a conceptual, DDLEs, hard, and
tacit scaffold (Hadwin & Winne, 2001; Hill & Hannafin, 2001; Saye & Brush, 2002;
Sharma, Oliver, & Hannafin, 2007) in facilitating knowledge acquisition from online
hypertext materials.

Compared to face-to-face learning environments, due to a lack of facial
expression and verbal communication, self-directed learning plays a significant role
in online learning settings (Moore & Kearsley, 2005). Past research, discussed
earlier, showed that self-directed learning is a key factor for students’ learning
outcomes. A positive relationship exists between these two variables. In this
dissertation, a Web-based learning context embedded with four different instructional activities, created by the researcher, is extremely similar to a directed distance learning environment which emphasizes “the acquisition of specified knowledge with aligned assessment” (Sharma, Oliver & Hannafin, 2007, p. 259). The researcher in this dissertation perceives that learners’ self-directed learning abilities may influence knowledge acquisition from online learning materials.

Empirical studies discussed earlier revealed that concept mapping is a valuable learning tool or technique in facilitating students’ knowledge construction and fostering students’ cognitive thinking development. Such learning benefits have led to a variety of applications in different learning contexts. Built on the foundation of past research, the researcher in this dissertation perceives that the concept mapping may also support learning in enhancing students’ online reading performance for different educational objectives. When designing instructional materials for treatment groups, this study constructs not only traditional concept mapping (see Novak, 1990), but also visualized-based concept mapping. The assumption of the latter strategy is based on dual-coding theory, which contends that using verbal (text) and nonverbal (image) representations may strengthen cues for specific information being processed in learners’ minds (Clark & Paivio, 1991).

Summary

This chapter reviews four theoretical constructs: cognitive information processing, scaffolding in an online environment, self-directed learning, and concept mapping. A theoretical justification describes how these five concepts are employed
in this dissertation. Table 2-2 summarizes the main idea of this chapter.

Table 2-2 Summary of Chapter2

<table>
<thead>
<tr>
<th>Construct</th>
<th>Covered Contents</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Information processing</td>
<td>1. Cognitive learning 2. Information processing theory</td>
<td>To describe how students receive information by studying hypermedia</td>
</tr>
<tr>
<td>Scaffolding</td>
<td>1. The concept of scaffolding 2. Different types of scaffolds</td>
<td>To emphasize the importance of online scaffolding (i.e. concept mapping)</td>
</tr>
<tr>
<td>Concept mapping</td>
<td>1. The meaning of concept mapping 2. The effect of concept mapping on learning 3. The trend of research-based studies 4. Related studies</td>
<td>To describe the independent variable, concept map, in detail</td>
</tr>
</tbody>
</table>
Chapter 3

RESEARCH METHODS

This chapter describes the research methods applied in this dissertation. Specifically, chapter three includes instrumentation, research design, pilot study, and major study.

Instrumentation

Instructional Material

The instructional design for four treatment groups in this dissertation has its bases in Dwyer’s (1978) 2000-word heart content material. This instructional script is chosen specifically because (a) “it provided a hierarchy of several types of educational objectives extending from the learning of basic facts to complex problem solving…” (p. 44), (b) its assessment measures reflect high reliability coefficients: 0.83 for terminology test, 0.81 for identification test, 0.77 for comprehension test, and 0.92 for total criterion test, and (c) its contents are not related to participants’ courses of study, thereby, avoiding potential threats to internal validity in its experimental design. In each treatment group, the original instructional script is transformed into online hypertext material with or without provision for scaffolds; that is, concept mapping strategies.
Self-directed Learning Measurement

In this study, Guglielmino’s (1977) Self-Directed Learning Readiness Scale (SDLRS) is utilized to measure students’ self-directed learning ability because SDLRS is a widely accepted measurement to assess self-directed learning ability (Merriam & Caffarella, 1991). The SDLRS uses a 58-item 5-point Likert scale. Overall scores range from 58 to 290. 214 is a cut score for an average adult population, including normal adults, older adults, and young adults (college students). Scores higher than 214 occurring in the SDLRS represent higher readiness for self-directed learning (See Figure 3-1). However, since participants in this dissertation are all young adults, using 214 as a cut score may be inappropriate. Instead, the median score of students’ self-directed learning was used to divide participants into high and low levels of self-directed learners.

![Figure 3-1 SDLRS scores’ normal distribution](Source: Guglielmino, 2008)
A number of empirical studies have supported the reliability and validity of the SDLRS (Guglielmino, 1989). For instance, McCune and Guglielmino (1991) analyzed 3,125 SDLRS test scores and the analysis yielded a reliability coefficient of 0.91. A meta-analysis of 29 studies involving SDLRS also provided evidence of validity (Hsu & Shiue, 2005).

**Criterion Tests**

Three post-test criterion tests are used to measure students’ learning performance after students complete the instructional treatments. Detailed descriptions of three tests are adapted and summarized as the follows (Dwyer, 1978, pp. 45-47):

1. Identification test: This test evaluates students’ abilities to identify parts or positions of an object. This multiple-choice test (20 items) requires students to identify the numbered parts on a detailed drawing of a human heart. The objective of this test is to measure the ability of the student to use visual cues to discriminate one structure of the heart from another and to associate specific parts of the heart with their proper names.

2. Terminology test: This test consists of 20 multiple-choice items designed to measure knowledge of specific facts, terms, and definitions. The objectives measured by this type of test are appropriate to all content areas that have an understanding of basic elements as a prerequisite to the learning of concepts, rules, and principles.

3. Comprehension test: This test consists of 20 multiple-choice items. Given the
location of certain parts of the heart at a particular moment of its functioning, the student is asked to determine the position of other specified parts of the heart at the same time. This test requires that the students have a thorough understanding of the heart, its parts, its internal functioning, and the simultaneous processes occurring during the systolic and diastolic phases. The comprehension test is designed to measure a type of understanding in which the individual can use the information being received to explain some other phenomenon.

Research Design

The Structure of Experimental Design

This dissertation’s foundation is a randomized-based experimental design. The independent variables are concept mapping and self-directed learning; the dependent variables are the three criterion tests described earlier. A two (high and low levels of self-directed learning) by four (instructional treatments with or without concept mapping) factorial posttest (three criterion tests) design is utilized to test the instructional effectiveness of concept mapping integrating in an online learning setting and the effect of self-directed learning ability. Figure 3-2 shows the structure of the experimental design for this dissertation.
Instructional Treatments

Participants in all treatment groups receive the same instructional material, which is a hypertext version of Dwyer’s (1978) heart content. In order to avoid cognitive learning load, the instructional material is divided into five learning units: (a) the hearts’ main structure, (b) the veins, arteries, and valves of the heart, (c) the blood flow of the heart 1, (d) the blood flow of the heart 2, and (e) the phases of the heart cycle (See Figure 3-3). In addition, an introduction unit is provided to teach basic concepts of the human heart. Each learning unit consists of three to five Web pages. Totally, five learning units yield 19 Web pages.
Introduction

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 to your visual left. Likewise, the left side of the person’s heart would be illustrated on the right side in the 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 ounces. And a woman’s heart weighs about 9 ounces.

Figure 3-3 Learning units in this dissertation

No time limit is imposed for any groups. In other words, participants can determine their own reading paces by clicking hyperlinks before taking a battery of criterion tests. A distinct difference among treatment groups is the provision for instructional scaffoldings. The details are:

Treatment 1 (Control group A: Text only): In this treatment group, students only receive hypertext material. No instructional scaffolding is provided. A sample screenshot for the Treatment 1 appears in Figure 3-4. The complete Treatment 1 can be found at http://www.personal.psu.edu/pxc251/te.htm.
Treatment 2 (Control group B: Text + Image): In this treatment, 19 static heart images, which relate to reading contents, are inserted into the instructional material. The rationale for implementing this treatment is to compare the instructional effectiveness with Treatment 4 since two groups all receive a presentation of images. A sample screenshot for the Treatment 2 appears in Figure 3-5. The complete Treatment 2 can be found at [http://www.personal.psu.edu/pxc251/im.htm](http://www.personal.psu.edu/pxc251/im.htm).
Treatment 3 (Traditional concept map): In this treatment, 19 concept maps, which summarize the reading contents’ main ideas, are inserted into the instructional material. A concept map is a top-down diagram showing the relationships between concepts. An oval-shaped box with text represents a concept. A labeled arrow shows the relationship between two concepts. Before proceeding to learning units, participants will receive an instructional description of concept mapping (See Figure 3-6). A sample screenshot of Treatment 3 appears in Figure 3-7. The complete Treatment 3 can be found at http://www.personal.psu.edu/pxc251/co.htm.
Study Description

In this study, you will read a 2000-word instructional material which aims to teach the functions of human heart. There is no time limit on this online reading. You can determine your own reading pace by clicking hyperlinks. You also can navigate specific web pages by clicking hyperlinks if you cannot understand some instructional contents. After completing this instructional activity, you will receive three criterion tests, which measure your understanding of instructional contents.

As you engage in instructional materials, there will be several concept maps supporting your online reading. Concepts maps summarize main ideas of what you read. Here is an example:

A concept map is a top-down diagram showing the relationships between concepts. An oval-shaped box with text represents a concept. A labeled arrow shows the relationship between two concepts.

I understand above description and want to start instructional activity.

Figure 3-6 Instructional description of concept mapping

Unit 1: The Heart’s Main Structure (3 pages)

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 circulates 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 common wall, the septum, between them.

Figure 3-7 Sample screenshot for Treatment 3
Treatment 4 (Visualized-based concept map): In this treatment, 19 visualized-based concept maps, which combine static heart images with traditional concept maps, are inserted into the instructional material. The traditional concept maps in this group are the same as Treatment 3. When participants’ mouse pointers move over one pink oval-shaped box in the visualized-based concept maps, Flash animation will show a related static heart image, which is similar to those of Treatment 2. Before proceeding to learning units, participants will also receive an instructional description of visualized-based concept mapping (See Figure 3-8). A sample screenshot of Treatment 4 appears in Figure 3-9. The complete Treatment 4 can be found at http://www.personal.psu.edu/pxc251/vi.htm.

**Study Description**

In this study, you will read a 2000-word instructional material which aims to teach the functions of human heart. There is no time limit on this online reading. You can determine your own reading pace by clicking hyperlinks. You also can navigate specific web pages by clicking hyperlinks if you cannot understand some instructional contents. After completing this instructional activity, you will receive three criterion tests, which measure your understanding of instructional contents.

As you engage in instructional materials, there will be several concept maps supporting your online reading. Concept maps summarize main ideas of what you read. Here is an example:

![Concept Map Example](Image)

A concept map is a top-down diagram showing the relationship between concepts. An oval-shaped box with text represents a concept. A labeled arrow shows the relationship between two concepts. In a concept map, you can move your mouse icon over pink oval-shaped boxes, which will show you related static images. You can try this function by employing above concept map.

I understand above description and want to start instructional activity.

Figure 3-8 Instructional description of visualized-based concept mapping
The objectives of Pilot Study 1 are twofold:

1. To examine the rate of item difficulty on the achievement test without offering any online scaffoldings to students.

2. To provide a basis for instructional remedy for Treatment 3.

Before the implementation of Pilot Study 1, a collaborator was hired to verify the correctness of the instructional materials and the functionality of the Web pages for Treatment 1 at a computer lab, where the model of computers is the same as those for the Pilot Study 1. During this time, a few typos and hyperlink errors were corrected.

The Pilot Study 1, which focuses on Treatment 1 (control group), was
conducted in January, 2009. 10 participants, from the College of Information Sciences and Technology at the Pennsylvania State University, were recruited. In the computer lab, participants were assigned to Treatment 1. After reading the instructional materials, participants received a battery of three criterion tests. Once participants completed the study, they all earned 10 dollars, obtained two extra credits from one course instructor, and one McDonald’s cheeseburger.

After Pilot Study 1, 60 items in three criterion tests were analyzed. Table 3-1 shows the results of item analysis.

Table 3-1 Item Analysis for Pilot Study 1

<table>
<thead>
<tr>
<th>Item Number(\textbf{Test1})</th>
<th>Item Difficulty</th>
<th>Item Number(\textbf{Test2})</th>
<th>Item Difficulty</th>
<th>Item Number(\textbf{Test3})</th>
<th>Item Difficulty</th>
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</thead>
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<tr>
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<td>60</td>
<td>0.50</td>
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</tbody>
</table>

Grey Area: item difficulty below 0.6
In Table 3-1, test items with a correct-response rate of less than 0.6 were considered difficult items. Therefore, 45 items out of the total 60 need remedial improvement by different instructional treatments (i.e. Treatment 3).

Based on the results of item analysis for Pilot Study 1, the website of Treatment 1 underwent examination to identify Web pages which relate to test items with less than 0.6 correct-response rate. Subsequently, according to the contents of the Web pages, revision of the instructional design for Treatment 3 was made.

**Pilot Study 2**

The objectives of Pilot Study 2 are threefold:

1. To examine the rate of item difficulty on the achievement test for Treatment 3.
2. To compare the instructional effectiveness between Treatment 1 and Treatment 3.
3. To provide a basis for instructional remedy for Treatment 3 and Treatment 4.

Before the implementation of Pilot Study 2, a hired collaborator verified the correctness of the instructional materials and the functionality of the Web pages for Treatment 3 at a computer lab. During this time, four typo errors were corrected.

The Pilot Study 2, which focuses on Treatment 3, was conducted in February, 2009. 33 undergraduate students at the Pennsylvania State University were recruited. In the computer lab, participants were randomly assigned to Treatment 1 and Treatment 3. After reading the instructional materials, participants received a battery of three criterion tests. Once participants completed the study, they all earned 15 dollars.
T-Test statistic technique analyzed the collected data. The results of t-test (see Table 3-2) indicate that statistically significant differences exist between Treatment 1 and Treatment 3. In other words, the experimental group was superior to the control group for three different types of tests. Also, effect size (Cohen’s d) for three tests is greater than 0.8, which indicates that a large difference between the experimental group and the control group.

<table>
<thead>
<tr>
<th>Test</th>
<th>Control Mean(17)</th>
<th>SD</th>
<th>Treatment3 Mean(16)</th>
<th>SD</th>
<th>p-value</th>
<th>Cohen’s d</th>
</tr>
</thead>
<tbody>
<tr>
<td>Identification</td>
<td>7.82</td>
<td>3.41</td>
<td>11.06</td>
<td>4.41</td>
<td>0.024*</td>
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<tr>
<td>Terminology</td>
<td>7.59</td>
<td>3.26</td>
<td>10.38</td>
<td>3.61</td>
<td>0.027*</td>
<td>0.810</td>
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<tr>
<td>Comprehension</td>
<td>7.18</td>
<td>2.18</td>
<td>9.62</td>
<td>3.87</td>
<td>0.032*</td>
<td>0.777</td>
</tr>
</tbody>
</table>

* indicates the significant difference (p<0.05)

Item analysis of 60 items in three criterion tests for both control and experimental groups considered the results. Table 3-3 shows the results of item analysis. As shown in Table 3-3, overall, most test items improved as a result of the experimental treatment (17 items in the identification test; 16 items in the terminology test; 15 items in the comprehension test). However, 39 test items (gray area: item difficulty below 0.6) in Treatment 3 still have room for improvement. This result prompted revision of some contents of the Web pages for Treatment 3 and Treatment 4 for better instructional improvement.
Table 3-3 Item Analysis for Pilot Study2

<table>
<thead>
<tr>
<th>Item Number</th>
<th>Item Difficulty (Control)</th>
<th>Item Difficulty (Experiment)</th>
<th>Item Number</th>
<th>Item Difficulty (Control)</th>
<th>Item Difficulty (Experiment)</th>
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<td>60</td>
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<td>0.63*</td>
</tr>
</tbody>
</table>

* Test items improved by experimental treatment

Grey Area: item difficulty below 0.6
After Pilot Study 1 and Pilot Study 2, several decisions were made before the implementation of a major study:

- A retained collaborator verified the correctness of the instructional materials and the functionality of the Web pages for Treatment 2 and Treatment 4.
- More information was provided in a participant recruitment website.
- After participants register for this study, they will receive a notification e-mail.
- Putting recruitment advisements on bulletin boards can not attract undergraduate students’ attention and expand the number of potential subjects, and more visits to course instructors can further promote this study.
- A self-directed learning measurement was transformed into an online survey. When participants register for this study, they also should complete this survey.

Major Study

Research Procedure

The target population for this study is undergraduate students in a northeast university. A power analysis, conducted by the GPower program, indicates 16 participants for each treatment cell would yield an 80% chance (power = 0.80) of detecting an effect size of 0.25 between the experimental and control conditions using a 2 x 4 factorial design (alpha = 0.05). Therefore, 128 students are needed.

A personal recruitment effort in the target courses promoted the study. Students who participate in this study received 15 dollars. When students agree to participate in this study, they were directed to a recruitment website. They must read an
electronic consent form and click an “agree” button before proceeding to answer a self-directed learning questionnaire. After completing the required tasks on the Web pages, students can schedule a time to complete the study in reserved computer labs.

Before students come to the computer labs, a division of student participants will create two groups (high vs. low) by the median score of self-directed learning, and then the participants will be randomly assigned into to one of the four treatment groups. Subsequently, students in the computer labs would receive assigned instructional tasks. Immediately upon completion of their respective instructional presentations, students in each treatment received a battery of three tests: identification, terminology, and comprehension.

**Threats to Validity**

In the research design, an experimenter must be able to minimize the treats to internal validity (McMillan, 2004; Creswell, 2009). This dissertation adopts a randomization-based experimental design and a one-shot recruitment procedure (i.e. recruiting participants at the computer labs one at a time) which greatly decrease the effect of extraneous factors affecting internal validity that Campbell and Stanley (1963) addressed. In response to these factors, Table 3-4 describes the actions this dissertation took.
Table 3-4 Actions to Extraneous Factors Affecting Internal Validity

<table>
<thead>
<tr>
<th>Factors</th>
<th>Description of threat</th>
<th>Actions</th>
</tr>
</thead>
<tbody>
<tr>
<td>History</td>
<td>Threat from extraneous events that affect the dependent variable</td>
<td>One-shot recruitment procedure prevents this threat.</td>
</tr>
<tr>
<td>Selection</td>
<td>Threat from the characteristics of subject</td>
<td>Randomization mitigates this effect of the factor.</td>
</tr>
<tr>
<td>Maturation</td>
<td>Threat from changes in subjects over time</td>
<td>One-shot recruitment procedure prevents this threat.</td>
</tr>
<tr>
<td>Testing</td>
<td>Threat from the effect of taking the pretest</td>
<td>No pretest of the dependent variable will be given.</td>
</tr>
<tr>
<td>Instrumentation</td>
<td>Threat from unreliability in measurement</td>
<td>Instruments used in this study all reflect high reliability.</td>
</tr>
<tr>
<td>Mortality</td>
<td>Threat from loss of subjects</td>
<td>One-shot recruitment procedure prevents this threat.</td>
</tr>
<tr>
<td>Regression</td>
<td>Threat from change of extreme scores to those closer to the mean</td>
<td>Randomization mitigates this effect of the factor.</td>
</tr>
<tr>
<td>Diffusion of treatment</td>
<td>Threat from treatment effect on one group affecting other groups</td>
<td>Randomization and one-shot recruitment procedure mitigates this effect of the factor.</td>
</tr>
<tr>
<td>Compensatory/resentful</td>
<td>The benefits of an experiment may be unequal or resented when only the experimental</td>
<td>Control group in this study will receive a treatment.</td>
</tr>
<tr>
<td>demoralization</td>
<td>group receives the treatment</td>
<td></td>
</tr>
<tr>
<td>Compensatory rivalry</td>
<td>Threat from effects of awareness of being a subject in specific treatment</td>
<td>Randomization mitigates this effect of the factor.</td>
</tr>
</tbody>
</table>

Source: information in column two adapted from McMillan (2004, pp. 212-214)

In addition to interval validity, external validity should also be taken into account (McMillan, 2004; Creswell, 2009). According to Campbell and Stanley (1963), external validity relates to the generalizability of experimental results. Since
the characteristics of participants (undergraduate students), research settings (computer labs), experimental treatments (concept mapping designed for this specific research), and measures (criterion tests and self-directed learning measurement), limitations to generalizability of research findings in this dissertation may exist.

Even though some potential limitations are present for this dissertation, the findings may be generalized to the following situations:

1. Individuals: Since the students involved in this study are from normal undergraduate classes, a conclusion may be that the findings are appropriate to similar types of students who take online courses.

2. Instructional materials: Although this study is conducted in the computer labs, the instructional materials at treatment websites are similar to those appearing in online courses. The conclusion may be that the findings are appropriate to similar types of instructional materials in online courses.

**The Influence of Recruitment Process on Data Collection**

A monetary incentive ($15 payment) was used to recruit student participants in the major study. According to Davern et al. (2003), the use of monetary incentives may influence the accuracy and completeness of collected data in a qualitative research. However, whether or not this approach affect collected data in an experimental study still needs further exploration. The researcher in this dissertation perceives that money payment may influence subjects’ motivation, which yields little impact on experimental data.
**Data Analysis**

The Statistical Package for the Social Sciences (SPSS) software version 14 was used to complete data analysis. The collected data was analyzed by a statistical technique: Two-Way Multivariate Analysis of Variance (MANOVA), whose purpose is to test for treatment group differences when two or more independent variables are to be considered simultaneously. If a significant F value is realized, then the Tukey HDS method will be used to perform a multiple comparison test.

**Summary**

This dissertation adopts a randomized-based experimental design. A two (high and low levels of self-directed learning by SDLRS) by four (instructional treatments with or without concept mapping) factorial research model was built. The independent variables are concept mapping and self-directed learning; the dependent variables are the three criterion tests (identification, terminology, and comprehension test) measuring participants’ hypermedia learning performances. In order to increase a chance of reaching a significant difference between the experimental and control treatments, two pilot studies were conducted before a major study. In the Pilot Study 2, a significant difference was found between Treatment 3 (traditional concept mapping) and Treatment 1 (control group 1) for three criterion tests. Also, to decrease the effect of extraneous factors affecting internal validity in an experimental study, several prevention actions were taken. In the major study, participants in an estimated sample size (128) are divided into two
levels of self-directed learning groups by the median score of the SDLRS measurement. Subsequently, students in each group are randomly assigned to four instructional treatments. Collected data are analyzed by Two-Way MANOVA to fulfill three research objectives.
Chapter 4

RESULTS OF THE RESEARCH

This chapter reports the quantitative results of the major study and discusses six subtopics: research participants, analysis of SDLRS pretest, analysis of criterion posttest, MANOVA analysis, test of null hypotheses, and additional findings. A summary ends this chapter.

Research Participants

Background Information

The major study involved 149 undergraduate students who voluntarily registered to participate. However, only 126 participants completed the SDLRS measurement. Further statistical analyses use this sample size (n=126). Table 4-1 shows participants’ background information.

<table>
<thead>
<tr>
<th>Source</th>
<th>Number of Participant</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Gender</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>67</td>
<td>53.2%</td>
</tr>
<tr>
<td>Female</td>
<td>59</td>
<td>46.8%</td>
</tr>
<tr>
<td><strong>Curriculum Major</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Science Major</td>
<td>60</td>
<td>47.6%</td>
</tr>
<tr>
<td>Non-Science Major</td>
<td>66</td>
<td>52.4%</td>
</tr>
<tr>
<td><strong>Experience Using Concept Mapping in Coursework</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>16</td>
<td>12.7%</td>
</tr>
<tr>
<td>No</td>
<td>110</td>
<td>87.3%</td>
</tr>
</tbody>
</table>
The results in Table 4-1 show that 67 male and 59 female students participated in the major study. From the aspect of curriculum major in the college, among the participants, 60 students are science majors; 66 students are non-science majors. However, only 16 students had experience using concept mapping in their coursework.

**Stratified Sampling**

One week prior to the study, grouping participants used a median score (203.5) of the SDLRS measurement to segregate student participants into high- and low-level of self-directed learning groups. During implementation of the major study, each member of a high- and low-level of self-directed learning group was randomly assigned to one of four instructional treatments. Figure 4-1 shows the distribution of research participants across self-directed learning and treatment groups.

![Figure 4-1 Sample population distribution](image-url)
From Figure 4-1, the distribution of participants was almost exactly balanced across treatment groups. In other words, the number of participants in each sub-group (e.g. T1 in High vs. T1 in Low) nearly achieves an equal number (as shown in Table 4-2).

<table>
<thead>
<tr>
<th>Treatment Group</th>
<th>High level</th>
<th>Low level</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>T1: Control 1 (Text-only)</td>
<td>15</td>
<td>17</td>
<td>32</td>
</tr>
<tr>
<td>T2: Control 2 (Static images)</td>
<td>16</td>
<td>15</td>
<td>31</td>
</tr>
<tr>
<td>T3: Traditional Concept Mapping</td>
<td>16</td>
<td>16</td>
<td>32</td>
</tr>
<tr>
<td>T4: Visualized-based Concept Mapping</td>
<td>16</td>
<td>15</td>
<td>31</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>63</strong></td>
<td><strong>63</strong></td>
<td><strong>126</strong></td>
</tr>
</tbody>
</table>

Table 4-2 Distribution of Participants in Treatment Groups

Analysis of SDLRS Pretest

**Independent T-test**

In order to validate the division of participants into groups of high- and low-levels of self-directed learning, an independent T-test was conducted. Before using independent T-test analysis, two assumptions need to be considered: normality of measurement and equality of variances (Hays, 1963; Morgan & Griego, 1998). The check of these two assumptions appears in Table 4-3.

<table>
<thead>
<tr>
<th>SDLRS</th>
<th>Mean</th>
<th>Skewness</th>
<th>Kurtosis</th>
<th>Median</th>
<th>SD</th>
<th>Min</th>
<th>Max</th>
<th>Levene’s Test</th>
</tr>
</thead>
<tbody>
<tr>
<td>203.55</td>
<td>0.51</td>
<td>2.10</td>
<td></td>
<td>203.5</td>
<td>16.34</td>
<td>165</td>
<td>269</td>
<td>F=0.251 p=0.62</td>
</tr>
</tbody>
</table>

Score in the SDLRS ranges from 58 to 290

From the results of Table 4-3, skeweness value (0.51<1), kurtosis value (2.10<10), and p value for Levene’s test (p=0.62>0.05) verify that the SDLRS
measurement used in this study meets the basic assumptions of the independent T-test (Morgan & Griego, 1998; Kline, 1998; Huck, 2008). Subsequently, the independent T-test was analyzed, with the results appearing in Table 4-4.

Table 4-4 Results of Independent-sample T-test

<table>
<thead>
<tr>
<th>SDLRS</th>
<th>N</th>
<th>Mean</th>
<th>SD</th>
<th>t</th>
<th>df</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low level</td>
<td>63</td>
<td>191.59</td>
<td>10.03</td>
<td>-12.07</td>
<td>124</td>
<td>0.000*</td>
</tr>
<tr>
<td>High level</td>
<td>63</td>
<td>215.51</td>
<td>12.13</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* indicates the significant difference (p<0.05)

From the results shown in Table 4-4, the mean of the high-level of the self-directed learning group is 191.59, with a standard deviation of 10.03; the mean of the low-level of self-directed learning group is 215.51, with a standard deviation of 12.13. The p value (0.00<0.05) shows that a statistically significant difference exists between high- and low-level groups. In other words, a distinct difference between the two levels validates the division created by the median score.

**Reliability Analysis**

In order to ensure the SDLRS measurement’s internal consistency, a reliability analysis developed the results shown in Table 4-5.

Table 4-5 Reliability Analysis of SDLRS

<table>
<thead>
<tr>
<th>Measures</th>
<th>Number of Items</th>
<th>Number of Participants</th>
<th>Cronbach’s Alpha</th>
</tr>
</thead>
<tbody>
<tr>
<td>SDLRS</td>
<td>58</td>
<td>126</td>
<td>0.82</td>
</tr>
</tbody>
</table>

Table 4-5 shows that the SDLRS measurement’s reliability coefficient is 0.82, indicating this measurement’s high reliability and proper design for 58 test items.
This result also corresponds to previous studies which reported that the SDLRS has strong internal consistency (Guglielmino, 1989).

**Comparison with Guglielmino’s Normal Distribution**

In Figure 4-2, the histogram shows the normal distribution of the SDLRS measurement with a mean of 203.55. Overall, compared to Figure 3-1 in Chapter3, however, the mean score of the sample for the current study is 10.45 points lower than Guglielmino’s reported mean score (214).
Analysis of Criterion Posttest

Reliability Analysis

Three criterion posttests were measured in this study: identification, terminology, and comprehension. Table 4-6 shows the results of these three posttests which used the Kuder-Richardson 21 (K-R 21) reliability test for analysis. Overall, the reliability coefficient ranges from 0.78 to 0.93, indicating each criterion test has strong internal consistency. Also, this result is consistent with Dwyer’s (1978) reported reliability coefficients.

Table 4-6 Reliability Analysis for Three Criterion Posttest (n=126)

<table>
<thead>
<tr>
<th>Measures</th>
<th>Number of Items</th>
<th>K-R 21</th>
</tr>
</thead>
<tbody>
<tr>
<td>Identification</td>
<td>20</td>
<td>0.84</td>
</tr>
<tr>
<td>Terminology</td>
<td>20</td>
<td>0.83</td>
</tr>
<tr>
<td>Comprehension</td>
<td>20</td>
<td>0.78</td>
</tr>
<tr>
<td>Total</td>
<td>60</td>
<td>0.93</td>
</tr>
</tbody>
</table>

Descriptive Statistics

For this study, in order to ensure participants’ immersion in each instructional treatment in the computer labs, students must spend at least 25 minutes (Based on pilot studies’ experiences) reading hypertext materials before receiving the three criterion tests. Table 4-7 reports a summary of descriptive statistics regarding the criterion tests. Overall, regardless of instructional treatment and self-directed learning, on average, students obtained 12.40 points (S.D. = 5.03) in the identification test, 11.30 points (S.D. = 4.84) in the terminology test, 11.00 points (S.D. = 4.56) in the comprehension test. Students tended to score higher on the identification test.
Table 4-7 Overall Summary for Each Posttest (n=126)

<table>
<thead>
<tr>
<th>Criterion Posttest</th>
<th>Mean</th>
<th>Standard Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Identification</td>
<td>12.40</td>
<td>5.03</td>
</tr>
<tr>
<td>Terminology</td>
<td>11.30</td>
<td>4.84</td>
</tr>
<tr>
<td>Comprehension</td>
<td>11.00</td>
<td>4.56</td>
</tr>
</tbody>
</table>

Score in each posttest ranges from 0 to 20

From the perspective of students’ SDLRS scores, Table 4-8 reports a summary of descriptive statistics regarding high- and low-level of the self-directed learning groups on each posttest. Overall, the mean score between the two groups is close.

Table 4-8 Summary of High/Low Group on Each Posttest

<table>
<thead>
<tr>
<th>Criterion Posttest</th>
<th>High Level (n=63)</th>
<th>Low Level (n=63)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean/ SD</td>
<td>Mean/ SD</td>
</tr>
<tr>
<td>Identification</td>
<td>12.48/ 4.80</td>
<td>12.32/ 5.12</td>
</tr>
<tr>
<td>Terminology</td>
<td>11.30/ 4.96</td>
<td>11.30/ 4.76</td>
</tr>
<tr>
<td>Comprehension</td>
<td>11.11/ 4.44</td>
<td>10.89/ 4.72</td>
</tr>
</tbody>
</table>

Score in each posttest ranges from 0 to 20

Consideration of the different instructional treatments in each posttest produced the summary of descriptive statistics appearing in Table 4-9. Overall, students in T4 (visualized-based concept mapping) performed better than those in the other three groups.

Table 4-9 Summary of Instructional Treatment for Each Posttest

<table>
<thead>
<tr>
<th>Criterion Posttest</th>
<th>T1 (n=32)</th>
<th>T2 (n=31)</th>
<th>T3 (n=32)</th>
<th>T4 (n=31)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean/ SD</td>
<td>Mean/ SD</td>
<td>Mean/ SD</td>
<td>Mean/ SD</td>
</tr>
<tr>
<td>Identification</td>
<td>9.34/3.91</td>
<td>14.26/5.32</td>
<td>11.03/4.98</td>
<td>15.09/3.58</td>
</tr>
<tr>
<td>Comprehension</td>
<td>8.66/3.28</td>
<td>11.58/5.08</td>
<td>10.84/4.33</td>
<td>13.00/4.49</td>
</tr>
</tbody>
</table>

Score in each posttest ranges from 0 to 20
Figure 4-3 shows graphic representations of instructional treatments for each posttest.

While taking instructional treatment and high/low group into account, an analysis of descriptive statistics in Table 4-10 and Table 4-11 shows that high-level self-directed learners scored higher in T2. As for low-level self-directed learners, they performed better in T4. However, determining whether or not an interaction will occur between the two levels and the four instructional treatments requires further information from the results of MANOVA analysis.
Table 4-10 Summary of Instructional Treatment for High-Level Group on Each Posttest

<table>
<thead>
<tr>
<th>Criterion Posttest</th>
<th>High Level</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>T1 (n=15)</td>
<td>T2 (n=16)</td>
<td>T3 (n=16)</td>
<td>T4 (n=16)</td>
</tr>
<tr>
<td>Identification</td>
<td>9.55/3.56</td>
<td>14.21/5.25</td>
<td>10.67/4.61</td>
<td>13.71/3.18</td>
</tr>
<tr>
<td>Terminology</td>
<td>8.85/3.78</td>
<td>13.07/4.54</td>
<td>11.27/4.38</td>
<td>11.43/3.42</td>
</tr>
<tr>
<td>Comprehension</td>
<td>8.35/1.92</td>
<td>12.14/4.69</td>
<td>10.87/4.70</td>
<td>11.71/3.83</td>
</tr>
</tbody>
</table>

Score in each posttest ranges from 0 to 20
T1: Control1; T2: Control2; T3: Traditional concept mapping
T4: Visualized-based concept mapping

Table 4-11 Summary of Instructional Treatment for Low-level Group on Each Posttest

<table>
<thead>
<tr>
<th>Criterion Posttest</th>
<th>Low Level</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>T1 (n=17)</td>
<td>T2 (n=15)</td>
<td>T3 (n=16)</td>
<td>T4 (n=15)</td>
</tr>
<tr>
<td>Terminology</td>
<td>8.58/3.56</td>
<td>11.47/4.79</td>
<td>9.77/4.91</td>
<td>15.11/3.28</td>
</tr>
<tr>
<td>Comprehension</td>
<td>7.50/3.89</td>
<td>11.12/4.34</td>
<td>10.82/3.89</td>
<td>14.06/4.75</td>
</tr>
</tbody>
</table>

Score in each posttest ranges from 0 to 20
T1: Control 1; T2: Control 2; T3: Traditional concept mapping
T4: Visualized-based concept mapping

**MANOVA Analysis**

**Statistical Assumption Check**

Before conducting factorial MANOVA analysis, three statistical procedures must be checked: (a) correlation between dependent variables, (b) normality of dependent variables, and (c) homogeneity of variance among dependent variables (Morgan & Griego, 1998; Tabachnick & Fidell, 2007). First of all, Pearson’s correlation technique analyzed three dependent variables (i.e. three criterion tests). As Table 4-12 shows, each dependent variable highly correlates. All correlation coefficients are higher than 0.7 (p<0.05), indicating a strong relationship exists among each posttest.
Table 4-12 Pearson’s Correlation among Each Posttest

<table>
<thead>
<tr>
<th></th>
<th>Identification</th>
<th>Terminology</th>
<th>Comprehension</th>
</tr>
</thead>
<tbody>
<tr>
<td>Identification</td>
<td>1</td>
<td>0.82*</td>
<td>0.76*</td>
</tr>
<tr>
<td>Terminology</td>
<td>0.82*</td>
<td>1</td>
<td>0.83*</td>
</tr>
<tr>
<td>Comprehension</td>
<td>0.76*</td>
<td>0.83*</td>
<td>1</td>
</tr>
</tbody>
</table>

*Correlation significant at the 0.05 level

Second, descriptive statistics tested the normality of dependent variables. The result in Table 4-13 indicates that skewness is -0.22 (<-1) with kurtosis of -1.08 (<10) in the identification test; skewness is -0.99 (<-1) with kurtosis of -1.08 (<10) in the terminology test; skewness is 0.12 (<1) with kurtosis of -1.09 (<10) in the comprehension test. According to the standards of Kline (1998) and Huck (2008), these values are acceptable.

Table 4-13 Skewness and Kurtosis of Dependent Variables

<table>
<thead>
<tr>
<th>Posttest</th>
<th>Skewness</th>
<th>Kurtosis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Identification</td>
<td>-0.22</td>
<td>-1.08</td>
</tr>
<tr>
<td>Terminology</td>
<td>-0.99</td>
<td>-1.08</td>
</tr>
<tr>
<td>Comprehension</td>
<td>0.12</td>
<td>-1.09</td>
</tr>
</tbody>
</table>

The final step is to verify the homogeneity of variance among dependent variables. Box’s test of equality of covariance matrices and Levene’s test of equality of error variances were analyzed with the results appearing in Table 4-14 and Table 4-15. The results show that significance values in both tests are higher than 0.05. In other words, covariance matrices of the dependent variables are equal across groups; the error variance of the dependent variable is equal across groups.
Table 4-14 Box’s Test of Equality of Covariance Matrices

<table>
<thead>
<tr>
<th>Box’ M</th>
<th>F</th>
<th>df1</th>
<th>df2</th>
<th>Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>46.72</td>
<td>1.02</td>
<td>42</td>
<td>19604.86</td>
<td>0.44</td>
</tr>
</tbody>
</table>

Table 4-15 Levene’s Test of Equality of Error Variances

<table>
<thead>
<tr>
<th>Test</th>
<th>F</th>
<th>df1</th>
<th>df2</th>
<th>Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Identification</td>
<td>1.81</td>
<td>7</td>
<td>118</td>
<td>0.09</td>
</tr>
<tr>
<td>Terminology</td>
<td>1.88</td>
<td>7</td>
<td>118</td>
<td>0.08</td>
</tr>
<tr>
<td>Comprehension</td>
<td>1.53</td>
<td>7</td>
<td>118</td>
<td>0.17</td>
</tr>
</tbody>
</table>

Based on the previous statistical assumptions’ check, two-way MANOVA analysis is justified for analyzing collected data in this study.

**Results of MANOVA**

According to Tabachnick and Fidell (2007), Wilks’ Lambda value in MANOVA analysis can determine the effect of independent variables on dependent variables and interactional effect between independent variables. Table 4-16 reports the overall results of MANOVA.

Table 4-16 Overall Results of MANOVA

<table>
<thead>
<tr>
<th>Effect</th>
<th>Wilk’s Lambda</th>
<th>F</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Self-directed learning</td>
<td>0.97</td>
<td>1.08</td>
<td>0.36</td>
</tr>
<tr>
<td>Treatment</td>
<td>0.75</td>
<td>3.96</td>
<td>0.00*</td>
</tr>
<tr>
<td>Self-directed learning* Treatment</td>
<td>0.87</td>
<td>1.82</td>
<td>0.07</td>
</tr>
</tbody>
</table>

*Significant at the 0.05 level

From the results shown in Table 4-16, a statistically significant difference appeared among treatment groups (Lambda=0.75, F=3.96, p=0.00<0.05). However, no statistically significant difference exists between the two levels of self-directed
learning groups (Lambda=0.75, F=3.96, p=0.36>0.05), and no significant interaction exists between instructional treatment and self-directed learning (Lambda=0.87, F=1.82, p=0.07>0.05).

Due to the existence of significant differences for one independent variable, the detailed results of MANOVA were analyzed and appear in Table 4-17.

Table 4-17 Detailed Results of MANOVA

<table>
<thead>
<tr>
<th>Source</th>
<th>Sum of Squares</th>
<th>df</th>
<th>F</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>A: Self-directed learning</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Identification</td>
<td>3.75</td>
<td>1</td>
<td>0.20</td>
<td>0.66</td>
</tr>
<tr>
<td>Terminology</td>
<td>0.54</td>
<td>1</td>
<td>0.03</td>
<td>0.87</td>
</tr>
<tr>
<td>Comprehension</td>
<td>3.66</td>
<td>1</td>
<td>0.20</td>
<td>0.66</td>
</tr>
<tr>
<td>B: Instructional Treatment</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Identification</td>
<td>704.55</td>
<td>3</td>
<td>12.25</td>
<td>0.00*</td>
</tr>
<tr>
<td>Terminology</td>
<td>343.63</td>
<td>3</td>
<td>5.64</td>
<td>0.00*</td>
</tr>
<tr>
<td>Comprehension</td>
<td>320.00</td>
<td>3</td>
<td>5.72</td>
<td>0.00*</td>
</tr>
<tr>
<td>A &amp; B Interaction</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Identification</td>
<td>35.829</td>
<td>3</td>
<td>0.59</td>
<td>0.62</td>
</tr>
<tr>
<td>Terminology</td>
<td>148.81</td>
<td>3</td>
<td>2.39</td>
<td>0.08</td>
</tr>
<tr>
<td>Comprehension</td>
<td>75.41</td>
<td>3</td>
<td>1.34</td>
<td>0.27</td>
</tr>
</tbody>
</table>

*Significant at the 0.05 level

From the results shown in Table 4-17, the effect of instructional treatment was found on three criterion tests (Identification test: F=12.25, p=0.00<0.05; Terminology test: F=5.64, p=0.00<0.05; Comprehension test: F=5.72, p=0.00<0.05). Therefore, a follow-up comparison procedure, Tukey HDS, was performed with the results appearing in Table 4-18. In the identification test, statistically significant differences exist between Treatment 1 and Treatment 2 (p=0.00<0.05), between Treatment 1 and Treatment 4 (p=0.00<0.05), between Treatment 2 and Treatment 3 (p=0.02<0.05), and between Treatment 3 and Treatment 4 (p=0.00<0.05). In the
terminology test, statistically significant differences exist between Treatment 1 and Treatment 2 (p=0.045<0.05), between Treatment 1 and Treatment 4 (p=0.00<0.05), and between Treatment 3 and Treatment 4 (p=0.048<0.05). In the comprehension test, statistically significant differences exist between Treatment 1 and Treatment 2 (p=0.04<0.05), and between Treatment 1 and Treatment 4 (p=0.00<0.05).

Table 4-18 Tukey HDS Analysis of MANOVA

<table>
<thead>
<tr>
<th>Source</th>
<th>Mean Difference</th>
<th>Std. Err.</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Identification Test</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Treatment 1 &amp; 2</td>
<td>-4.91</td>
<td>1.10</td>
<td>0.00*</td>
</tr>
<tr>
<td>Treatment 1 &amp; 3</td>
<td>-1.69</td>
<td>1.09</td>
<td>0.42</td>
</tr>
<tr>
<td>Treatment 1 &amp; 4</td>
<td>-5.75</td>
<td>1.10</td>
<td>0.00*</td>
</tr>
<tr>
<td>Treatment 2 &amp; 3</td>
<td>3.23</td>
<td>1.10</td>
<td>0.02*</td>
</tr>
<tr>
<td>Treatment 2 &amp; 4</td>
<td>-0.84</td>
<td>1.14</td>
<td>0.88</td>
</tr>
<tr>
<td>Treatment 3 &amp; 4</td>
<td>-4.07</td>
<td>1.13</td>
<td>0.00*</td>
</tr>
<tr>
<td><strong>Terminology Test</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Treatment 1 &amp; 2</td>
<td>-3.00</td>
<td>1.14</td>
<td>0.045*</td>
</tr>
<tr>
<td>Treatment 1 &amp; 3</td>
<td>-1.28</td>
<td>1.13</td>
<td>0.67</td>
</tr>
<tr>
<td>Treatment 1 &amp; 4</td>
<td>-4.26</td>
<td>1.13</td>
<td>0.00*</td>
</tr>
<tr>
<td>Treatment 2 &amp; 3</td>
<td>1.72</td>
<td>1.14</td>
<td>0.43</td>
</tr>
<tr>
<td>Treatment 2 &amp; 4</td>
<td>-1.26</td>
<td>1.15</td>
<td>0.69</td>
</tr>
<tr>
<td>Treatment 3 &amp; 4</td>
<td>-2.98</td>
<td>1.15</td>
<td>0.048*</td>
</tr>
<tr>
<td><strong>Comprehension Test</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Treatment 1 &amp; 2</td>
<td>-2.92</td>
<td>1.09</td>
<td>0.04*</td>
</tr>
<tr>
<td>Treatment 1 &amp; 3</td>
<td>-2.19</td>
<td>1.08</td>
<td>0.19</td>
</tr>
<tr>
<td>Treatment 1 &amp; 4</td>
<td>-4.34</td>
<td>1.09</td>
<td>0.00*</td>
</tr>
<tr>
<td>Treatment 2 &amp; 3</td>
<td>0.74</td>
<td>1.09</td>
<td>0.91</td>
</tr>
<tr>
<td>Treatment 2 &amp; 4</td>
<td>-1.42</td>
<td>1.10</td>
<td>0.57</td>
</tr>
<tr>
<td>Treatment 3 &amp; 4</td>
<td>-2.16</td>
<td>1.09</td>
<td>0.20</td>
</tr>
</tbody>
</table>

*Significant at the 0.05 level;
Treatment 1: Control 1
Treatment 2: Control 2
Treatment 3: Traditional concept mapping
Treatment 4: Visualized-based concept mapping
Test of Null Hypotheses

Test of Null Hypothesis 1

Hypothesis 1: No significant differences exist in achievement tests measuring different learning objectives among students receiving different concept maps.

The purpose of Hypothesis 1 is to examine the effect of varied concept mapping scaffoldings on students’ hypermedia learning performances. MANOVA results show that Wilk’s Lambda value (F=3.96, p=0.00<0.05) determines the effect of different instructional treatments on hypermedia learning. Considering the effect of varied concept mapping scaffoldings on three criterion tests, the results reported:

1. Identification Test

The results from MANOVA analysis show that a statistically significant difference among the four treatment groups in the identification test appeared (F=12.25, p=0.00<0.05). Based on Tukey’s follow-up comparison technique, statistically significant differences exist between visualized-based and traditional concept mapping (p=0.00<0.05), and between visualized-based concept mapping and Control group 1 (text-only) (p=0.00<0.05). Because visualized-based concept mapping is superior to traditional concept mapping for identification test, Hypothesis 1 is rejected at the 0.05 confidence level.

However, students in Control Group 2 (static image) performed well in the identification test. From the results in Tukey’s follow-up comparison, statistically significant differences exist between Control Group 2 and Control Group 1.
(p=0.00<0.05), and between Control Group 2 and traditional concept mapping (p=0.02<0.05).

2. Terminology Test

The results from MANOVA analysis show that a statistically significant difference exists among the four treatment groups in the terminology test (F=5.64, p=0.00<0.05). Based on Tukey’s follow-up comparison technique, statistically significant differences exist between visualized-based concept mapping and Control Group 1 (p=0.00<0.05), between traditional and visualized-based concept mapping (p=0.048<0.05), and between Control Group 2 (static image) and Control Group 1 (text-only) (p=0.045<0.05). Since visualized-based concept mapping is superior to traditional concept mapping for terminology test, Hypothesis 1 is rejected at the 0.05 confidence level.

3. Comprehension Test

The results from MANOVA analysis show that a statistically significant difference exists among four treatment groups in the comprehension test (F=5.72, p=0.00<0.05). Based on Tukey’s follow-up comparison technique, statistically significant differences exist between visualized-based concept mapping and Control Group 1 (p=0.00<0.05), and between Control Group 2 (static image) and Control Group 1 (text-only) (p=0.04<0.05). However, because visualized-based concept mapping is not better than traditional concept mapping for comprehension test, Hypothesis 1 is retained.
**Test of Null Hypothesis 2**

Hypothesis 2: No significant differences exist for student achievement of different learning objectives between students identified with high- and low-level of self-directed learning.

The purpose of Hypothesis 2 is to explore whether or not students’ self-directed learning abilities will influence their hypermedia learning performances. The results from MANOVA analysis show that no statistically significant differences exist for the three criterion tests between students identified with high- and low-level of self-directed learning (Identification test: F=0.20, p=0.67>0.05; Terminology test: F=0.03, p=0.87>0.05; Comprehension test: F=0.20, p=0.66>0.05). Therefore, hypothesis 2 is retained.

**Test of Null Hypothesis 3**

Hypothesis 3: No significant interaction exists between high- and low-level of self-directed learning and different concept maps on tests measuring different learning objectives.

The purpose of Hypothesis 3 is to identify if an interaction occurs between two independent variables (i.e. concept mapping and self-directed learning) for the three criterion tests. The results from MANOVA analysis show that no statistically significant interactions exist between the four instructional treatments and the two self-directed learning group levels for three posttests (Identification test: F=0.59, p=0.62>0.05; Terminology test: F=2.39, p=0.08>0.05; Comprehension test: F=1.34,
p=0.27>0.05). Therefore, Hypothesis 3 is retained.

**Additional Findings**

**Additional Finding 1 (Participants’ Experiences)**

Since 16 participants had experience using concept mapping in their coursework, observing their learning performances can provide an understanding of how their past experiences influence hypermedia learning. Of the 16 research subjects, only 6 students received random assignment to Treatment 3 (n=3) and Treatment 4 (n=3). These 6 participants’ learning outcomes produced the results in Table 4-19.

<table>
<thead>
<tr>
<th>Test</th>
<th>3 Students in T3 (Mean)</th>
<th>T3 (n=32) (Mean)</th>
<th>3 Students in T4 (Mean)</th>
<th>T4 (n=31) (Mean)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Identification</td>
<td>5.67</td>
<td>11.03</td>
<td>15.33</td>
<td>15.09</td>
</tr>
<tr>
<td>Terminology</td>
<td>3.33</td>
<td>10.47</td>
<td>14.67</td>
<td>13.45</td>
</tr>
<tr>
<td>Comprehension</td>
<td>5.33</td>
<td>10.84</td>
<td>14.67</td>
<td>13.00</td>
</tr>
</tbody>
</table>

T3: Traditional concept mapping; T4: Visualized-based concept mapping

From the results in Table 4-19, the 3 students in Treatment 3 had learning performances on three tests significantly lower than students (n=32) in Treatment 3, overall; the 3 students in Treatment 4 had learning outcomes on three tests higher than students (n=31) in Treatment 4, overall. However, due to the small sample size (n=6), whether or not students’ past experiences affect their learning under varied concept mapping treatments needs further exploration in the future.
**Additional Finding 2 (Composite Test)**

Even though three criterion tests are the focus of the major study, examination of the composite test, which sums the scores of the three criterion tests, is a feasible way to evaluate students’ overall hypermedia learning performances from different instructional treatments. Table 4-20 shows descriptive statistics of different treatments on the composite test.

<table>
<thead>
<tr>
<th>Instructional Treatment</th>
<th>Mean</th>
<th>Standard Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Treatment 1</td>
<td>27.22</td>
<td>9.41</td>
</tr>
<tr>
<td>Treatment 2</td>
<td>38.03</td>
<td>14.79</td>
</tr>
<tr>
<td>Treatment 3</td>
<td>32.66</td>
<td>13.04</td>
</tr>
<tr>
<td>Treatment 4</td>
<td>41.54</td>
<td>11.50</td>
</tr>
</tbody>
</table>

Score in composite test ranges from 0 to 60
Treatment 1: Control 1; Treatment 2: Control 2
Treatment 3: Traditional concept mapping
Treatment 4: Visualized-based concept mapping

Figure 4-4 shows graphic representations of instructional treatment on the composite test results.

![Composite Test](image)

Figure 4-4 Means per treatment for composite test
Based on the results in Table 4-20, the effect of the instructional treatment was analyzed by One-Way Analysis of Variance (ANOVA) with the results appearing in Table 4-21.

### Table 4-21 Results of ANOVA

<table>
<thead>
<tr>
<th>Source</th>
<th>Sum of Squares</th>
<th>df</th>
<th>F</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Instructional Treatment</td>
<td>3721.88</td>
<td>3</td>
<td>8.16</td>
<td>0.00*</td>
</tr>
<tr>
<td>Within Groups</td>
<td>18545.33</td>
<td>122</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>22267.214</td>
<td>125</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Significant at the 0.05 level

From Table 4-21, a statistically significant difference appeared among the four instructional treatment groups (F=8.16, p=0.00<0.05). Therefore, a follow-up comparison technique, the Scheffe method, compared these four treatments. The comparison results appear in Table 4-22.

### Table 4-22 Scheffe Analysis of ANOVA

<table>
<thead>
<tr>
<th>Source</th>
<th>Mean Difference</th>
<th>Std. Err.</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Treatment 1 &amp; 2</td>
<td>-10.81</td>
<td>3.11</td>
<td>0.01*</td>
</tr>
<tr>
<td>Treatment 1 &amp; 3</td>
<td>-5.44</td>
<td>3.08</td>
<td>0.38</td>
</tr>
<tr>
<td>Treatment 1 &amp; 4</td>
<td>-14.33</td>
<td>3.11</td>
<td>0.00*</td>
</tr>
<tr>
<td>Treatment 2 &amp; 3</td>
<td>5.38</td>
<td>3.11</td>
<td>0.40</td>
</tr>
<tr>
<td>Treatment 2 &amp; 4</td>
<td>-3.52</td>
<td>3.13</td>
<td>0.74</td>
</tr>
<tr>
<td>Treatment 3 &amp; 4</td>
<td>-8.90</td>
<td>3.11</td>
<td>0.47*</td>
</tr>
</tbody>
</table>

*Significant at the 0.05 level

Treatment 1: Control 1; Treatment 2: Control 2
Treatment 3: Traditional concept mapping
Treatment 4: Visualized-based concept mapping

From Table 4-22, significance differences exist between Treatment 1 and Treatment 2 (p=0.01<0.05), between Treatment 1 and Treatment 4 (p=0.00<0.05), and between Treatment 3 and Treatment 4 (p=0.47<0.05).
**Additional Finding 3 (Gender & Major)**

The major study is a randomization-based experiment. Each participant has an equal chance of receiving any of the different instructional treatments. Under such an experimental situation, participants’ background information may not greatly influence the results of the study (Campbell and Stanley, 1963). However, in order to ensure little impact from students’ background information, one-way MANCOVA was used to exclude the effect of extraneous variables. Table 4-23 lists the results of MANCOVA analysis for the gender variable.

**Table 4-23 Results of MANCOVA on Gender**

<table>
<thead>
<tr>
<th>Source</th>
<th>Sum of Squares</th>
<th>df</th>
<th>F</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Identification</td>
<td>645.69</td>
<td>3</td>
<td>11.01</td>
<td>0.00*</td>
</tr>
<tr>
<td>Terminology</td>
<td>303.43</td>
<td>3</td>
<td>4.90</td>
<td>0.00*</td>
</tr>
<tr>
<td>Comprehension</td>
<td>284.32</td>
<td>3</td>
<td>5.18</td>
<td>0.00*</td>
</tr>
<tr>
<td>Composite</td>
<td>3404.33</td>
<td>3</td>
<td>7.81</td>
<td>0.00*</td>
</tr>
</tbody>
</table>

*Significant at the 0.05 level

From Table 4-23, statistically significant differences appeared for each type of test (Identification test: F=11.01, p=0.00<0.05; Terminology test: F=4.90, p=0.00<0.05; Comprehension test: F=5.18, p=0.00<0.05; Composite test: F=7.18, p=0.00<0.05). Therefore, influenced by the gender variable, the effect of the instructional treatment still remains significant for three criterion tests. Through a follow-up comparison (LDS mean comparison) in Table 4-24, the results of significant differences among instructional treatments produce the same data as in Table 4-18 and Table 4-22. In the identification test, statistically significant differences exist between Treatment 1 and Treatment 2 (p=0.00<0.05), between
Treatment 1 and Treatment 4 (p=0.00<0.05), between Treatment 2 and Treatment 3 (p=0.01<0.05), and between Treatment 3 and Treatment 4 (p=0.00<0.05); in the terminology test, statistically significant differences exist between Treatment 1 and Treatment 2 (p=0.01<0.05), between Treatment 1 and Treatment 4 (p=0.00<0.05), and between Treatment 3 and Treatment 4 (p=0.01<0.05). In the comprehension test, statistically significant differences exist between Treatment 1 and Treatment 2 (p=0.01<0.05), and between Treatment 1 and Treatment 4 (p=0.00<0.05). In the composite test, significance differences exist between Treatment 1 and Treatment 2 (p=0.00<0.05), between Treatment 1 and Treatment 4 (p=0.00<0.05), and between Treatment 3 and Treatment 4 (p=0.01<0.05). To summarize, gender, as one of extraneous variables, did not influence the results of this study.

Table 4-24 LDS Mean Comparison of MANCOVA

<table>
<thead>
<tr>
<th>Source</th>
<th>Identification Test</th>
<th>Terminology Test</th>
<th>Comprehension Test</th>
<th>Composite Test</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean Difference</td>
<td>Std. Err.</td>
<td>Sig.</td>
<td></td>
</tr>
<tr>
<td><strong>Identification Test</strong></td>
<td>Treatment 1 &amp; 2</td>
<td>-4.77</td>
<td>1.11</td>
<td>0.00*</td>
</tr>
<tr>
<td></td>
<td>Treatment 1 &amp; 4</td>
<td>-5.54</td>
<td>1.12</td>
<td>0.00*</td>
</tr>
<tr>
<td></td>
<td>Treatment 2 &amp; 3</td>
<td>3.19</td>
<td>1.11</td>
<td>0.01*</td>
</tr>
<tr>
<td></td>
<td>Treatment 3 &amp; 4</td>
<td>-3.97</td>
<td>1.12</td>
<td>0.00*</td>
</tr>
<tr>
<td><strong>Terminology Test</strong></td>
<td>Treatment 1 &amp; 2</td>
<td>-2.85</td>
<td>1.14</td>
<td>0.01*</td>
</tr>
<tr>
<td></td>
<td>Treatment 1 &amp; 4</td>
<td>-4.05</td>
<td>1.15</td>
<td>0.00*</td>
</tr>
<tr>
<td></td>
<td>Treatment 3 &amp; 4</td>
<td>-2.89</td>
<td>1.14</td>
<td>0.01*</td>
</tr>
<tr>
<td><strong>Comprehension Test</strong></td>
<td>Treatment 1 &amp; 2</td>
<td>-2.80</td>
<td>1.08</td>
<td>0.01*</td>
</tr>
<tr>
<td></td>
<td>Treatment 1 &amp; 4</td>
<td>-4.17</td>
<td>1.08</td>
<td>0.00*</td>
</tr>
<tr>
<td><strong>Composite Test</strong></td>
<td>Treatment 1 &amp; 2</td>
<td>-10.37</td>
<td>3.04</td>
<td>0.00*</td>
</tr>
<tr>
<td></td>
<td>Treatment 1 &amp; 4</td>
<td>-13.71</td>
<td>3.05</td>
<td>0.00*</td>
</tr>
<tr>
<td></td>
<td>Treatment 3 &amp; 4</td>
<td>-8.62</td>
<td>3.04</td>
<td>0.00*</td>
</tr>
</tbody>
</table>

*Significant at the 0.05 level;
Treatment 1: Control 1; Treatment 2: Control 2; Treatment 3: Traditional concept mapping
Treatment 4: Visualized-based concept mapping
The other background information collected in the major study is student’s curriculum major. Table 4-25 summarizes the results of MANCOVA analysis for the curriculum major variable.

**Table 4-25 Results of MANCOVA for Curriculum Major**

<table>
<thead>
<tr>
<th>Source</th>
<th>Sum of Squares</th>
<th>df</th>
<th>F</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Identification</td>
<td>672.14</td>
<td>3</td>
<td>11.78</td>
<td>0.00*</td>
</tr>
<tr>
<td>Terminology</td>
<td>311.71</td>
<td>3</td>
<td>5.18</td>
<td>0.00*</td>
</tr>
<tr>
<td>Comprehension</td>
<td>287.76</td>
<td>3</td>
<td>5.48</td>
<td>0.00*</td>
</tr>
<tr>
<td>Composite</td>
<td>3527.95</td>
<td>3</td>
<td>8.41</td>
<td>0.00*</td>
</tr>
</tbody>
</table>

*Significant at the 0.05 level

From Table 4-25, statistically significant differences appeared for each type of test (Identification test: F=11.78, p=0.00<0.05; Terminology test: F=5.18, p=0.00<0.05; Comprehension test: F=5.48, p=0.00<0.05; Composite test: F=8.41, p=0.00<0.05). Therefore, from the influence of the curriculum major variable, significant differences still exist for three criterion tests among the different instructional treatments. Through a follow-up comparison (LDS mean comparison) in Table 4-26, the results of significant differences among instructional treatments are the same as the results shown in Table 4-18 and Table 4-22.
From Table 4-27, in the identification test, statistically significant differences exist between Treatment 1 and Treatment 2 (p=0.00<0.05), between Treatment 1 and Treatment 4 (p=0.00<0.05), between Treatment 2 and Treatment 3 (p=0.01<0.05), and between Treatment 3 and Treatment 4 (p=0.00<0.05). In the terminology test, statistically significant differences exist between Treatment 1 and Treatment 2 (p=0.01<0.05), between Treatment 1 and Treatment 4 (p=0.00<0.05), and between Treatment 3 and Treatment 4 (p=0.02<0.05). In the comprehension test, statistically significant differences exist between Treatment 1 and Treatment 2 (p=0.00<0.05), and between Treatment 1 and Treatment 4 (p=0.00<0.05). In the composite test,
significance differences exist between Treatment 1 and Treatment 2 (p=0.00<0.05),
between Treatment 1 and Treatment 4 (p=0.00<0.05), and between Treatment 3 and
Treatment 4 (p=0.01<0.05). To summarize, students’ curriculum majors, as one of
extraneous variables, did not influence the results of this study.

Additional Finding 4 (Item Analysis)

In addition to statistical analysis on instructional treatments, item analysis for
criterion tests can provide an alternative way to examine students’ learning
performances from the influence of different instructional treatments (Nitko &
Brookhart, 2006). In the major study, item analysis for the three criterion tests was
analyzed with the results appearing in Table 4-27, Table 4-28, and Table 4-29.
Table 4-27 Item Analysis for Major Study-1

<table>
<thead>
<tr>
<th>Item Number</th>
<th>Item Difficulty (Control-1)</th>
<th>Item Difficulty (Control-2)</th>
<th>Item Number</th>
<th>Item Difficulty (Control-1)</th>
<th>Item Difficulty (Control-2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.34</td>
<td>0.57*</td>
<td>31</td>
<td>0.28</td>
<td>0.30*</td>
</tr>
<tr>
<td>2</td>
<td>0.66</td>
<td>0.77*</td>
<td>32</td>
<td>0.41</td>
<td>0.60*</td>
</tr>
<tr>
<td>3</td>
<td>0.72</td>
<td>0.83*</td>
<td>33</td>
<td>0.53</td>
<td>0.60*</td>
</tr>
<tr>
<td>4</td>
<td>0.41</td>
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* Test items improved by Control-2
Grey Area: item difficulty below 0.6
Table 4-28 Item Analysis for Major Study-2

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* Test items improved by Treatment 4
Grey Area: item difficulty below 0.6
Table 4-29 Item Analysis for Major Study-3

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* Test items improved by Treatment 3  
Grey Area: item difficulty below 0.6
From Table 4-27, compared to Control group 1, 52 test items were improved by instructional Treatment 2 (Control Group 2: static image) and 35 test items’ difficulty were higher than 0.6 (16 items in the identification test; 12 items in the terminology test; 7 items in the comprehension test). By contrast, from Table 4-28, 55 test items were improved by instructional Treatment 4 (Visualized-based concept mapping) and 41 test items’ difficulty were higher than 0.6 (16 items in the identification test; 12 items in the terminology test; 13 items in the comprehension test). When compared to Control Group1 (without scaffolding tool), the scaffolding tool in Treatment 4 is superior to that in Treatment 2, indicating students performed better in Treatment 4.

From Table 4-29, 40 test items were improved by instructional Treatment 3 (Traditional concept mapping) and 20 test items’ difficulty were higher than 0.6 (8 items in the identification test; 5 items in the terminology test; 7 items in the comprehension test). Even though these results are better than those from Pilot Study 2, a comparison of treatment between Control Group1 and Treatment 3 does not yield a statistically significant difference in MANOVA analysis (See Table 4-18).

Summary

This chapter describes several statistical techniques, which include descriptive statistics, independent T-test, reliability analysis, Pearson’s correlation, MANOVA, ANOVA, and MANCOVA. Corresponding statistical results were also reported. To summarize, 126 undergraduate students voluntarily participated in the major study. Based on the median score of the SDLRS measurement, student participants were
divided into two levels (high/low) of self-directed learning. Through stratified sampling, participants in each group were randomly assigned to four instructional treatments: Treatment 1 (Control 1: text-only), Treatment 2 (Control 2: static images), Treatment 3 (traditional concept map), and Treatment 4 (visualized-based concept map). From the statistical results, two null hypotheses proposed for the study are not rejected; only one significant difference was found from the main effect (i.e. different instructional treatments). In addition, four additional findings which relate to participants’ background information, composite criterion test, and item analysis were identified.
Chapter 5

DISCUSSION AND CONCLUSIONS

This chapter first provides a summary of the major study, and second presents and discusses the results of the previous chapter, including possible explanations in relation to existing literature. Third, the results of discussion which raise issues regarding instructional design appear in the conclusions. Next, some limitations are identified. Finally, proposed recommendations for future research end the chapter.

Summary of the Major Study

The purpose of the major study is to examine the instructional effectiveness of varied concept maps in measuring different learning objectives for students with different levels of self-directed learning abilities in a hypertext learning environment. The study’s three hypotheses are:

\( H_01 \): No significant differences exist in achievement tests measuring different learning objectives among students receiving different concept maps.

\( H_02 \): No significant differences exist for student achievement of different learning objectives between students identified with high- and low-level of self-directed learning.

\( H_03 \): No significant interaction exists between high- and low-level of self-directed learning and different concept maps on tests measuring different learning objectives.

The major study adopts a randomized-based experimental design. A two (high- and low-level of self-directed learning by SDLRS) by four (instructional treatments
with or without concept maps) factorial research model was built. The independent variables are concept map and self-directed learning; the dependent variables are the three criterion tests measuring participants’ hypermedia learning performances. MANOVA, a primary statistical technique, was used in this experimental study.

Undergraduate students (n=126) voluntarily participated in this study. Based on the median score of the SDLRS measurement, student participants were divided into two levels (high and low) of self-directed learning. Through stratified sampling, participants in each group were randomly assigned to four instructional treatments: Treatment 1 (Control 1: text-only), Treatment 2 (Control 2: static images), Treatment 3 (traditional concept maps), and Treatment 4 (visualized-based concept maps). The statistical results show that only Hypothesis 1 is rejected.

**Discussion**

*Null Hypothesis 1*

From MANOVA analysis, Hypothesis 1 was rejected at the 0.05 confidence level. For two criterion tests (identification and terminology), significant differences were found between visualized-based and traditional concept maps. A similar result also exists in the composite test. In other words, students in Treatment 4 (visualized-based concept maps) outperformed those in Treatment 3 (traditional concept maps) for identification, terminology, and composite tests. Two approaches can interpret this result. First, since visualized-based concept maps allow students to click targeted areas in the concept maps, this interaction function indeed increases
information processing in students’ minds (Jonassen, 1999). The other interpretation point is dual code theory. In Treatment 4, students received not only verbal (text), but also nonverbal (image) representations, which in turn strengthens cues to process for specific information in learners’ minds (Clark & Paivio, 1991).

By transforming the statistically significant results between traditional and visualized-based concept maps into effect size, Cohen’s d value is 0.94 in the identification test, 0.64 in the terminology test, and 0.71 in the composite test, which indicate that visualized-based concept maps greatly supports student learning in the identification test (identification > composite > terminology). This result can be explained by considering the purpose of the identification test. Since students needed to identify different parts of the human heart in the identification test, visualized-based concept maps are better than traditional concept maps by showing students several static images related to the human heart.

Considering the comprehension test, although students in visualized-based concept maps performed better than those in traditional concept maps, no significant difference exists between the two treatment groups. In this study, because only the comprehension test did not show a significant instructional benefit for visualized-based concept maps, further exploration for this phenomenon is needed in the future research. Whether or not increasing sample size will identify a significant difference between traditional and visualized-based concept maps remains unknown.

In the major study, even though students in Treatment 3 (traditional concept maps) learn better than those in Treatment 1 (Control Group1: text-only) for the three criterion tests, a statistically significant difference was not found between
Treatment 1 and Treatment 3 from MANOVA analysis. This result is not the same as Pilot Study 2. A reasonable explanation attributes to sample size. The number of participants in the major study (n=64 in Treatment 1 and Treatment 3) is nearly twice than of Pilot Study 2 (n=33). According to statistical theories, small sample size often leads to significant differences between treatment groups (Gall, Gall, & Borg, 2007).

Novak (1990), the developer of traditional concept map, claimed that a concept map visualizes the text-based contents, which in turn enhances students’ comprehension skills. In the major study, however, when compared to the other two visual scaffoldings in Treatment 2 (static images) and Treatment 4 (visualized-based concept maps), the visual effect of traditional concept maps decreases significantly. From the results of descriptive statistics, students in Treatment 2 and Treatment 4 perform better than those in Treatment 3. This phenomenon can be attributed to the function of traditional concept maps. A concept map is one type of advanced organizers which aim to help students organize a large amount of information and summarize the main ideas (Willerman & MacHarg, 2006). However, in fact, it is still a text-based scaffolding and does not have a visual effect on learning unlike static images.

Even though Treatment 2 (static images) is another control group in the major study, students who received this instructional treatment performed well on each criterion tests. From MANOVA analysis, significant differences exist between Treatment 2 and Treatment 1 for all criterion tests. In other words, static images also can significantly improve students’ learning performances regardless of the types of
cognitive learning.

In addition to Treatment 4 (visualized-based concept maps), Treatment 2 is a better instructional presentation for student participants in the major study. Simple static images which serve as instructional scaffolding in Treatment 2 allow students to better comprehend the contents in the hypermedia material. This result supports the findings of Rieber and Hannafin (1988) and Lin and Dwyer (2004) which showed that basic static visuals could effectively support student learning. However, in this study, simple static visuals (images) are not better than animated visuals (i.e. visual-based concept maps) because no significant difference was found between Treatment 2 and Treatment 4.

In the identification test, a significant difference was found even between Treatment 2 and Treatment 3 (traditional concept maps). This result indicates that static visuals are superior to text-based concept maps when students engage in factual knowledge acquisition, which is regarded as a lower order thinking process (Dick, Carey, & Carey, 2005).

Regardless of the level of self-directed learning ability, compared to Treatment 1 (no scaffolding), students who received instructional presentations in Treatment 2 and Treatment 4 greatly enhanced their learning outcomes. For three criterion tests, significant differences exist between Treatment 1 and Treatment 2 and between Treatment 1 and Treatment 4. In other words, from factual (identification test) to principal/procedural (comprehension test) levels of cognitive processes, two visual instructions (static images/visuals and visualized-based concept maps) can support students’ hypermedia learning. This result is accord with past research’s findings.
which reported that students preferred visual scaffoldings when they received both
text-based and visual instruction (Thomas & Cook, 2004; Lin & Dwyer, 2004; Lin,
2006; Dwyer, 2007).

Although improving students’ hypermedia learning for three types of cognitive
processes (factual, conceptual, and rule/principle), the two visuals in Treatment 2
and Treatment 4 can not outperform each other. MANOVA analysis shows that no
significant difference can be found between Treatment 2 and Treatment 4. In other
words, from a statistical perspective, static and animation visuals can with equal
effectiveness strengthen students’ learning performances from lower to higher order
thinking domains, which is consistent with the finding in the Lin and Dwyer study
(2004).

From the results of item analysis, 35 test items’ difficulty in Treatment 2 are
higher than 0.6 (16 items in the identification test, 12 items in the terminology test,
and 7 items in comprehension test); 44 test items’ difficulty in Treatment 4 are
higher than 0.6 (16 items in the identification test, 12 items in the terminology test,
and 13 items in comprehension test). Obviously, visualized-based concept maps in
Treatment 4 can enhance rule/principle knowledge acquisition in the comprehension
test than the static images in Treatment 2. However, whether or not replicating this
study by increasing the sample size will cause a statistically significant difference
between Treatment 2 and Treatment 4, especially on the comprehension test, needs
further exploration.
Null Hypothesis 2

Based on Guglielmino’s (2008) standard, the average score for the SDLRS is 214. Students who score higher than 214 (cut score) are considered high-level self-directed learners while those who obtain scores below 214 are low-level self-directed learners. However, in the major study, participants’ average score for the SDLRS is 203.5. If the study had followed Guglilmino’s suggested cut score, only 25 students would be high-level self-directed learners. This finding shows that the sample population in this study tends to represent low-level self-directed learners when compared to Guglilmino’s research population. Since Guglilmino’s sample participants includes different types of adult learners, such as young adults and the elderly, following Guglilmino’s standard is unwise for this study which only recruited normal college-age students (young adults).

From MANOVA analysis, Hypothesis 2 was not rejected at the 0.05 confidence level. For different achievement tests, no significant difference exists between the high- and low-level of self-directed learning. In other words, regardless of types of criterion tests, for hypermedia learning, students identified as high-level self-directed learners did not perform better than their counterparts (i.e. low-level self-directed learners). Learning performances for the groups’ two levels are the same in a hypertext learning environment. However, this result contradicts a theoretical statement saying that a reasonable link exists between self-directed learning and academic success (Chou & Chen, 2008). Furthermore, this finding is not consistent with several quantitative studies (Savoie, 1980; Harriman, 1990; Anderson, 1993; Darmayanti, 1994; Morris, 1995; Horng, 1995; Ogazon, 1995;
Haggerty, 2000, Hsu & Shiue, 2005; Stewart, 2007) which emphasize the importance of self-directed learning ability in different learning settings.

Null Hypothesis 3

From MANOVA analysis, Hypothesis 3 was not rejected at the 0.05 confidence level. For the three criterion tests, no significant interaction was found between self-directed learning and concept map. In other words, varied concept maps would not influence learners’ self-directed learning abilities; different concept maps cannot improve students’ self-directed learning abilities. This result cannot support one research segment’s claim that instructors may use instructional strategies and activities to enhance students’ self-directed learning abilities (Long, 2003). In this study, therefore, a feasible way to explain the finding is that self-directed learning is an internal and psychological learning trait for an individual student, which cannot easily be altered by external learning strategies.

Additional Findings

The major study is voluntary-participation research. Before implementation of the study, predicting participants’ background information is impossible. Thus, gender and college curriculum major are two covariance variables used for analyzing the influence of individual differences. From MANCOVA analysis, by excluding the effect of gender and college curriculum major, significant differences among instructional treatments remain the same as the results from MANOVA. In
other words, students’ background information did not influence the results of this study. This finding is not consistent with past findings which show that females and males have different learning styles when receiving visual instruction (Dwyer, 2007), or that science curriculum majors outperform than non-science curriculum majors in visual instruction (Taricarni, 2002). One possible explanation is that the randomization process in this experimental study has mitigated the effect of gender and college curriculum major on students’ achievement tests (Campbell & Stanley, 1963).

Considering the other participants’ information (past experiences using concept maps in coursework), only six students involved in Treatment 3 and Treatment 4. The small sample size could not offer an in-depth insight of how students’ past experiences affect their hypermedia learning under different concept map treatments. Therefore, future studies need to test this covariance variable by increasing sample size for students who have experience creating concept maps.

**Conclusions**

This dissertation confirmed the instructional effectiveness of varied concept maps in facilitating different types of knowledge acquisition in a hypertext learning environment, and disclaimed the effect of learners’ self-directed learning abilities on hypermedia learning and the interaction effect between concept maps and self-directed learning. Since hypertext learning materials are main components for imparting instructional knowledge in Web-based, online learning environments (Chen & Dwyer, 2006), the findings of this study may be applied to hypermedia
design at current distance education programs. Several suggestions are proposed for instructional designers and educators:

1. Self-directed learning ability: Today, corporate training programs and academic programs all emphasize the role of self-directed learning. However, one of findings in this study shows that students’ self-directed learning abilities do not influence their learning performances. No direct link appeared between self-directed learning and learning outcomes. Therefore, educators should re-think the effect of students’ self-directed learning abilities during hypermedia development because high and low level self-directed learners performed equally on different types of achievement tests. Furthermore, since no interaction exists between instructional strategies and self-directed learning, while designing course materials, instructional designers should not try to employ instructional strategies to enhance students’ self-directed learning abilities.

2. Traditional concept maps: Compared to one instructional treatment without scaffolds, traditional concept maps do not statistically improve student learning in different types of cognitive learning processes. From a cost-effectiveness perspective, inserting concept maps into hypertext learning materials is not an efficient strategy for instructional designers because students also comprehend information in text-only instruction without any scaffolds. Therefore, in situations of limited instructional resources, for instructional designers, if visual scaffolds, such as static images, are not provided in the hypertext learning materials, text-only learning still has the same instructional benefits as traditional concept map-provided learning.
3. Visualized-based concept maps: Incorporating multimedia instruction into Web-based environments is a future trend in the development of distance courses (The Horizon Report, 2007). In this study, animated-based scaffolding (visualized-based concept maps) is superior to static-based scaffolding (traditional concept maps) for students’ hypermedia learning. Therefore, in situations of sufficient instructional resources, visualized-based concept map is the best choice for instructional designers if providing concept maps to learners is necessary.

4. Visual aids: The results of this study indicate that visual aids are students’ preference in the hypertext learning environment. Two visuals (static images and visualized-based concept maps) developed in this study all support student learning. However, no significant difference appeared between these two visuals. In other words, static images can be as efficient as visualized-based concept maps for improving students’ knowledge acquisition. From a cost-effectiveness perspective, for instructional designers, providing only static visuals to students can also satisfactorily create a better learning environment. In contrast, if multimedia instruction is an attractive trademark for distance education programs, especially student recruitment, developing animated visuals (visual-based concept maps) is an alternative to enhance learners’ learning outcomes.

**Limitations**

This study identified four limitations, which relate to the interpretation of the findings. First, compared to past studies using Dwyer’s heart content material to design instructional treatments, the sample size (126) in this study is small.
Increasing sample size may influence the statistical power of MANOVA analysis. Second, concept maps created in this study were only reviewed by a small cadre of colleagues. Additional ideas for enhancing concept maps’ quality may occur by allowing professional instructional designers or graphic developers to review the contents of concept maps. Third, participants’ reading time was not recorded during the implementation of the study. Students’ efforts expended for reading hypertext learning materials may influence overall learning performance. Finally, participants in this study all received monetary incentives after completing instructional treatments. Learning attitudes may be different when participants receive extra credit from course instructors.

**Recommendations for Future Research**

Based on this study’s discussion and conclusions discussed earlier, a number of recommendations for future research are proposed:

1. Examine the effect of individual differences (locus of control, intelligence, and field dependent/field independent and prior knowledge) on students’ hypermedia learning under varied concept map treatments.
2. Replicate this study by increasing sample size.
3. Study the instructional effectiveness of different concept maps by combining other learning strategies, such as feedback and questioning.
4. Use different types of measurements (Oddi Continuing Learning Inventory and Bartlett-Kotrlik Inventory of Self Learning) to assess students’ self-directed learning abilities.
5. Record participants’ reading time and analyze the effect of that time on students’ hypermedia learning under varied concept map treatments.

6. Allow professional instructional designers to review the contents of concept maps before implementation of the study.

7. Give students extra credit after they complete the study rather than use monetary incentives.

8. Integrate varied concept maps into real online courses and analyze students’ learning outcomes.

9. Study the effect of varied concept maps on another group of participants, such as graduate students or medical students.

10. Integrate varied concept maps into contents of different subjects (economics or English literature) in the hypertext environments rather than the physiology/science oriented human heart.

11. Use different multimedia programs to design visualized-based concept map rather than the Flash program.

12. Combine other multimedia elements, such as sounds and videos, with visualized-based concept map.

13. Divide Dwyer’s instructional material into different learning units to see if the amount of information will influence the effect of varied concept maps.

14. Recruit participants who have experience creating concept maps in their coursework and randomly assign them into different concept mapping treatments.
REFERENCES


John Wiley & Sons.


APPENDIX A

PRETEST MEASUREMENT
In this dissertation, Self-Directed Learning Readiness Scale (SDLRS) is used for assessing participants’ self-directed learning abilities. The SDLRS uses a 58-item 5-point Likert scale. Through factor analysis, the scale includes eight factors: openness to learning opportunities, self-concept as an effective learner, initiative and independence in learning, informed acceptance of responsibility for one’s own learning, love of learning, creativity, positive orientation to the future, and ability to use basic study and problem-solving skills. Higher scores occurring from using the scale represent higher readiness for self-directed learning. Currently, this measurement has a copyright issue in the market. If you need a copy of this measurement, you need to contact with Dr. Lucy Guglielmino by visiting the following website: http://www.lpasdlrs.com/.
APPENDIX B

POSTTEST MEASUREMENT
1. Arrow number one (1) points to the ________.
   A. Septum B. Aorta C. Pulmonary Artery D. Pulmonary Vein E. None of These above

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 Auricle D. Left Ventricle 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 Valve

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 three (13) points to the _______.  
A. Pericardium  B. Endocardium  C. Ectocardium  D. Endoderm  E. Myocardium

14. Arrow number four (14) points to the _______.  
A. Right Ventricle  B. Left Ventricle  C. Left Auricle  D. Right Auricle  E. Apex

15. Arrow number five (15) points to the _______.  
A. Pulmonary Veins  B. Tendons  C. Aortas  D. Pericardium  E. None of These

16. Arrow number six (16) points to the _______.  
A. Venic Valve  B. Pulmonary Valve  C. Tricuspid Valve  D. Mitral Valve  E. Aortic Valve

17. Arrow number seven (17) points to the _______.  
A. Superior Vena Cava  B. Tricuspid Valve  C. Aortic Valve  D. Pulmonary Valve  E. Mitral Valve

18. Arrow number eight (18) points to the _______.  
A. Right Auricle  B. Right Ventricle  C. Left Auricle  D. Left Ventricle  E. Semi-Lunar Chamber

19. Arrow number nine (19) points to the _______.  
A. Inferior Vena Cava  B. Superior Vena Cava  C. Aortas  D. Pulmonary Veins  E. Pulmonary Arteries

20. Arrow number ten (20) points to the _______.  
A. Inferior Vena Cava  B. Aorta  C. Pulmonary Artery  D. Septum  E. Superior Vena Cava

**TEST 2 --- TERMINOLOGY TEST**

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

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

24. Blood from the right ventricle goes to the lungs through the ______.  
A. Tricuspid Valve  B. Aortic Artery  C. Pulmonary Artery  D. Pulmonary Veins  E. Superior Vena Cava

25. The ______ is(are) the strongest section(s) of the heart.  
A. Left Ventricle  B. Aorta  C. Septum  D. Right Ventricle  E. Tendons

26. 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

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

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

29. 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
30. The _______ is another name for the part of the heart called the heart muscle.
   A. Apex B. Epicardium C. Endocardium D. Myocardium E. Septum

31. _______ is(are) the part(s) of the heart which controls its contraction and relaxation.
   A. Myocardium B. Endocardium C. Ventricle D. Auricles E. Septum

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

33. Blood from the body enters the heart through the______.
   A. Aortic Artery B. Pulmonary Veins C. Pulmonary Artery D. Superior and Inferior Vena Cavas
   E. Superior Vena Cava Only,

34. The membrane which borders on the inside lining of the pericardium and is connected to the heart
   muscle is called the_______.
   A. Extoxim B. Epicardium C. Endocardium D. Myocardium E. Ectocardium

35. The _______ allow(s) blood to travel in one direction only.
   A. Septum B. Valves C. Arteries D. Veins E. Tendons

36. 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

37. 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

38. 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. Ventricle

39. The outside covering of the heart is called the_______.
   A. Endocardium B. Epicardium C. Pericardium D. Myocardium E. None of These

40. 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

**TEST 3 --- COMPREHENSION TEST**

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

42. 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

43. 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

44. The contraction impulse in the heart starts in
   A. The Right Auricle B. Both ventricles simultaneously C. Both Auricles Simultaneously
   D. The Arteries
45. In the diastolic phase the ventricles are
A. Contracting, full of blood B. Contracting, partially full of blood
C. Relaxing, full of blood D. Relaxing, partially full of blood

46. During the first contraction of the systolic phase, in what position will the mitral valve be?
A. Begging to open B. Open C. Beginning to close D. Closed

47. 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 Cava
C. Tricuspid and Mitral Valves D. Pulmonary Veins

48. When blood is entering through the vena cava, it is also entering through the
A. Mitral Valve B. Pulmonary Veins C. Pulmonary Artery D. Aorta

49. When the heart contracts, the
A. Auricles & Ventriles contract simultaneously
B. Ventriles contract first, then the auricles C. Right side contracts first, then the left side D. Auricles contract first, then the ventricles

50. 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

51. 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

52. 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

53. When the ventricles contract, blood is forced out the
A. Superior and Inferior Vena Cava B. Pulmonary veins C. Tricuspid and Mitral Valves
D. Pulmonary and Aortic Valves

54. Blood leaving the heart through the aorta had left the heart previously through the
A. Vena cava B. Pulmonary veins C. Pulmonary artery
D. Tricuspid and Mitral Valves

55. 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

56. 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

57. 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
58. Blood is being forced out the auricles simultaneously as blood is
   A. Entering only the vena cava
   B. Being forced out the pulmonary and aortic valves
   C. Passing through the tricuspid & mitral valves
   D. Being forced out through the pulmonary artery
59. 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

60. 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 auricle
APPENDIX C

INSTRUCTIONAL MATERIAL
The Heart and Its Functions

The human heart is a hallow, 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 eleven ounces and a woman’s heart weighs about nine ounces. 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.

In order to better comprehend the following instruction, it will be helpful to visualize a cross-section view of a human heart in a position such that you are facing the person. As you visualizing it, the right side of the heart will be on the left side. To understand the functioning of the heart you will need to be able to identify the parts of the heart. The heart is enclosed in a thin double-walled sac. The layer which forms the outer wall of the sac is called the pericardium. It is composed of a tough, transparent elastic tissue. It protests 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 throughout the body. The myocardium varies in thickness. For example, the myocardium forming the auricle walls is thin when compared to the thickness of the myocardium forming the ventricle walls.

The endocardium is the name given to the inside lining of the heart wall. The human heart is really two pumps combined into a single organ which circulates blood to all parts of the body. The heart is divided longitudinally into two halves by 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 are called auricles and the lower chamber are called ventricles. Although there is no direct communication between the right and left sides of the heart, both sides function simultaneously. As we stated previously, the upper chambers on each sides of the septum are auricles, the lower chambers are called ventricles. Auricles have thin walls and act as receiving rooms for the blood while the ventricles below act as pumps, moving the blood away from the heart.

As you would view a cross-sectional diagram of the heart, blood enters the right auricle through veins. Only veins carry blood to the heart. The superior and inferior vena cava are the two veins which deposit blood in the right auricle. The superior vena cava deposits blood into the right auricle from all body parts above the
heart level, for example, the head and the arms. The other vein, the inferior vena cava, deposits blood into the right auricle from the trunk and legs --- that is from regions below the heart level. As blood from the body fills the right auricle, some of it begins to drip into the right ventricles immediately. The auricles and ventricles on each side of the heart communicate with each other through openings. The 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 right ventricles, 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.

The three flaps act like swinging doors which open only in one direction. Thus, blood passes from the right auricle through the tricuspid valve into the right ventricle. As soon as the right ventricle is filled with blood, both ventricles begin to contract. The first effect of the pressure produced in the right ventricle is to force blood behind the flaps of the tricuspid valve. While the blood pressure behind the flaps brings the flaps together and prevents the flow of the blood, the contraction of the right ventricle continues until the blood presses hard enough to open the pulmonary valve and to force the blood into the pulmonary artery. The pulmonary valve is located between the right ventricle and the pulmonary artery.

The pulmonary valve, like the tricuspid valve, consists of three flaps which fill with blood backing up in the pulmonary artery. As soon as the right ventricle begins to relax from its contraction, the pulmonary valve prevents blood from flowing back into the right ventricle from the pulmonary artery. The pulmonary valve opens only when the pressure in the right ventricle is greater than the pressure in the pulmonary artery, forcing the blood into the pulmonary artery.

The pulmonary valve is composed of flaps or pockets, which the swollen pulmonary artery quickly fill with blood as soon as the right ventricle begins to relax from its contraction. The flaps or pockets of the valve are thus pressed together, and no blood flows back into the right ventricle. After the blood passes through the pulmonary valve it enters the pulmonary artery, from which it is carried up through the heart to both the left and right lungs where it is cleaned and oxygenated.

Returning from the lungs, the blood enters the heart through four pulmonary veins and collects in the left auricle. Like the right auricle, the left auricle also contracts when it is full, squeezing blood through the mitral valve into the left ventricle. The mitral valve is located between the left auricle and left ventricle. The mitral valve is similar in contraction to the tricuspid valve. As the left ventricle contracts simultaneously with its mate, the right ventricle, it forces blood behind the flaps of the mitral valve, thereby closing the path back to the left auricle.

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 which is filled with blood contracts, the resulting pressure in the ventricle opens the aortic valve located in the mouth of the aorta. The aorta is the largest artery which carries the blood from the left ventricle.

The Circulation of the Blood

The directional flow of blood in the heart is determined by valves which allow the blood to flow in only one direction. Both auricles receive blood simultaneously through unguarded opening in the veins. The right auricle receives its blood through the superior and interior vena cavas 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 through both the tricuspid and mitral valves.

As the ventricles fill, eddies of the blood float the flaps on both the tricuspid and mitral valves out to a partially closed position. As the ventricle pressure becomes greater than that in the auricles, the valves are tightly closed and so prevent blood from being forced backward into the auricles. While the auricles are relaxing from the contraction, blood flows into them from the veins as the contraction of the ventricle is initiated. The instant that the contraction of the auricles has been completed, the ventricles are stimulated to contract; this contraction increases the pressure in the chambers forcing the valves, both the tricuspid and mitral, completely shut.

The pulmonary valve and aortic valve, also called the semi-lunar-valves, that guard the entrances to the pulmonary artery on the right and aortic artery on the left are closed by the back pressure provided by blood already in these vessels. When the ventricle pressure becomes greater than in the exit vessels, the pulmonary and aortic valves open.

Blood flows from the right ventricles into pulmonary artery then route to the lungs and from the left ventricle into the aorta for distribution through the entire body. Immediately following ejection of blood into the arteries, the ventricles begin to relax; this lowers the pressure within their chambers, and the greater pressure in the arteries closed the semi-lunar valves. Pressure within the ventricle 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 decreases correspondingly, and the tricuspid ad mitral valves are forced open by increased auricle pressure caused by blood flowing into them from veins. Therefore, before the next auricle
contraction, blood is already flowing from the auricles into the ventricles because a greater blood pressure exits in the auricles than in ventricles.

**The Cycle of the Heartbeat Consists of Two Parts**

The relaxation of the ventricles, during which they are filled with blood is called the diastolic phase. The heart relaxes between beats in the diastolic phase. Blood flows into the heart filling both auricles. While blood is flowing into the auricles, the recoil of the artery wall still maintains part of the pressure developed by the contraction of the ventricles. This is the time of lowest pressure in the arteries or what is called the diastolic pressure.

The contraction phase or systolic phase begins when the auricles contract. The blood forces its way through the mitral and tricuspid valves into ventricles. The ventricles contract and force the blood through the semi-lunar valves, that is, the pulmonary and aortic valves. After passing through the pulmonary and aortic valves the blood enters 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; this pressure is called the systolic pressure. The heart relaxes again and the tricuspid and mitral valves close. Blood flows into the auricles; the mitral and tricuspid valves are forced to open, and the cycle begins again.
APPENDIX D

INFORMED CONSENT FORM
Informed Consent Form for Social Science Research
The Pennsylvania State University

Title of Project: Concept Mapping on Students’ Learning

Principal Investigator: Pao-Nan Chou, Graduate Student
314 Keller Building
University Park, PA 16802
(814) 308-3971; pxc251@psu.edu

Advisor: Dr. Wei-Fan Chen
305 Keller Building
University Park, PA 16802
(814) 883-8057; weifan@psu.edu

1. **Purpose of the Study:** The purpose of this study is to examine the effect of different concept mapping strategies on undergraduate students’ learning performance in online reading.

2. **Procedures to be followed:** After reading the contents of this consent form, you can schedule a time to visit the assigned computer labs. You come into the lab and are randomly assigned to one of the instructional activities, which aim to imparting knowledge about human heart. In each instructional group, you will receive a reading material with or without the support of concept mapping. After finishing reading materials, you will be asked to complete identification, terminology and comprehension tests (three achievement tests).

3. **Benefits:** Concept mapping is a very useful learning strategy. It helps people clarify the concepts and their relationships by using graphics like lines and boxes. Participants in this study will learn basic ideas of concept mapping strategy which will be beneficial to their study in the university.

4. **Duration:** It will take about 1 hour to complete the instructional activity.

5. **Statement of Confidentiality:** Your participation in this research is confidential. No real name will be used in this study. The test data will be stored and secured in PI’s computer. In the event of a publication or presentation resulting from the research, no personally identifiable information will be shared.

6. **Right to Ask Questions:** Please contact Pao-Nan Chou at (814) 308-3971 with questions or concerns about this study.

7. **Payment for participation:** Participants will receive $15 in cash.

8. **Voluntary Participation:** Your decision to be in this research is voluntary. You can stop at any time. You do not have to answer any questions you do not want to answer.
You must be 18 years of age or older to take part in this research study. If you agree to take part in this research study and the information outlined above, please sign your name and indicate the date below.

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

______________________________________________
Participant Signature Date

______________________________________________
Person Obtaining Consent Date
APPENDIX E

INSTRUCTIONAL TREATMENT1
Unit 1: The Heart’s Main Structure—[3 pages]

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 circulates 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 common walls, the septum, between them.

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Previous  Next

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Unit 1: The Heart’s Main Structure—[3 pages]

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

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Previous  Next
Unit1: The Heart's Main Structure—(3 pages)

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

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

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

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Unit2: The Veins, Arteries, & Valves of The Heart—(5 pages)

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 opening 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 the parts of the body below heart level, for example, the trunk and legs, depositing the blood in the right auricles.

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

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Unit 2: The Veins, Arteries, & Valves of The Heart

The right atrium is the upper right chamber of the heart, which receives blood from the body through the superior vena cava and inferior vena cava. The right atrium wall is thinner and more delicate than the left atrium. The right atrium has a greater surface area than the left, allowing for greater efficiency in the intake of blood. Throughout the heart cycle, both the right atrium and the right ventricle are primarily responsible for pumping deoxygenated blood back to the lungs where it will be oxygenated.

Learning Unit

1. The Heart’s Main Structure
2. The Veins, Arteries, & Valves of The Heart
3. The Blood Flow through the Heart (1)
4. The Blood Flow through the Heart (2)
5. The Phases of the Heart Cycle

Unit 2: The Veins, Arteries, & Valves of The Heart

While the blood pressure behind the tricuspid valve brings the flaps together and prevents the flow of blood between the right atrium and the right ventricle, the contraction of the right ventricle continues until the blood pressure is high 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.
Unit 2: The Veins, Arteries, & Valves of The Heart (5 pages)

Returning from the lungs, the blood enters the heart through four pulmonary veins and collects in the left atrium; these vein openings, like the vena cavae, have no valves. The left atrium then contracts when it is full, squeezing blood through the mitral valve into the left ventricle.

The mitral valve, located between the left atrium 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 atrium. 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 the 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.

--- End ---
Unit 3: The Blood of Flow through the Heart (1) - [4 pages]

The directional flow of blood in the heart is determined by valves which allow the blood to flow only in 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.

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Learning Unit

1. The Heart’s Main Structure
2. The Veins, Arteries, & Valves of the Heart
3. The Blood Flow through the Heart (1)
4. The Blood Flow through the Heart (2)
5. The Phases of the Heart Cycle

Unit 3: The Blood of Flow through the Heart (1) - [4 pages]

Both auricles receive blood simultaneously through ven openings which have no valves. The right auricle receives its blood through the superior and inferior vena cavae, while the left auricle receives its blood through the pulmonary veins.

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Previous  Next
Unit 3: The Blood of Flow through the Heart (1) [4 pages]

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 pate and in doing so the blood in their chambers is subjected to increase pressure which forces blood to the ventricles through the opened tricuspid and mitral valves.

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

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Unit 4: The Blood of Flow through the Heart (2) -- [4 pages]

As the ventricles continue to contract, pressure in these chambers forces 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 eart arteries. When pressure in the ventricles becomes greater than that in the eart arteries due to ventricle contraction, the semi-lunar valves open.

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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.

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Unit 4: The Blood of Flow through the Heart (2) -- [4 pages]

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 closes 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.

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Unit 4: The Blood of Flow through the Heart (2) -- [4 pages]

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.

--- 4 ---
Unit 5: The Phases of the Heart Cycle

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 atria. While blood is flowing into the atria, 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 atria and partially opened tricuspid and mitral valves.

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Unit 5: The Phases of the Heart Cycle

The second phase, the systolic or contraction phase, begins when the atria 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.

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Unit 5: The Phases of the Heart Cycle

The heart begins to relax again. The semi-lunar valves are closed, blood flows into the aortoles 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.

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Previous  Proceed to Test
APPENDIX F

INSTRUCTIONAL TREATMENT2
Unit 1: The Heart's Main Structure — [3 pages]

The heart lies toward the front of the body and is in a slanting position between the lungs, immediately below the breastbone. The valve 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 essentially two pumps combined in a single organ which circulates 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 common walls, the septum, between them.

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Unit 1: The Heart's Main Structure — [3 pages]

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

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Unit 1: The Heart's Main Structure... [3 pages]

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

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

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

Unit 2: The Veins, Arteries, & Valves of The Heart... [5 pages]

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 atrium; there are no valves at the opening of these veins.

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

As blood from the body fills the right auricles, some of it begins to flow into the right ventricle immediately, through a common opening.
This common opening, between the right auricle and the right ventricle, is called the tricuspid valve. This valve consists of three triangular flaps or 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 creating 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 pressures 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, facing 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.
Unit 2: The Veins, Arteries, & Valves of The Heart — [5 pages]

Returning from the lungs, the blood enters the heart through four pulmonary veins and collects in the left auricle; these vein openings, like the vein cavas, 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.

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Unit 2: The Veins, Arteries, & Valves of The Heart — [5 pages]

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 the 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.

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Unit 3: The Blood of Flow through the Heart (1)---[4 pages]

The directional flow of blood in the heart is determined by valves which allow the blood to flow only in 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 cavae, while the left auricle receives its blood through the pulmonary veins.
Unit 3: The Blood of Flow through the Heart (1) — [4 pages]

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 pate and in doing so the blood in their chambers is subjected to increase pressure which forces blood to the ventricles through the opened tricuspid and mitral valves.

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

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Unit 3: The Blood of Flow through the Heart (1) — [4 pages]

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 veins.
Unit 4: The Blood of Flow through the Heart (2) -- [4 pages]

As the ventricles continue to contract, pressure in these chambers forces 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.

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Previous Next

Unit 4: The Blood of Flow through the Heart (2) -- [4 pages]

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.

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Previous Next
Unit 4: The Blood of Flow through the Heart (2) — [4 pages]

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 closes 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.

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Unit 4: The Blood of Flow through the Heart (2) — [4 pages]

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.

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Unit 5: The Phases of the Heart Cycle — [3 pages]

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 relaxed 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 fall auricles and partially opened tricuspid and mitral valves.

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Unit 5: The Phases of the Heart Cycle — [3 pages]

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 artor arterines.

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.

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Unit 5: The Phases of the Heart Cycle — [3 pages]

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.
APPENDIX G

INSTRUCTIONAL TREATMENT3
Unit 1: The Heart's Main Structure — [3 pages]

The heart lies toward the front of the body and is in a standing 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 circulates 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 common walls, the septum, between them.

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[Diagram of the heart's main structure]

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Unit 1: The Heart's Main Structure — [3 pages]

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

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[Diagram of the heart's main structure]
**Unit 1: The Heart's Main Structure** — [3 pages]

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

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

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

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**Unit 2: The Veins, Arteries, & Valves of the Heart** — [3 pages]

Blood enters the heart through veins. Only veins carry blood to the heart. The superior and inferior vena cava are the two veins which deposit blood in the right atrium; there are no valves at the opening of these veins.

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

As blood from the body fills the right atrium, some of it begins to flow into the right ventricle immediately, through a common opening.
Unit 2: The Veins, Arteries, & Valves of The Heart – [5 pages]

This common opening, between the right auricle and the right ventricle, is called the tricuspid valve.

This valve consists of three triangular flaps on 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 creating pressure.

![Diagram showing the tricuspid valve and its flaps]

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Unit 2: The Veins, Arteries, & Valves of The Heart – [5 pages]

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 passes 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.

![Diagram showing the pulmonary valve and its flaps]

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Unit 2: The Veins, Arteries, & Valves of the Heart... [5 pages]

Returning from the lungs, the blood enters the heart through four pulmonary veins and collects in the left atrium; these vein openings, like the vein cusps, have no valves. The left atrium then contracts when it is full, squeezing blood through the mitral valve into the left ventricle.

The mitral valve, located between the left atrium 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 atrium. Like the tricuspid valve, the ends of the mitral valve flaps are anchored to the floor of the left ventricle by ligamentum.

Unit 2: The Veins, Arteries, & Valves of the Heart... [5 pages]

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 the 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.
Learning Unit

Unit 3: The Blood of Flow through the Heart (1) [4 pages]

The directional flow of blood in the heart is determined by valves which allow the blood to flow only in 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 cavae, while the left auricle receives its blood through the pulmonary veins.
Unit 3: The Blood of Flow through the Heart (1) – [4 pages]

The instant that the contraction of the atria 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 atria.

The atria, relaxing from their contraction, receive a continuous blood flow from the veins and veins.
Unit 4: The Blood of Flow through the Heart (2) [4 pages]

As the ventricles continue to contract, pressure in these chambers forces 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.
Unit 4: The Blood of Flow through the Heart (2) – [4 pages]

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 closes 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.

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Unit 4: The Blood of Flow through the Heart (2) – [4 pages]

...As the ventricles relax further, pressure within them rapidly decreases. At the same time, blood flowing into the arteries 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...
Unit 5: The Phases of the Heart Cycle... [3 pages]

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

In the diastolic phase, the heart relaxed between contractions. Blood flows into the heart, filling both cavities. While blood is flowing into the cavities, the atrioventricular valves maintain part of the pressure developed by the atrial contraction. This is the time of lowest pressure in the atria, 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 fall in atrial and partially opened tricuspid and mitral valves.

Unit 5: The Phases of the Heart Cycle... [3 pages]

The second phase, the systolic or contraction phase, begins when the atrioventricular valves 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 systemic 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.
Unit 5: The Phases of the Heart Cycle... [3 pages]

The heart begins to relax again. The semi-lunar valves are closed; blood flows into the atricles 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.
APPENDIX H

INSTRUCTIONAL TREATMENT
Unit 1: The Heart's Main Structure — [3 pages]

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 circulates 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 common walls, the septum, between them.

Unit 1: The Heart's Main Structure — [3 pages]

Each half of the heart is divided into an upper chamber and a lower chamber. The upper chambers on each side of the septum are called auricles; the lower chambers are called ventricles. Auricles have thin walls and act as receiving rooms for the blood, while the ventricles have 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.
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 it's contraction is responsible for the propulsion of the blood through the body. The muscle varies in thickness; for example, the muscle in the atrial walls is thin when compared to the thickness of the muscle in the ventricle walls.

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

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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 the parts of the body below heart level, for example, the trunk and legs, depositing the blood in the right auricles.

As blood from the body fills the right auricles, some of it begins to flow into the right ventricle immediately, through a common opening.
Unit 2: The Veins, Arteries, & Valves of The Heart – [5 pages]

This common opening, between the right auricle and the 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 creating pressure.

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.
in the left atrium; these vein openings, like the vena cava, have no valves. The left atrium then contracts when it is full, squeezing blood through the mitral valve into the left ventricle.

The mitral valve, located between the left atrium 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 atrium.

Like the tricuspid valve, the ends of the mitral valve flaps are anchored to the floor of the left ventricle by slender tendons.

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.
Unit3: The Blood of Flow through the Heart (1) — [4 pages]

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.
Learning Unit

1. The Heart's Main Structure
2. The Veins, Arteries, & Valves of the Heart
3. The Blood Flow through the Heart (1)
4. The Blood Flow through the Heart (2)
5. The Phases of the Heart Cycle

Unit 3: The Blood of Flow through the Heart (1)—[4 pages]

The instant that the contraction of the atria 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 atria.

The atria, relaxing from their contraction, receive a continuous blood flow from the vena cava and veins.
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.

Unit 4: The Blood Flow through the Heart (2)—[4 pages]

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.
Unit 4: The Blood of Flow through the Heart (2) -- [4 pages]

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 causes the semi-lunar valves. Pressure within the ventricles is sufficient, however, to maintain closure of the tricuspid and mitral valves against the already increasing atrial pressure.

Blood flowing into the atria from the veins increases the atrial pressure. Due to the differential pressure between the atria and ventricles, the tricuspid and mitral valves are forced partially open.

The circulation of blood through the heart begins again with the next atrial contraction. Atrial 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 consists of two distinct phases. One of these phases is called the diastolic or relaxation phase.

In the diastolic phase, the heart relaxed 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.

![Diagram of blood flow through the heart](image)

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.
Unit 5: The Phases of the Heart Cycle... [3 pages]

The heart begins to relax again. The semi-lunar valves are closed, blood flows into the aortics from the aortas, and the tricuspid and mitral valves are forced partially open.

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