The Effects of Scaffolding on the Performance of Students in Computer-based Concept Linking and Retention of Comprehension

Deyu Hu

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Dr. John Burton, Chair
Dr. Mike Moore
Dr. Barbara Lockee
Dr. Ken Potter
Dr. Peter Doolittle

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ABSTRACT

The purpose of this study was to examine two scaffolding methods on the performance of students in computer-based concept linking and retention of comprehension. After training and practice in concept mapping and CmapTools—a computer-based concept mapping program, 116 undergraduate students were randomly assigned to one of four treatment groups to work on a computer-based concept mapping task. Students in the no scaffolding (NS) group did not receive any scaffolding. Students in the linking phrase scaffolding (PS) group received linking words or phrases as scaffolding. Students in the articulation hint scaffolding (AS) group received a hint question as scaffolding, which asked them to elaborate on relationships between concepts in full sentences. Students in the linking phrase and articulation hint scaffolding (PAS) group received both scaffolding while working on the computer-based concept mapping task. One week after the treatment, students took a concept linking posttest, in which they constructed a concept map in CmapTools based on a web-based instruction on the human heart. After another week, they took another posttest on retention of comprehension about the heart. Two 2 X 2 factorial Analysis of Variance (ANOVA) were conducted to examine the main effects of linking phrase scaffolding and articulation hint scaffolding and any interaction effect between them on the performance of students in computer-based concept linking and retention of comprehension. The results showed no significant difference in the performance of students in both tests. However, the Pearson's correlation analysis showed that there was a positive correlation between students' performance in computer-based concept linking and retention of comprehension ($\gamma = 0.447$, $p < 0.01$).

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INTRODUCTION

Experts and novices in a field differ in many ways, such as their ability to solve a problem in their area. Research reveals that the differences, however, are not caused by intelligence or general use of strategies, but their knowledge in the field. Experts often have extensive and organized knowledge within a field. They organize information around core concepts and are good at recognizing patterns as well as meaningful features of information. These differences, in turn, influence how an individual interprets information and their problem-solving abilities in a field. With this understanding, Bransford, Brown & Cocking (1999, p. 237) believe that the study of how experts act is important in that it illustrates the ideal performance in a field. Preferably, students should be taught to think and perform like experts. However, many researchers (Brandt et al., 2001; Bransford et al., 1999; Kinchin, Hay, & Adams, 2000) find it is common that students' knowledge in an area is isolated, their understanding of relationships between concepts or ideas is implicit and unclear, and they do not have a holistic view of the subject matters.

Several factors may contribute to this problem. First, traditional school courses are often taught linearly in which students only learn discrete pieces of information and they normally do not consider relationships between concepts or phenomena (Brandt et al., 2001). Second, most of the traditional testing approaches, such as multiple choice questions or short answer questions, only assess students' learning of isolated knowledge, which does not encourage the synthesis of learning (Kinchin, 2000). To ameliorate the situation, students should have opportunities to explicitly link concepts or ideas so that they can form integrated view of subject matters. Further, to match this effort, methods used to assess student learning should also target at measuring integrated knowledge instead of discrete facts in students.

Concept mapping, which requires students to "organize and link data in a logical way"

(All, Huycke, & Fisher, 2003, p. 311), is believed to be one of the potential ways that can help students establish systematic and integrated knowledge structures. In concept mapping students have to think over relationships between concepts or phenomena and express them explicitly in visual format, which they may not do spontaneously (Hsu, 2004; Kinchin, 2000; Novak & Gowin, 1984). A study by Ferry, Hedberg, and Harper (1997) verified this statement. Preservice teachers in this study reflected that before being introduced to concept mapping they did not realize that they only have a superficial understanding of the subject matters. They either did not consider relationships between concepts or their understanding of the relationships was inaccurate. By means of concept mapping, however, their knowledge in the subject areas became more extensive, structured, and integrated. When serving as an assessment tool, concept mapping measures students' overall understanding of topics and thus encourages students to integrate knowledge into meaningful structures.

As a potential solution, however, concept mapping is not a simple process (Novak & Gowin, 1984). It is "an intellectually challenging task" (Fisher et al., 1990, p. 352), which requires various higher order thinking skills, such as assessing and classifying information, recognizing patterns, identifying and prioritizing main ideas, comparing and contrasting, identifying relationships, and logical thinking (Jonassen, 1996). As a result, students find concept mapping is "effort-demanding" and requires "elaborate consideration" (Chang, Sung, & Chen, 2001, p. 28), which is especially challenging for less advanced students (Fisher et al., 1990). Among the various difficulties that students may encounter in concept mapping, researchers (Fisher et al., 1990; Jonassen, 1999; Novak & Gowin, 1984) found that it is most difficult to add linking words or phrases between concepts and establish relationships between them.

The difficulty that students face in linking concepts indicates that they need help. Previous research in concept mapping focused on examining the effects of concept mapping on student's learning. Only few studies explored how to help students build concept maps (Chang et al., 2001). Among these studies, no effort has been made to study how to facilitate students with concept linking tasks, which are regarded as the most difficult tasks in concept mapping. To fill the gap, this study will explore potentially effective ways that can aid students in building relationships between concepts and examine how they may influence students' performance in concept linking and other achievement tests.

Scaffolding, as instructional support, can help learners achieve goals or finish tasks that they cannot accomplish on their own but can do with the help from other people or tools. Scaffolding has effectively promoted learning among different learners, for various learning goals, and in diverse learning environments (Beed, Hawkins, & Roller, 1991; Chang et al., 2001; Davis, 1996; Hogan & Pressley, 1997; King, Staffieri, & Adelgais, 1998; Palincsar, 1998). It was also proved to be effective in helping learners construct concept maps. For example, Chang and her colleagues (2001) provided students in one of the experimental groups with a partially finished expert map in computer-based concept mapping. The existing nodes and links in the partially finished map serve as scaffolding to students by reducing their cognitive load and providing a referent structure. The findings indicated that seven grade students in this group outperformed their peers who did not receive such scaffolding in a biology achievement test. Given its success in enhancing students' performance in various tasks, including creating concept maps, scaffolding is a promising solution to enhancing students' performance in constructing quality relationships between concepts.

Scaffolding can be provided in a variety of ways. To find out which kind of scaffolding can help improve students' performance in concept linking, it is necessary to understand the possible reasons that cause the difficulty. Many factors may account for the difficulty that students have in linking concepts, for example, lack of understanding of the subject matter or/and deficiency in concept mapping knowledge and skills (Fisher et al., 1990; Hsu, 2004; Kinchin, 2000). In addition, unfamiliarity with the words or phrases that are used to describe relationships between concepts may also result in the problem. It has been found that rather than using accurate terms to describe relationships between concepts, novices often use “ambiguous terms”, such as “is connected to”, “is related to”, or “involves”, which do not illustrate the nature of relationships between concepts (Jonassen, 1996, p. 109). Although no field study has been conducted, several authors (Fisher et al., 1990; Jonassen, 1996) suggest that providing students with linking words or phrases may help improve this situation. Thus, in this study concept linking words or phrases will be provided to students as scaffolding and the effects that it has on students’ performance in concept linking will be examined.

In addition to the reasons aforementioned, ambiguous understanding about relationships between concepts or ideas may also impede students from stating the nature of relationships between concepts. In many concept mapping tasks, learners are only required to use a couple of words or phases to connect concepts. Statements that explicitly describe relationships between concepts are often not required. Consequently, students may not reflect their thinking completely and accurately (Taber, 1994). They may have the illusion that they understand relationships between concepts while their understanding was “unclear, ambiguous or entirely implicit” (Fisher et al., 1990, p. 350). As a solution to this problem, the second scaffolding method in this study is to ask students to elaborate relationships between concepts by writing down the relationship statements rather than just labeling them using simple phrases. The effect of this scaffolding method on students’ performance in concept linking will also be examined.

Additionally, the interaction effects of the two scaffolding methods will also be studied. Thus, the effect of a third scaffolding method, which combines both linking phrase scaffolding and relationship articulation scaffolding, on the performance of students will also be investigated.

It is expected that as efforts to facilitating students in building relationships between concepts, the scaffolding methods may also help them better understand the underlying structure of subject matters and thus improve their achievements in other academic areas, such as comprehension and recall of instructional contents. In the literature, there are conflicting results reported for the effects of concept mapping on students' achievements (Brandt et al., 2001; Chmielewski & Dansereau, 1998; Sturm & Rankin-Erickson, 2002; Uzuntiryaki & Geban, 2005). As a further contribution to the existing literature, the effects of the scaffolding methods on students' performance in retention of comprehension will also be examined. To this end, this study seeks to answer the following questions:

1) Does *linking phrase scaffolding*, which provides students with relationship phrases, positively affect students' performance in constructing relationships between concepts and retention of comprehension?
2) Does *articulation hint scaffolding*, which requires students to explicitly state relationships between concepts, positively affect students' performance in constructing relationships between concepts and retention of comprehension?
3) Does *linking phrase scaffolding in addition to articulation hint scaffolding* positively affect students' performance in constructing relationships between concepts and retention of comprehension?

4) Is there a positive relationship between students' performance in constructing relationships between concepts and retention of comprehension?

An experimental design will be employed to answer these research questions. Seeking answers to these questions is meaningful since it might find out ways that will help learners better understand the nature of relationships between concepts or phenomena and the underlying structure of subject matters. Having an integrate view about subject topics allows an individual retrieve information and apply it to different contexts easily.

LITERATURE REVIEW

With the goal of seeking a concept mapping related research problem and solving it with scaffolding approaches in mind, relevant literatures on concept mapping and scaffolding were reviewed, including the meanings and historical development of the two concepts, their theoretical basis, applications, and related research. In addition, previous studies that lay the ground for research methodologies and measurements used in this study were also inspected.

Concept Mapping

According to information processing theory, information has to be encoded before it is stored in long term memory. Psychologists proposed several ways that information can be encoded. One way is through meaning, that is, information is encoded by means of general idea rather than exact words or phrases in it. The smallest unit of meaning is proposition. Proposition is usually presented in the form of a statement that involves at least two objects or events and one relationship between them (Ormrod, 2004). For instance, the statement “Dog is animal” consists of two objects (“dog” and “animal”) and one relationship (“is”). When it is encoded, the two objects are treated and stored as connected information in long term memory.

Based on prior knowledge and experience, however, different individuals may encode the same information in their own ways and organize it differently in their long term memory. Although there are individual differences, research in various areas, such as math, chess, history, and science, shows that in addition to having large sets of knowledge and holistic view of their field, experts in a field often organize information around important concepts or principles (Bransford et al., 1999). Contrarily, novices treat information as isolated pieces. For instance, many secondary and college students seldom consider relationships between different concepts in science and do not have a holistic view of the subject matters (Brandt et al., 2001).

The way that an individual organizes information influences how s/he understands, represents, and solves problems (Bransford et al., 1999). Experts with highly structured knowledge in an area often organize information into chunks around major concepts and principles. They also establish more links within and among the chunks than novices do. This way of knowledge organization supports easy information retrieval and application of knowledge to problem-solving situations. In contrast, the isolated pieces of facts in novices make it difficult to retrieve relevant and required information and apply it to problem solving contexts.

To help novices think and perform like experts, Novak and Gowin (1984) suggested that concept mapping can be applied. They believe that concept mapping can help students "learn about the structure of knowledge and the process of knowledge production" (p. 8).

Overview of Concept Mapping

Concept is "a regularity in events or objects designated by some label" (Novak & Gowin, 1984, p. 4). Here, the label could be language or symbol. Concepts are important in learning. It is estimated that in most subject areas more than 99% of subject specific vocabularies are concepts (Fisher et al., 1990). Novak and Gowin (1984) believe that "people think with concepts" (p. 2), so they introduced *concept map*, which is a visual representation of the "meaningful relationships between concepts in the form of propositions" (p. 15), to help teachers and students see the "structure and meaning" (p. 2) of instructional materials. Later, the scope of concept map is expanded to include not only relationships between concepts but also relationships between ideas or phenomena (In later discussions, only concepts will be used to represent concepts, ideas, and phenomena). The process, in which relationships between concepts, ideas, or phenomena are expressed in visual format, is known as *concept mapping*. In some occasions, concept mapping also refers to the strategies used in creating concept maps.

While concept map can externalize an individual's thinking about concepts and their relationships, it should be noted that a concept map is not "a complete representation of the relevant concepts and propositions the learner knows" (Novak & Gowin, 1984, p. 40) but "rather representations of what we think is in the mind" (Jonassen, 1996, p. 115). Thus, a concept map is "a workable approximation" (Novak & Gowin, 1984, p. 40), which to some degree reflects an individual's personal understanding of a specific topic (All et al., 2003; Conlon, 2004; Ruiz-Primo, 2004) and this reflection is more about the cognitive structure rather than memorized facts that an individual has (Jonassen, 1999).

Theoretical Basis of Concept Mapping

Meaningful learning is the theoretical basis of concept mapping (Novak, 2000). Ausubel (Ausubel, 1963; Ausubel & Robinson, 1969) proposed the idea of meaningful learning in contrast with rote learning. He believes that meaningful learning occurs when students make sense of new information by relating and incorporating it to what they have already known and form various relationships between them, such as "derivative, elaborative, correlative, supportive, qualifying or representation relationships" (Ausubel, 1963, p. 22).

According to Ausubel (Ausubel, 1963; Ausubel & Robinson, 1969), meaningful learning requires three conditions: (a) the learning material itself has logical meaning, that is, it is nonarbitrarily connected to a cognitive structure; (b) the learner should have an existing cognitive structure, which the relevant ideas can relate to; (c) the learner must have the intention to relate the new idea to his/her existing knowledge structure. Lack any of the three conditions may cause rote learning (Ausubel & Robinson, 1969). However, rote learning and meaningful learning only differ in the degree that the conditions are met. When the meaningful learning conditions are less met, the degree of rote learning increases. Compared with rote learning, meaningful learning has the advantage of less learning effort, longer retention time, and greater applicable potential to new contexts. It also facilitates the formation of more integrated view about knowledge in students (Ausubel, 1963).

Among the three conditions of meaningful learning, the first refers to the meaningfulness of relationships between different components but not the meaningfulness of each component in the learning material (Ausubel, 1963). Thus, even when all words in a sentence are meaningful, the whole sentence may not be meaningful if relationships between words has no meaning or does not make sense. For example, "Cat has dinosaur".

The second condition refers to the prior knowledge and its structure that a learner should have in order to make sense of new information. Ausubel, Novak, and Hanesian (1978) believe that an individual's existing knowledge structure influences meaningful learning. They stated:

> If cognitive structure is clear, stable, and suitably organized, accurate and unambiguous meanings emerge and tend to retain their dissociability strength or availability. If, on the other hand, cognitive structure is unstable, ambiguous, disorganized, or chaotically organized, it tends to inhibit meaningful learning and retention. (p. 164)

The third condition, which requires a learner has intention to relate new knowledge to his/her existing knowledge, is where concept mapping process can be helpful. Traditionally, students are taught using linear instructional materials and curricula (Brandt et al., 2001; Kinchin et al., 2000; Taber, 1994). If relationships between new information and existing knowledge are not explicitly identified, then student's understanding of the relationships is often "unclear, ambiguous or entirely implicit" (Fisher et al., 1990, p. 350). As a result, students only know isolated facts and they do not have an integrated knowledge structure about a topic. Concept mapping, which requires students to analyze underlying relationships between new and existing concepts or ideas and present them in visual format, encourages synthesis of knowledge and have the potential to enhance information comprehension and retention.

Application of Concept Maps

Concept mapping has been used in different subject areas and learner groups. Research and application of concept mapping focused on science-related subjects (Chang, Sung, & Chen, 2002), such as middle school biology (Chang et al., 2001); secondary school chemistry (Brandt et al., 2001); high school computer technology (Conlon, 2004); and college biology (Cliburn, 1990). In addition, it was also used in areas outside of science, such as content comprehension and summarization in elementary students (Chang et al., 2002). Based on decades' of research in concept mapping, Novak and Gowin (1984) found that concept mapping activities can not only enhance students' cognitive performance and motor skills but also boost their motivation in learning. They claim that "achievement in nearly every area of human endeavor would probably be enhanced if the relevant concepts and how they function were understood and used to interpret events or objects" (p. 48).

Application of concept maps covers all the "spectrum of educational applications" (Cliburn, 1990, p. 212), including as (a) instructional tool; (b) assessment tool; (c) curriculum planning tool; and (d) knowledge eliciting and capturing tool (Jonassen, 1996; Novak & Gowin, 1984). These applications will be discussed in detail below.

As Instructional Tool

There are two different ways that concept maps can be used in instruction (Cliburn, 1990; Jonassen, 1996). They are teacher/other-prepared maps and student-constructed maps. Concept mapping by student is regarded as a legitimate activity (Cliburn, 1990) since it engages students in active and meaningful learning processes. In comparison, there are disagreements upon the use of teacher/other-prepared concepts maps. For example, as a pre-post instructional aid, many science textbooks use concept maps to help students organize and summarize instructional contents at the beginning or end of a chapter or unit (Jonassen, 1996). Although this method can help students see the big picture of a subject topic, it is expository in nature. It may not facilitate meaningful learning if students try to remember or just ignore the maps (Cliburn, 1990). However, if applied in a thoughtful and systematic manner, concept maps constructed by other people can be very effective in promoting learning (Cliburn, 1990). For example, in college biology class Cliburn (1990) made use of teacher-prepared concept maps as advanced organizers. He found that students taught with concept maps outperformed their peers taught without concept maps in knowledge retention. Survey and classroom observation also showed that students liked instructions with teacher-prepared concept maps and were more engaged in classroom discussions. With teaching experience in both situations, Cliburn (1990) suggested that selection of an appropriate approach should be based on the nature of the learning task, the intended learning outcome, and the characteristics of the learners. In this study, review of literature focused on student-constructed concept maps.

Student-constructed concept maps have been utilized in many ways, such as reviewing and summarizing topics (Conlon, 2004; Jonassen, 1996; Puntambekar & Kolodner, 2005), planning prewriting activities (Sturm & Rankin-Erickson, 2002) , developing study skills (All et al., 2003), and organizing hypertext or hypermedia structure (Jonassen, 1999). They were also used to facilitate higher order thinking tasks that involve problem solving, critical thinking, and decision making skills (Ferrario, 2004; Jonassen, 1999). For example, Hsu (2004) conducted a study in which concept mapping was used with problem-based scenario discussions to help nursing students link theories with clinical practices.

Many studies (Chmielewski & Dansereau, 1998; Novak & Gowin, 1984; Sturm & Rankin-Erickson, 2002; Uzuntiryaki & Geban, 2005) revealed that student-based concept mapping activities can facilitate learning. To understand the mechanism, Fisher et al. (1990) examined the roles that concept mapping plays in learning.

Reorganizing knowledge. Concept mapping helps students reorganize knowledge and achieve comprehensive understanding of subject topics. In some cases it may even help students "recognize new relationships and hence new meanings (or at least meanings they did not consciously hold before making the map)" (Novak & Gowin, 1984, p. 17). In concept mapping, learners have to understand the meaning of information, including concepts or ideas and relationships between them, and then reorganize their understanding to reflect the underlying knowledge structure. It is believed that these activities will enhance students' comprehension and retention of knowledge (Jonassen, 1996; Kinchin, 2000). Novak and Gowin (1984) explored using concept maps to help students comprehend instructional texts and other articles. They found that concept mapping helped students identify and extract main concepts or ideas and enhanced knowledge comprehension and recall.

Making thinking explicit. As mentioned earlier, experts differ from novices in the extensiveness of their knowledge as well as the way they organize knowledge (Bransford et al., 1999). Experts organize information around major concepts or ideas and they can build complex and structured concept maps (Ruiz-Primo & Shavelson, 1996). In contrast, novices often have a fragmentary understanding of complex ideas (Kinchin, 2000) due to the way they learn. Generally, students acquire knowledge through a series of lectures over a period time. If not explicitly required, they do not think about relationships between concepts. To create a concept map, however, students have to think about relationships between concepts and ideas, understand the "underlying structure of the idea they are studying" (Jonassen, 1999, p.163), and "have a grasp of the entire situation rather than rely on fragmentary facts from rote memory" (Hsu, 2004, p. 510). Thus, concept mapping process helps learners form a more coherent view of topics (Kinchin et al., 2000). In a study by Zanting, Verloop and Vermunt (2003), student teacher mentors claimed that concept mapping process helped them reflect their own thinking, make tacit knowledge explicit, and reorganize their knowledge structures.

Deep information processing. Concept mapping process involves deep information processing. During concept mapping, students need to identify and classify concepts, clarify relationships between them, and synthesize their understanding into a connected whole (Kinchin et al., 2000). This process requires them to elaborate and organize information in meaningful ways, which cannot be realized through simply memorizing facts without understanding their meaning and underlying associations. This type of deep information processing promotes information retention, retrieval, and application to new contexts (Ausubel & Robinson, 1969).

Multiple channel encoding. Concept mapping activities involve encoding and organizing information in multiple formats (Chmielewski & Dansereau, 1998). During concept mapping, students use labels and propositions to represent concepts and relationships between them. This engages encoding information in verbal format. In addition, they need to encode information in visual format by illustrating relationships between concepts. According to information processing theory, encoding information both visually (the image of concept map) and verbally (labels of concepts and their relationships) utilizes both visual and verbal communication channels in short term memory. This can increase the amount of information to be processed and enhance information encoding and retrieval (Moore, Burton, & Mayer, 2004).

The visual nature embedded in concept maps can also take over part of the cognitive burden. Sturm and Rankin-Erickson (2002) used both hand-drawn and computer-based concept mapping activities to aid eighth graders on essay writing. They found that concept maps helped these students who have learning disabilities see the visual structures of their essays so that they could focus on regulating the writing process.

Facilitating reflection. Concept mapping promotes “autonomous, self-regulated thinking” (Ferrario, 2004, p. 262). Kinchin, Hay, and Adams (2000) believe that concept mapping facilitate reflection by providing “explicit point of focus” (p. 45). Other researchers (Ferry et al., 1997; Taber, 1994) claimed that concept mapping helps learners on metacognition by requiring them to reflect and monitor their own learning, which they may not do spontaneously. For example, in a study by Taber (1994), one student commented that “My knowledge of physics is very unorganized.” Similarly, another student stated that “… I didn’t realize how much the different areas interlinked” (p. 280). In another study by Ferry and his colleagues (1997), preservice teachers used concept mapping tools to organize curriculum content knowledge in science. These students reported that before constructing concept maps they often did not realize that they only had a superficial understanding of a topic—they either did not consider relationships between concepts or their understandings of the relationships were inaccurate. But with the help of concept mapping process and tools, they began to have more integrated view about subject matters. Their curriculum planning skills were also improved through concept mapping practices.

Exploring structural knowledge. Jonassen (1996; 1999) explained the function of concept mapping differently based on Diekhoff’s (1983, as cited in Jonassen, 1996) discussion about structural knowledge. According to Diekhoff, factual knowledge includes declarative, procedural, and structural knowledge. Structural knowledge is about how concepts or ideas are “integrated and interrelated” within a subject area. It is the knowledge between declarative and procedural knowledge. All knowledge has certain structure. Learning structural knowledge promotes “the articulation of declarative and procedural knowledge” (Jonassen, 1996, p. 95). Concept mapping process is the process to explore structural knowledge, which can enhance student performance in information recall and comprehension as well as problem solving (Jonassen, 1996).

In addition to the cognitive effects, the positive feelings generated from successful learning also provide emotional rewards. Novak and Gowin (1984) reported that a student who was deemed as having learning disabilities were actually very smart and performed very well in concept mapping activities. They suggest that many students do not perform well in traditional tests is because they do not like rote learning and the skills associated with it. Concept mapping activities that encourage meaningful learning can be used to boost students’ motivation and improve their academic performance. Moreover, concept mapping was proven effective to enhance motor skill related activities, such as athletic coaching, laboratory, and field studies (Novak & Gowin, 1984).

As Assessment Tool

As addressed previously, many researchers (Jonassen, 1996; Novak & Gowin, 1984; Ruiz-Primo, 2004) believe that concept maps can externalize and reflect students’ understanding of subject matter contents. Thus, it could be used to assess students’ knowledge structure as well as its change as the result of learning.

Concept maps constructed by students can provide detailed information about their misconception and exact weakness (Austin & Shore, 1995; Taber, 1994). For example, in a given context if students associate a different meaning to a concept from what a teacher want them to, then the teacher will know that the students do not differentiate the various attributes of the concept (Novak & Gowin, 1984). Moreover, concept mapping allows teachers to have "a valuable insight into the mental models of students" (Kinchin et al., 2000, p. 44). When concept map is used to examine student's integrated understanding of a topic, it has advantages over traditional testing methods, such as multiple choice questions or fill-in-blank questions, which only examine students' understanding of "isolated ideas" (Kinchin et al., 2000, p. 52) and thus suffer from measuring "isolated fragments" from its context (Kinchin, 2001, p. 1258). In addition, traditional testing methods may even incorrectly judge students' mastery of knowledge. Novak and Gowin (1984) reported that a fourth grader was the best oral reader in her class. However, the concept map that she constructed about how paper is made from trees indicated that she only memorized the contents without much comprehension. Had traditional testing methods been used, the teacher would never know her actual understanding.

Concept map as an assessment tool can be applied to classroom settings where the learning of many students needs to be assessed. Studies showed that concept map is as powerful as some traditional measurement tools, such as personal interview, while it is more efficient and practical (Novak & Gowin, 1984). As a new assessment tool, the validity and reliability of concept map need to be examined by empirical studies (Ruiz-Primo, 2004). To qualify as a valid assessment tool, it is necessary to make sure that concept map reflects students' increasing learning. McGaghie and his colleagues (McGaghie, McCrimmon, Mitchell, & Thompson, 2004) studied concept maps produced by students before and after three weeks' instructions in pulmonary physiology. They found that after the instructions concept maps constructed by students were much similar to experts' maps, which suggests that concept map indeed reflects students' increasing learning.

Acton, Johnson, and Goldsmith (1994) further argued that to qualify as an assessment tool, concept map should reliably predict students' performance in other standard achievement tests. This point of view, however, is subject to criticism since it is assumed that concept mapping and traditional exams are measuring the same thing while some researchers (Kinchin, 2000, 2001; McGaghie et al., 2004) believe that they actually assess different knowledge in students. Thus, when discussing the validity of concept map as an assessment tool, it is inappropriate to use traditional assessment methods as criteria. This will cause a "circular reasoning" mistake (McGaghie et al., 2004, p. 237).

Although disagreement exists, research findings revealed that there is a high correlation between concept map and other testing measures. For example, Austin and Shore (1995) used concept maps to measure students' understanding of physics concepts in multiple-step problem solving. In their study, 12 students aged from 17 to 21 in an elementary electricity course were asked to solve problems and draw concept maps after 12 weeks' study. The results indicated that several quantitative indicators for assessing concept map have high correlations (0.71-0.82) with students' performance in multiple-step problem solving. This suggests that students' concept mapping performance is a good predictor of their performance in multiple-step problem solving.

As Knowledge Eliciting and Capturing Tool

Concept maps can be used to detect implicit knowledge and its structure in experts (Zanting, 2004). For example, in a semi-structured interview, Goodyear and his associates (Goodyear, Tracy, Claiborn, Lichtenberg, & Wampold, 2005) used concept maps to illustrate knowledge structure of two professionals in counseling psychology. They found that this method makes it easy to understand the differences between their knowledge structures. In another study (Zanting et al., 2003), 70 student teachers in Netherlands used concept maps and interviews to detect their mentors' practical knowledge in teaching, which is often implicit to both the mentors and student teachers. Based on content analysis of information elicited from the mentors, the researchers found that while interview produced "more concrete and practice-oriented information" (p. 206), the information generated from concept maps was more abstract and concise and had more useful information about mentors' practical knowledge that underlies their teaching. Moreover, with concept mapping the mentors had no constraint while articulating their knowledge. The researcher concluded that concept mapping was an easy to learn technique. It requires little cost yet has big potential to understand experts' knowledge and its structure. Furthermore, with experts' knowledge and its structure identified, they can be used to build expert systems or knowledge management systems (Jonassen, 1999).

As Curriculum Planning Tool

Novak (2000) suggests that teachers can use concept maps in curriculum planning. With the help of concept maps, important contents will not be missed out untaught. In addition, the organization of concepts often suggests an "optimal sequencing of instructional material" and "make the instruction 'conceptually transparent' to students". As an example, Ferry, Hedburg, and Harper (1997) utilized concept mapping process to help preservice teachers plan curriculum in science. They found that the concept mapping process helped preservice teachers form more integrated view of subject matters and improved their curriculum planning skills.

In summary, concept mapping can be applied to all aspects of education, including as instructional tool, assessment tool, knowledge eliciting and capturing tool, and curriculum planning tool. The following sections review the basic components and types of concept maps and the process involved in concept mapping. Then, difficulties that students have in concept mapping will be identified, which leads to the research problem of this study.

Components and Types of Concept Map

A concept map (see Figure 1) may include the following components: concepts, links, hierarchies, cross links, and examples. Concept, also known as node, is normally represented by one word or short phrase that is put in oval or rectangular. Concepts are connected by concept links, which are lines labeled with phrases to indicate the nature of the relationships (such as composition, function, or example) between concepts. Sometimes arrows are used in linking lines to indicate the direction of relationships. Hierarchy refers to the superordinate and subordinate relationships between concepts. Normally in hierarchical structure the most general concept will be on the top and the more specific concepts are arranged below. Cross links are different from regular links in that they are used to link concepts in one section of a map with concepts in another section of a map. Examples can also be used in concept maps to illustrate positive instances of concepts. To differentiate examples from concepts, examples normally are not arranged in oval or rectangular. For various instructional purposes, synonyms, pictures, or notes can be added to concept maps as well (Jonassen, 1996).

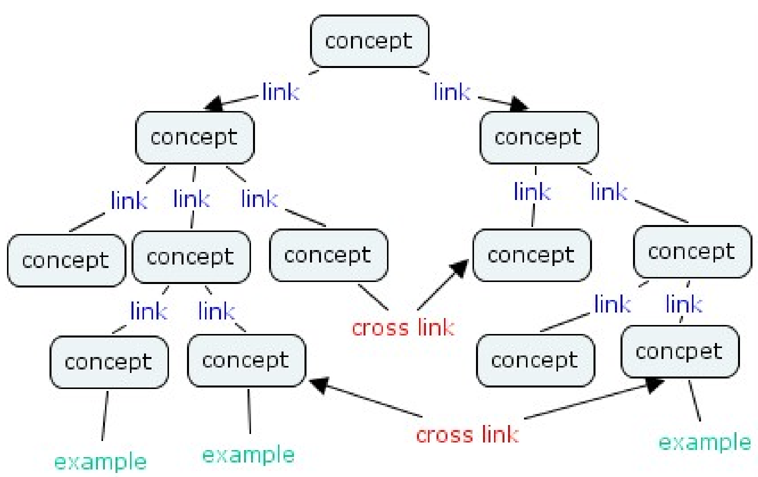

Figure 1. Components of a concept map.

Relevant to hierarchy in concept map, there are two different views about how knowledge is organized in long-term memory (Ormrod, 2004; Ruiz-Primo & Shavelson, 1996). The difference between the two views is that Ausubel and Robinson (1969) believe that the most common relationship between concepts is hierarchical with a single leading concept at the top of the hierarchy while Deese (1965, as cited in Ruiz-Primo & Shavelson, 1996) thinks that knowledge is organized as a network with various possible relationships, which are not necessarily hierarchical. Between these two models, hierarchical model is a more structured arrangement in which more general concepts are at the top of the structure and more specific concepts are below them. Network model is a more flexible propositional model, in which information is connected like a network without strict hierarchy (Ormrod, 2004). Figure 2 demonstrates a hierarchical concept map. Figure 3 is an example of network concept map.

In addition to the two major types of concept maps, researchers also proposed some other types of concept maps (see Figure 4), such as spoke map and chain map (Kinchin et al., 2000). Spoke map is a radial structure in which relevant sub-concepts directly link to a key concept. But there is no link between the sub-concepts. Chain map, also known as string map, is a linear structure in which a concept links to at most two other concepts that are either before or after it.

The different types of concept maps vary in their complexity as well as “accommodation” (Kinchin et al., 2000, p. 46) to further changes. They also reflect the degree of knowledge integration that an individual has on a given topic and can be used to predict how an individual will assimilate new information into his/her existing knowledge structure (Kinchin et al., 2000). For example, a chain map reflects that a student has a narrow view of a subject topic and his/her understanding of relationships between concepts or ideas is often incorrect (Kinchin et al., 2000; Novak, 2000). While it is easy to add new information at the end of an existing chain structure,

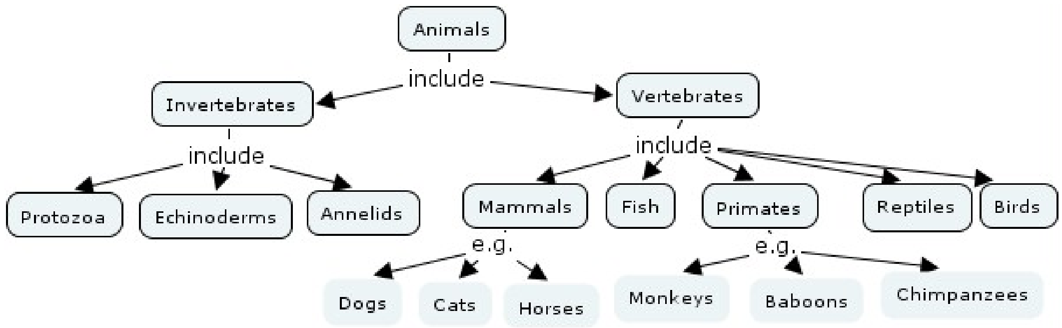

Figure 2. An example of hierarchical concept map.

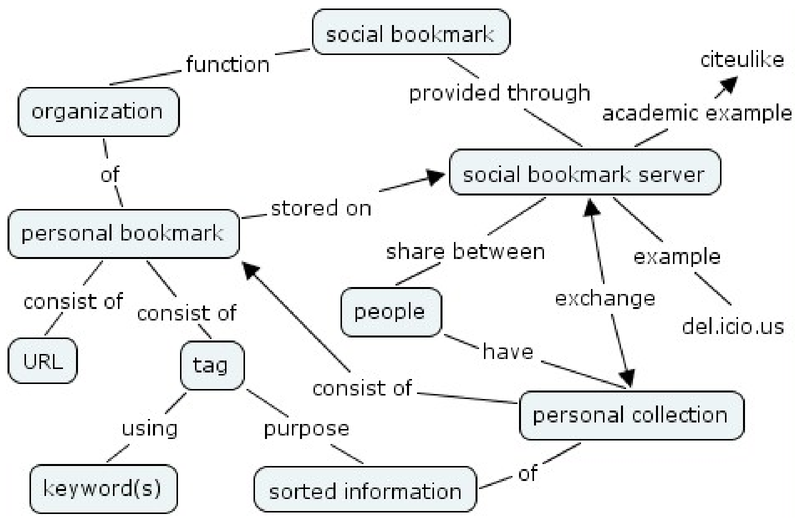

Figure 3. An example of network concept map.

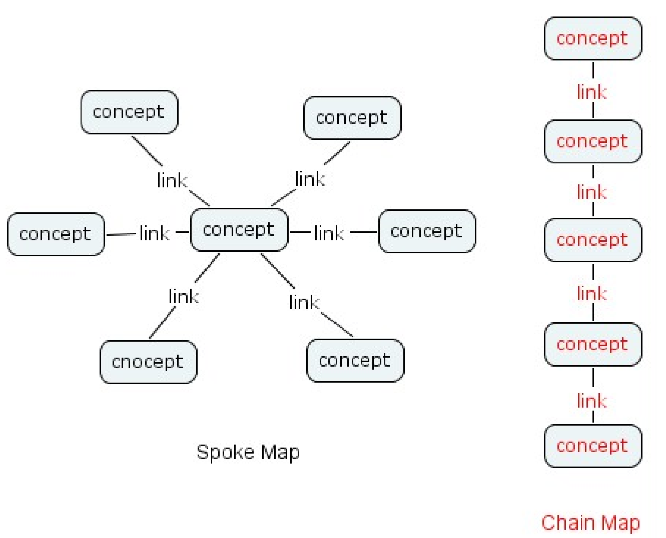

Figure 4. Other concept map types.

adding information in the middle or near the top of the chain may need considerable structural change. The quality differences among the various maps make it possible to evaluate students' understanding qualitatively by examining the type of concept map that they construct (Kinchin et al., 2000). This will be discussed in detail in the scoring system section.

Other authors (All et al., 2003) proposed more map types, like flow charts and system maps. Novak and Gowin (1984) believe that although these forms of maps can represent "relationship schemes", they are not concept maps because they are not "based on the theory of learning and theory of knowledge that underlie concept mapping strategies and their application to education" (p. 37).

Concept Mapping Process

Novak (2000) summarized the concept mapping procedure as: (a) select domain: start from familiar domain of knowledge and set up a context, such as "a segment of text, a laboratory activity, or a particular problem or question that one is trying to understand"; (b) identify the key concepts and rank them from the most general and inclusive to the more specific and least general; (c) construct a preliminary concept map; (d) establish links between concepts based on their relationship; and (e) revise the concept map. All, Huycke, and Fisher (2003) proposed a similar procedure. However, different from Novak, they added the step of "clustering concepts" after step b (ranking concepts) in the hope that it will help learners group relevant concepts together before they construct a preliminary concept map.

In addition to the basic steps, there are some tips that can facilitate a concept mapping process: (a) Use simple words or phrases rather than "sentences in the boxes" to represent concepts since "sentences in the boxes" indicates that there is a relationship statement in the box at the subordinate level (Novak, 2000); (b) try to identify if there is a relationship between each pair of concepts (Jonassen, 1996) but remain selective while constructing links (Novak, 2000);

(c) be “precise and succinct” while describing relationships between concepts and avoid using linking phrase such as “is connected to”, “is related to”, or “involves” because they do not identify the nature of relationships between concepts (Jonassen, 1996, p. 109; Novak, 2000); (d) avoid using chain maps (Kinchin et al., 2000); and (e) keep the meaning of links consistent across a map (Jonassen, 1996).

Besides concept mapping skills, researchers (Kinchin et al., 2000; Novak & Gowin, 1984) believe that an individual’s knowledge and understanding of a topic, which is influenced by his/her “experience, belief and biases” (Novak, 2000), may also affect the creation of concept maps. Jonassen (1996) further argued that learners’ perspective may also influence the final maps that they build. A study by McGaghie et al. (2004) supports this statement. In this study, 31 experts from the same institute were asked to construct concept maps in pulmonary physiology. The experts were classified into three groups based on their expertise: internist group, physiologist group, and anesthesiologist group. The results indicated that the three expert groups organized their concepts very differently. The internists organize their knowledge around “alveolar ventilation and lung perfusion”, while physiologist took “gas exchange” (p. 231) as the focus. As for the anesthesiologists, there was no significant internal coherence among this group, that is, anesthesiologists organized their knowledge very differently from each other. Schmidt (2006) reviewed the study and suggested that the differences might be a result that the experts dealt with the same topic from very different perspectives.

Computer-based Concept Mapping

When concept mapping was first introduced, paper and pencil were used to draw concept maps. The disadvantage of this method is that it is not easy to make changes. Later, Post-it or sticky paper was utilized. During the construction process, each concept was written on a piece of Post-it or sticky paper and then arranged on a big sheet of paper or whiteboard. In this way, it is easy to move concepts around. With the development and application of computer technologies, many computer-based concept mapping programs are now available. Similar to the Post-it method, computer-based concept mapping programs allow users to edit and move the map components easily while keeping concept links working (Novak, 2000).

Relevant research indicated that students had a positive feeling towards concept mapping, especially computer-based concept mapping (Ferry et al., 1997; Sturm & Rankin-Erickson, 2002). For instance, Taber (1994) studied students' reaction to concept mapping and found that most of the students in the one-year physics remedy class like the activity and think it is "a very pleasant experience" (p. 281). Compared with paper-and-pencil based concept mapping, computer-based concept mapping tools are more welcomed and generated better learning outcomes. For example, in a study by Chang et al. (2001), students using computer-based concept mapping tools had a more favorable attitude towards concept mapping than their peers who used the paper-and-pencil method. More than 88% of the students who used computer-based concept mapping tools would like both teachers and themselves to use concept mapping in the future. In contrast, only 53% of their peers in the paper-and-pencil group expressed the same desire. Similarly, Sturm and Rankin-Erickson (2002) studied the effects of computer-based and hand-drawn concept mapping on middle school students' writing. Participants of this study were 12 students with learning disabilities and needs in writing improvement. They were randomly assigned to six groups. Each group wrote descriptive essays under each of the three conditions: no mapping, hand-mapping, and computer-mapping. However, the orders that they experienced the conditions were different. Four writing attitude surveys were conducted before the treatments as well as under each condition. The results revealed that no matter which order they took the treatments, students had a significantly better attitude towards writing with computer-mapping than they did with hand-drawn mapping or no mapping.

While computer-based concept mapping tools are welcomed, it is necessary that they are easy to learn and use. Otherwise, they may increase learners' cognitive burden and turn them away. Colon (2004) suggests that the "10-minute rule", which means that a computer software should be easy to learn so that novices can learn to use it in 10 minutes, applies to selecting computer-based concept mapping tools. Although no research has been conducted to see if students can actually learn a concept mapping software in ten minutes, many authors (Fisher et al., 1990; Jonassen, 1999; Ruiz-Primo, 2004) believe that most concept mapping tools are easy to learn and within one to two hours most learners can learn how to use a concept mapping software. In a study by Ferry et al. (1997), they used a HyperCard-based concept map tool in pre-service teachers. The three independent observers verified that few participants had trouble with the software after one tutorial and an hour's practice. Ferry et al. concluded that with some practice a concept map tool should "became transparent" to the learners so that they can "focus on the cognitive process involved in constructing the concept map".

Difficulties Students Have

During concept mapping, students often face two hurdles: insufficient prior knowledge and experience in concept mapping as well as in subject matter (All et al., 2003; Hsu, 2004). Consequently, they find it is difficult for them to construct concept maps. In a study conducted by Chang et al. (2001), 94% of the students expressed that concept mapping is an "effort-demanding work" and it requires "elaborate consideration" (p. 28), which is especially difficult for less advanced students (Austin & Shore, 1995; Fisher et al., 1990). Students in other studies made similar statements (Ferry et al., 1997; Taber, 1994).

Efforts have been made to understand why concept mapping is difficult to students. Taber (1994) pointed out that traditional texts and lectures are organized in a linear way and require linear information processing. However, concept mapping requires structuring knowledge in interrelated networks, which can be built and read in many different ways. Since students are not familiar with this non-linear information acquisition, presentation, and processing method, they find it difficult, especially when they first work with concept maps.

Jonassen (1999) suggests that thinking involved in different tasks, such as "memorize a list, read a book, understand a lecture, solve a problem, design a new product, or argue for a belief" (p. 2), are quite different. Thus, to understand why students have difficulty in concept mapping, it is necessary to understand the nature of the task and the thinking skills required. Concept mapping is a complex task, which involves all six levels of learning, that is knowledge, comprehension, application, analysis, synthesize, and evaluation (Novak & Gowin, 1984). More specifically, concept mapping involves assessing and classifying information, recognizing patterns, identifying and prioritizing main ideas, comparing and contrasting, identifying relationships, and logical thinking. These activities requires critical, creative, and complex thinking, which are difficult to students (Jonassen, 1996).

Among the various difficulties that students have with concept mapping, researchers (Fisher et al., 1990; Jonassen, 1996; Novak & Gowin, 1984) found that constructing relationships between concepts is the most difficult for learners. It is also difficult to help learners with concept linking. All et al. (2003) stated that "helping students formalize concept links is one of the most challenging tasks in teaching" (p. 311).

Many factors may account for the difficulty that students have in concept linking. As discussed previously, in traditional instruction learners focus more on isolated pieces of knowledge. If not instructed, they seldom pay attention to relationships between concepts, including the phrases used to describe them. Thus, relationships between concepts or ideas often remain implicit to them (Fisher et al., 1990) and they found that it is difficult to describe them precisely using the relationship phrases. As a result, when describing the relationships, learners often use “ambiguous terms”, such as “is connected to”, “is related to”, and “involves”, which do not illustrate the nature of relationships between concepts (Jonassen, 1996, p. 109). Although no field study has been conducted to help students with this difficulty, several authors (Fisher et al., 1990; Jonassen, 1996) suggested that providing students with linking words or phrases may help them construct concept maps. This suggestion is based on the understanding that while concepts may be subject-specific, the phrases that describe relationships between concepts are just plain language and they can be classified into different relationship categories (Fisher et al., 1990; Jonassen, 1996). Moreover, classroom practices showed that a limited number of the phrases can meet the general needs of users, including both novices and experts in a field (Fisher et al., 1990). Thus, it is reasonable and feasible to provide the phrases.

In addition to the unfamiliarity with linking phrases, ambiguous understanding about relationships between concepts may also cause the difficulty. In many concept mapping practices, learners are only required to use a couple of words or phases to label relationships between concepts. This, however, leads to a potential that learners do not completely and accurately reflect their thinking (Taber, 1994). They may have the illusion that they understand relationships between concepts while they do not. This is especially true for learners who have low capability in monitoring their own learning (Driscoll, 2000). To ameliorate this situation, a promising solution is to require learners to explicitly identify relationships between concepts. This method has showed success although it is not based on empirical study. Students in a study by Ferry et al. (1997) used the notes function that is built in a computer-based concept mapping application to elaborate their understanding of concepts and their relationships. One student expressed that explaining relationships between concepts helped her become clearer about how they affect each other, which in turn helped her explain the scientific model that she constructed.

In summary, through literature review two possible solutions, which are providing concept linking phrases and asking students to elaborate relationships between concepts, were identified to help students with concept linking tasks. In this study, the effects of these two methods on students' performance in concept linking were explored. To make sure this was a worthwhile effort, research in concept mapping was examined to see if the research problem and potential solutions have been studied in previous research and what was the major research theme of concept mapping.

Research in Concept Mapping

Research in concept mapping focused on the effects that it has on students' academic performance, such as comprehension, recall, and problem solving. There are mixed results of the effects of concept mapping on student's leaning.

Significant effect found. Chmielewski and Dansereau (1998) studied the effect of knowledge mapping training on information acquisition and retrieval when learners were not explicitly reminded to use the mapping techniques. In their first study, they randomly assigned 60 college students to two treatment groups. Students in the experimental group received training in knowledge mapping while students in the control group took the same time to finish various tests that were not related to knowledge mapping. Two days later, students in the experimental group spent 15 minutes to review knowledge mapping instruction while their peers in the control group spent the same time on more measurement tests. In the following 15 minutes, both groups were provided two articles to read. No instruction was given to use the knowledge mapping techniques. Five days later, both groups took a free recall test on the two articles within a given time period. Students in the experimental group outperformed their peers in the control group in the recall of macro ideas. The authors then conducted a second study in an effort to replicate the first study and at the same time control the possible motivational influence on the results. In this experiment, 53 undergraduate students were randomly assigned to two treatment groups. The procedure was identical with the first study except that a multiplication test was used in both groups in order to find out if there is difference between the two groups in terms of motivation. The multiplication scores indicated that the two groups did not differ significantly in their motivation level. Findings from both studies suggest that learning concept mapping skills can help students recall text information. One explanation of this transfer effect is that mapping skill training provided students a technique to process information in a top-down way with focus on information at the macro level while traditionally students tend to focus more on details and facts at the micro level.

Concept mapping was also used with other teaching techniques to enhance student learning. Uzuntiryaki and Geban (2005) conducted a study to investigate the effect of concept change text and concept mapping instruction on changing students' misconception in science as well as their attitudes towards science. A total of 64 eighth graders were randomly assigned to the experimental and control groups. Both groups received one instruction each week for four weeks. Students in the experimental group received specifically designed texts that aim to change their misconceptions. In addition, they received instruction on concept mapping strategies before they constructed their own concept maps, which was planned to help them organize their knowledge. Students in the control group received traditional instruction with lectures and discussions. Findings from this study indicated that compared with their peers in the control group, students in the experimental group achieved significant concept change and they hold a more positive attitude to science.

Chang et al. (2001) studied students' performance under different concept mapping conditions. They recruited 48 seven graders from three classes. Each class had 15, 16, and 17 students respectively. The classes were randomly assigned to one of the treatment groups: "construct-by-self", "construct-on-scaffold", and "construct by paper-and-pencil". Before the treatments, each class received a general introduction on the techniques that they would be using in the experiment. This section lasted for one hour. Then the day after each biology lesson, individual student spent 50 minutes on building concept map about the instructional contents. This lasted for four weeks. Students in the "construct-by-self" group constructed maps on their own using a computer-based concept mapping system. The system provided them with a concept list and a relationship list that they can put in the map area. When a student clicks on the "Hint" button, the system compares his/her map with an expert map and provides a prompt. In addition, students can click on the "Evaluation" button to see the unmatched nodes and links as well as a score for the map. Students in the "construct-on-scaffold" group used the same computer system but a partially completed expert map was available in the map area with some blank nodes and links. The existing nodes and links in the partially finished map served as scaffolding to students by reducing their cognitive load and providing a referent structure. Students in the "construct by paper-and-pencil" group created maps using paper and pencil. Right after the last session, students took an achievement test in biology as well as a survey about concept mapping. The research findings indicated that the computer system helped students construct concept maps. In addition, students in the “construct-on-scaffold” group outperformed their peers who did not receive scaffolding in the biology posttest.

Significant effect not found. Some concept mapping studies showed that it is not always effective in promoting student learning. Sturm and Rankin-Erickson (2002) studied the effect of computer-based and hand-drawn concept mapping on 12 middle school students’ writing. All participants were identified as having learning disabilities and with needs in writing improvement. A repeated within-subject measurement design was used with a total of four measurements. The first measurement, in which the students wrote two baseline descriptive essays, was taken before the instructions. The other three measurements were taken in six weeks with two weeks’ interval between each measurement. All students went through the three different writing conditions: (a) no-mapping; (b) hand-mapping; and (c) computer-mapping. To eliminate the order effect on their writing, participating students were randomly assigned to six different order conditions: abc, acb, bca, bac, cab, and cba. Each student was required to finish two essays under each writing condition. So, in addition to the two baseline writings, they finished six writings. The research findings revealed that although students hold more positive attitude towards writing under computer-mapping condition, there was no significant difference among the three different writing conditions in term of their effects on writing longer and better essays. However, it should be aware that the design of the study may confound the results. First, all groups were exposed to the same instruction and the only difference among them was the order that they took the instructions. Thus, students may have benefited from previous instruction(s) and a residue effect occurred in the rest condition(s). In addition, another intervention, that is the writing strategy instruction, took place before students wrote under different conditions. The authors speculated that students might have learned how to write from this writing strategy instruction.

In another study, Brandt et al. (2001) studied the effects of concept mapping and visualization on students' construction of integrated knowledge structure. In their study, 132 students in ten classes were recruited from three Belgium schools. The classes were randomly assigned to four treatment groups: concept mapping (CM) group, extra visualization (VIS) group, visualization accompanied concept mapping (CM+VIS) group, and control (CONTR) group. All students attended six 50 minutes sessions on electrochemistry. Students in the CM group received brief introduction of concept mapping at the end of the first session. They also practiced concept mapping by filling in blanks in a partially finished concept map. A list of concepts and link phrases were provided to them. In the following four sessions, the teacher demonstrated how to construct a concept map step by step. At the end of the last session, students constructed their second concept map on their own. Students in the VIS group received extra drawings on experimental design and the electrochemical process. Students in the CM+VIS group received instruction in concept mapping and extra visualization drawings. Students in the CONTR group received neither concept mapping training nor extra visualization drawings. The research findings indicated that concept mapping was not significantly effective on helping students construct integrated knowledge structure. The authors proposed that one reason might be that concept mapping is a new tool for students to use. Without enough understanding and exercises of the tool, it hindered students' knowledge acquisition. They suggest that students should receive training and have enough time to practice the techniques before the experiment.

In summary, existing research on concept mapping focused on examining the effects of concept mapping on students' learning and generated mixed results. Scarce effort has been made in helping students build concept maps, which may in turn improve their learning. Although not designed for this purpose, the study by Chang et al (2001), which was reviewed previously, suggests that providing students with scaffolding can help them build concept maps. Thus, it is possible that it may also help students with concept linking tasks.

Here a new concept, scaffolding, emerges. Scaffolding is an instructional support that helps learners finish tasks that they cannot accomplish on their own but can do with some help. Scaffolding has effectively promoted learning among different learners, for various learning goals, and in diverse learning environments (Beed et al., 1991; Chang et al., 2001; Davis & Linn, 2000; Palincsar, 1998). Given its success in enhancing students' performance in various tasks, including building concept maps, the two methods proposed earlier, that is providing linking phrases and articulation hint, can be delivered as scaffolding and are promising to enhance students' performance in building quality relationships between concepts.

Before reviewing how scaffolding related research and practices can provide theoretical support to this study, however, it is necessary to find out how concept mapping related activities were designed and how students' concept mapping performance were evaluated in the literature, which lent to the design of this study.

Concept Map Assessment

Ruiz-Primo and Shevelson (1996) proposed a framework to assess students' science learning using concept maps. Their framework contains three components: (a) The task, which is the activity designed to examine student's concept map; (b) the format of student's response; and (c) the scoring system that is used to measure student's concept map with acceptable validity and reliability. Since students' responses have to match concept mapping tasks, they are discussed together below.

Concept Mapping Task and Response Format

Based on their previous work, Ruiz-Primo (2004) constructed a model (Figure 5) to illustrate different concept mapping tasks in terms of “degree of directedness” (p. 3). A concept mapping task, thus, can range from “high-directed” to “low-directed”. A “high-directed” concept mapping task provides more information than a “low-directed” concept mapping task. Along the degree of directedness continuum, the tasks with highest directedness are those “fill-in-map” tasks, including filling in nodes and/or fill in links. The tasks with lowest directedness are those free construction tasks in which students construct a map with no concept, linking phase, or structure provided. Between these two ends, from high to low directedness, a concept mapping task can vary from concepts and linking phases are provided, to concepts are provided and structure is suggested, to only concepts are provided (Ruiz-Primo, 2004). As an example, Chang et al. (2001) utilized concept mapping tasks with different directness. While all groups were given a list of concepts and linking phrases, only one group received a partially finished structure from an expert map. The other two groups built the maps freely without an expert map.

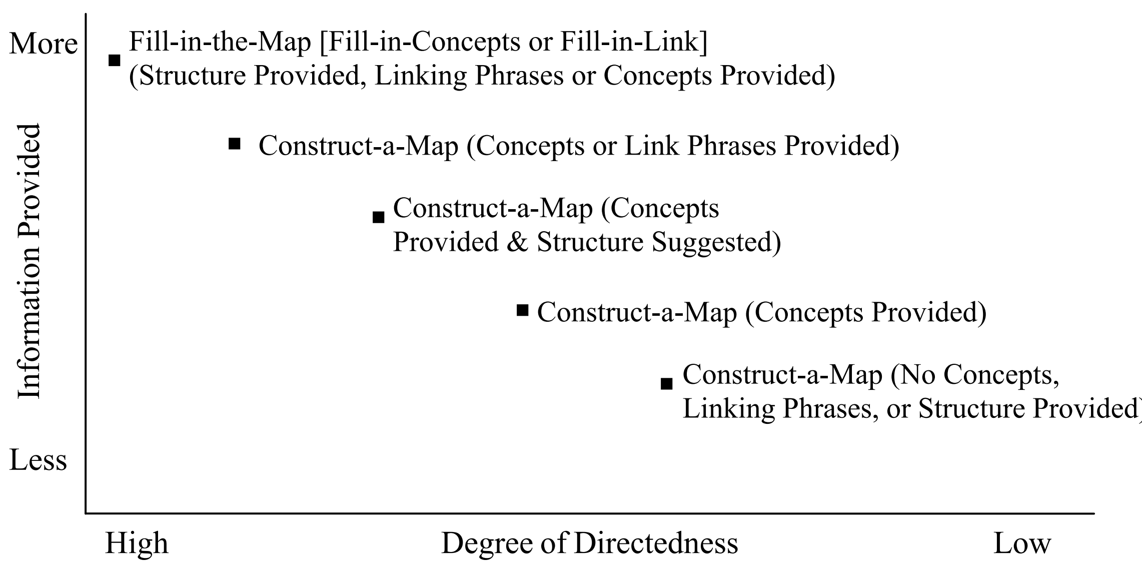

Figure 5. Concept mapping tasks model (adapted from Ruiz-Primo, 2004).

The different components of a concept map can be provided to learners in a variety of ways. In a study by Conlon (2004), part of the concepts were provided through classroom-wide brainstorming. In other studies (Chang et al., 2001; Hoeft et al., 2003), a list of concepts and linking phases were provided through computer-based concept mapping programs.

When it comes to concept mapping task design, teachers can always be creative and add more varieties to the existing task types. Chang et al. (2002) utilized map correction activity in college biology class. In his study, students were provided with a correct map structure but 40% of the nodes or their relationships are incorrect. In this way, students could start with the correct structure but still needed to "think critically" (p. 8) about the map, which helped avoid surface information processing. In another study by Ferry et al. (1997), students used the notes function built in a computer-based concept mapping program to elaborate on their understanding of concepts and their relationships. Tabor (1994) used a similar approach and stated that this method allowed the researcher better understand students' misconceptions based on the statements they made. Depending on the instructional goals, teachers can also ask learners to define concepts, justify their maps, or make maps collaboratively (Ruiz-Primo & Shavelson, 1996).

Different concept mapping tasks require different response formats, have different requirements on learners, and may cause different learning results. Compared with fill-in-map tasks, free map construction tasks require learners to process information more actively and may result in deeper learning. However, it is also time-consuming and requires more training and practice in concept mapping skills. Along with the subject matter to learn, it may cause cognitive overload in students. Thus, when designing a concept mapping task, it is necessary to consider the ultimate learning outcome, the nature of the learning task, and the characteristics of the learners and design the tasks accordingly.

Scoring Systems

Novak and Gowin (1984) first established a quantitative method to score concept maps. In their model four components of a concept map are examined: propositions, hierarchy, cross links, and examples. Figure 6 summarizes the scoring system. Two things should be noted. First, this scoring system was originally designed for measuring hierarchical concept maps but can be applied to network maps as well. Second, the scores assigned to each component were only recommendations. For example, Novak and Gowin suggested that a valid hierarchy should score three to ten times of the points of a proposition, and a valid cross link should earn two to three times of points of a hierarchy score.

Component	**Standard**	**Score Assigned**
Propositions	Is the meaning[ful] relationship between two concepts indicated by the connecting line and linking word(s)? Is the relationship valid?	1 point for each meaningful, valid proposition
Hierarchy	Does the map show hierarchy? Is each subordinate concept more specific and less general than the concept drawn above it (in the context of the material being mapped)?	5 points for each valid level of the hierarchy
Cross Links	Does the map show meaningful connections between one segment of the concept hierarchy and another segment? Is the relationship shown significant and valid?	10 points for each cross link that is both valid and significant; 2 points for each cross link that is valid but does not illustrate a synthesis between sets of related concepts or propositions.
Examples	Specific events or objects that are valid instances of those designated by the concept label.	1 point for each valid example.

Figure 6. Concept Map Scoring System (adapted from Novak & Gowin, 1984).

One issue with Novak and Gowin's (Novak & Gowin, 1984) model is that a relationship between two concepts is only measured as either correct or wrong. Students who construct a partially correct proposition will not receive credit. Thus, the richness of students' understanding is left out. Later, many quantitative scoring models were established based on Novak's model with some revision that took care of the partially correct propositions. For example, Conlon (2004) proposed a model in which students get points for both correct concepts/propositions and partly correct propositions. Thus, a correct concept gets 1 point; a correct proposition gets 2 points; and "a partly correct proposition" (p. 2) gets 1 points. The total score is the sum of the three types of scores. Austin and Shore (1995) utilized a similar model. But in their model the number of relationships between concepts was counted no matter if there is a true relationship between two concepts. A three-point scales coding was employed with code 3 representing a good indication of relationship between concepts, code 2 representing a less good indication of relationship between concepts, and code 1 representing linking two related concepts without labeling the nature of the relationship.

Another issue related to Novak's model is that while measuring the relationships between concepts, it ignores that within a given topic, some relationships are more critical than others (Chang, Sung, Chang, & Lin, 2005). For example, given an instruction on the human heart, which was used in this study (see Methodology for more information), a student can build relationships between body and arms, head, legs, trunk and state that the other concepts are *parts of* the body. If each valid relationship worth 4 points, then s/he will receive 16 points. However, these relationships are not as important as building relationships between right auricle, tricuspid valve, and right ventricle and state that blood *passes through* tricuspid valve and *enters into* right ventricle, from which he can only receive 8 points in Novak's model. To differentiate the importance of propositions within a topic, Chang et al. (2005) suggested that a weighted measurement system should be established. They used a weight index from 0 to 1 to indicate the importance of each proposition. Thus, an important proposition receives a higher weight index than a less important proposition. The weighted index can be determined by teachers based on their knowledge in the subject area.

As a general rule, the criteria, which were introduced by Stoddart et al. (Stoddart, Abrams, Gasper, & Canaday, 2000) to evaluate the depth of explanation of a proposition, can be used to determine the weighted index. Stoddart et al. believe that statement or linkage that answers “why” and “how” questions indicates sophisticated understanding and should be assigned a high weighted index. On the contrary, factual statement or linkage that answers “what” questions should receive a low weighted index. Thus, in the heart example addressed previously, the linkages that illustrate how blood flows from right auricle to tricuspid valve and then to right ventricle should receive higher weighted indices than propositions that state arms, head, legs, and trunk are part of the body. In this way, the assessment of a concept map is sensitive to detect the importance difference in propositions and reflects them in quantity.

In addition, other quantitative assessments of concept map were proposed. Jonassen (1996) suggested evaluating both nodes (concepts) and links (relations) by looking at the breadth of map (number of nodes), extent of map (number of propositions), integration of map (the ratio of propositions to concepts), and the depth of map (levels of nodes). Different from the above, Ferry et al. (1997) counted the number of links that a concept has with other concepts and then classified concepts into one of the following categories: concepts with two links, concepts with three links, concepts with four links, and concepts with more than four links. By comparing the number of concepts in each category before and after a treatment, the authors then could tell if students had a more integrated view about a topic. The various quantitative models indicate that a relatively flexible scoring scheme can be used in concept map assessment, in which the researcher can choose how to interpret a map based on what they are trying to measure.

Although there are slight differences among the scoring models, most of them assess "the number of valid links presented; the degree of cross-linkage indicated; the amount of branching; and the hierarchical structure" (Kinchin et al., 2000, p. 46). However, these quantitative scoring systems have limitations in that only valid links are evaluated. The important value of invalid links, which help detect learners' understanding, especially misunderstanding, is ignored (Kinchin et al., 2000). Therefore, Kinchin et al. (2000) suggested that concept maps should also be evaluated qualitatively and proposed a qualitative classification of concept maps. In the context of their study, 8-year-old students studied the reproduction of flowering plants and then built concept maps based on the content. The students' maps were classified into three categories: spoke, chain, and net maps. The researchers argued that the three types of concept maps represented qualitatively different understanding of the same topic. A linear structure suggests that students have "isolated conceptual understanding" (p. 48) and their interpretation of relationships between concepts is often incorrect. A spoke type of concept map demonstrates little integration of relevant concepts or ideas. A net type of concept map is a "highly integrated and hierarchical network" (p. 47), which shows that students have a deep and wide understanding of a topic.

Using Expert Map

Expert map, also known as referent map, was developed as another way to assess concept maps by comparing a student's map with an expert map. Different from the scoring systems discussed previously, the use of expert map does not focus on counting the number of valid components in a map (Stoddart et al., 2000). A referent map is often created based on two conditions. First, the topic is the same across learners. Second, the relationships between concepts are predictable based on a given topic. When the conditions are not met, it is not practical to create and use an expert map. For instance, in the study by Stoddart et al (2000), students could explore any science topic that they were interested in. It is not realistic to develop many expert maps since different students selected different topics and it was hard to predict which kind of relationships that they would construct.

The assumption underlying the use of criteria map is that experts have similar knowledge structures, which then could be used as standards. However, Acton et al. (1994) reviewed previous studies and found that there were conflicting results about if experts have similar knowledge structure. Based on the review, they studied the validity of using various expert "referent" (p. 303) structures to assess students' learning by comparing the scores generated from these structures with traditional exam scores. The findings showed that structures generated by individual expert varied substantially. Similar result was achieved from a study by McGaghie et al. (2004). In one of the reported studies, they compared concept maps constructed by 31 faculty on pulmonary physiology. The faculty members were classified as internists, physiologists, and anesthesiologists. They all worked in the same medicine school in a university. The findings indicated that faculty had significantly different concept structures within and across the groups. Thus, great caution should be paid when using "referent" structures generated by individual expert because they may lead to very different assessment results of students' knowledge structure (Acton et al., 1994). Further findings from Acton et al.'s study showed that a valid criteria map can be generated from the average of several experts' maps. However, they pointed out that sometimes the average among experts is "meaningless" (p. 304) especially when experts hold very different knowledge structures.

Another debatable practice in Acton et al.'s (1994) study is that traditional assessments, such as test scores from multiple choice questions, were used as standards to evaluate the validity of concept map as assessment tool (McGaghie et al., 2004). This is, however, based on the assumption that concept map and traditional exams are measuring the same thing. McGaghie et al. (2004) argued that they measure different knowledge in students. Study from other researchers supports this statement. Novak and Gowin (1984) reported that students with underachievement in traditional tests may be able to construct quality concept maps and their ability should be recognized. For example, one sixth grader who was tested as grade 4.5 constructed a good concept map that was used by the class. In another study, however, the best oral reader in a class did not perform well in a concept mapping task in which they were asked to explain how paper is made from trees. Based on these findings, it is debatable to use traditional assessments as criteria to study the validity of concept map as assessment tool. This will cause a "circular reasoning" mistake (McGaghie et al., 2004, p. 237).

In addition to serving as a summative evaluation tool, expert map can also be used for formative assessment (Conlon, 2004). Conlon designed the Reasonable Fallible Analyzer (RFA) as such an effort, in which the software-based analyzer was employed to compare concept maps constructed by students and an expert. Then it scored the student map and provided hints for enhancement. The trial in computer technology classrooms showed that high school students accepted the score from RFA as fair and they were motivated to revise their concept maps based on the feedback from the RFA.

Summary

While concept mapping can be used to enhance students' learning, it also has some constraints. Students in several studies reported that building concept maps is difficult and time-consuming especially when they first experience it (Cliburn, 1990; Hsu, 2004). This might be the result of years of rote learning experience. To help learners overcome this situation, training and practices on concept mapping knowledge and skills should be provided. This is what many researchers (Chmielewski & Dansereau, 1998; Sturm & Rankin-Erickson, 2002; Uzuntiryaki & Geban, 2005) have done in their study or made suggestions for future studies (Brandt et al., 2001).

However, even with basic training and practices, students still feel that it is difficult to build relationship between concepts (Fisher et al., 1990; Jonassen, 1996). They need support in order to finish the tasks successfully. Based on a review of literature, two scaffolding methods, which are providing linking phrases and asking students to state relationships between concepts in full sentences, were proposed. It was hoped that these two methods would help learners with concept linking tasks. Next, literature on scaffolding will be reviewed to find out how the two proposed scaffolding methods should be implemented in computer-based concept linking tasks.

Scaffolding

Scaffolding was originally introduced in the context of adults assisting children in acquiring knowledge or solving problems in informal learning environments (Wood, Bruner, & Ross, 1976). Later, it was adjusted to include a wider range of learners with diverse learning goals in formal education (Beed et al., 1991; Dennen, 2004; Kao, 1996; Sharma, 2001). With the development and application of new technologies in education, such as computer technologies, scaffolding was further expanded to learning environments based on these new technologies (Chang et al., 2001; Davis, 1996; Davis & Linn, 2000; Kao, 1996). More recently, the success of distance education is attracting interests for utilizing scaffolding in distance learning environments (Bean & Stevens, 2002; Bonk, Angeli, Malikowski, & Supplee, 2001; Orrill & Galloway, 2001). Despite the increasing interest in scaffolding, researchers have different understandings upon which the concept of scaffolding is built and issues related to it, such as its meaning and scope. As a result, the term scaffolding is often used rather loosely (Hammond & Gibbons, 2001). Thus, research studies involving scaffolding may or may not share common ground, which then requires careful judgment before applying the research findings to practice or conducting further studies based on them.

This section focuses on the theoretical and empirical foundations related to scaffolding in computer-based learning environment. To explore how to design effective scaffolding for computer-based instruction, (a) the term scaffolding will be defined, (b) the theoretical foundation of scaffolding will be clarified, (c) the attributes of scaffolding will be discussed, (d) the factors influencing the success of scaffolding will be summarized, (e) the technology-based scaffolding will be reviewed, and (f) the research in scaffolding relevant to this study will be examined. In short, issues related to scaffolding will be reviewed to lay a foundation for designing scaffolding strategies that can facilitate students with computer-based concept linking tasks.

The Metaphor and Definition of Scaffolding

Scaffolding is the structure outside of a building that supports workers in construction. In the context of education, it refers to the support that helps students finish a complex task or achieve a goal that they could not accomplish on their own (Wood et al., 1976). Based on the metaphor, instructional scaffolding has several characteristics: it supports learners; it functions as a tool; it extends what learners can do; it allows learners to accomplish a task that they cannot complete on their own; and it is used selectively to aid learners when needed (Driscoll, 2000).

Although the metaphor helps us understand the basic elements of scaffolding, it also causes confusion. Lepper, Drake, and O'Donnell-Johnson (1997) point out that the term scaffolding may lead people to think that when scaffolding is taken away, construction workers return to the ground. Mirroring to educational contexts, the situation will be: originally, students cannot complete a task on their own; with scaffolding students can accomplish it; however, when scaffolding is removed, they still cannot do it on their own. To avoid this kind of confusion, Lepper et al. suggest that scaffolding is the temporary structure that supports arches or tunnels under construction. When scaffolding is removed upon the completion of the construction, the arches or tunnels will still be in good condition. This explanation itself also carries confusion. It is not clear that the scaffolding subjects are the workers or the arches and tunnels. However, to some extent, it clarifies the idea that with the removal of scaffolding learners will not return to their previous level. Instead, their performance remains at the higher level, under which they used to complete tasks with scaffolding.

In addition to confusions caused by the metaphor, there is also a stereotype associated with scaffolding. Early practice in scaffolding was between a learner and another more capable individual. This, to some extent, made many researchers believe that scaffolding can only be applied to one-on-one situations. However, some researchers point out that the scope of scaffolding can be expanded beyond pair interactions. For example, Hogan and Pressley (1997) suggest using weaving as a metaphor to expand the use of scaffolding to a whole classroom community, in which not only the teacher supports each individual student, students also support each other.

More importantly, Palinscar (1998) recommends expanding the scaffolding metaphor to include contexts and activities as means of scaffolding in addition to human beings, be they instructors, parents, or more capable peers. Therefore, a tool designed for the same intent, for instance, a cueing card, can also scaffold students' learning (King, 1994). With the advance of new technologies, the scope of scaffolding is further expanded to computer and Internet based technologies. Thus, in technology-based instruction, learners can get help from a variety of resources, including instructor, expert, peer, and technology-based tools.

The increasing interest and application of scaffolding bring some problems. Lepper et al. (1997) note that the concept of scaffolding evokes different meanings among different researchers. Some researchers think of it as any form of support that students receive (e.g., McLoughlin & Oliver, 1998; Steiner & Moher, 1994). Others restrict it to particular processes, strategies, and techniques that support learners (e.g., Azevedo, Cromley, Thomas, Seibert, & Tron, 2003; Orrill & Galloway, 2001). "The popularity of the scaffolding metaphor indicates its conceptual significance and practical value for teaching and educational research" (Verenikina, 2003, p. 1). In 1998, *Journal of Learning Disability* dedicated Volume 31 Issue 4 to an extensive discussion of the metaphor of scaffolding.

Discussions of the scaffolding metaphor lay a ground to define the term scaffolding in this study. Here, *scaffolding* is defined as a process or product that enables a learner to achieve a goal, solve a problem, or finish a task that the individual would not be able to do without support from other human beings or tools. For the convenience of later discussion, the provider of scaffolding is recognized as *scaffolder*. The tools designed to scaffold learning are called *scaffolding tools*. The strategies and techniques used for the purpose of scaffolding are named as *scaffolding strategies*.

From its definition, we can see that the nature of scaffolding is instructional intervention, which is intentionally designed to enhance student's learning. Furthermore, scaffolding is not just any form of support that is offered to students. It has to be the support that helps learners construct knowledge and thinking rather than remembering simple facts (Hammond & Gibbons, 2001).

An Overview

This section is an overview of scaffolding, including its historical development, the roles it plays, and why it is needed in instruction. It is followed by a discussion of the theoretical basis that underpins the use of scaffolding.

Historical Development

Early research and practice on scaffolding focused on parents helping children in informal learning environments (Coltman, Petyaeva, & Anghileri, 2002; Day & Cordon, 1993). Tutoring is another important focus (Beed et al., 1991; Gaskins et al., 1997; King et al., 1998; Lepper et al., 1997; Wood et al., 1976). Because of its effectiveness in informal learning, it was adopted to formal education, which under natural settings is not based on one-on-one interaction but includes multiple learners (Brown et al., 1993; Hogan & Pressley, 1997; Roehler & Cantlon, 1997). With the advance of technologies and their application in education, there are considerable interests in scaffolding students' learning in technology-based environments (Azevedo, Cromley, Thomas et al., 2003; Bean & Stevens, 2002; Bonk et al., 2001; Ge & Land, 2003; Kao, 1996; Sharma, 2001). In addition, many studies have been conducted to use technological means, especially computer-based tools (Chang et al., 2001; Davis, 1996, 2003; Davis & Linn, 2000; Oliver, 1999; Salmon, Globerson, & Guterman, 1989; Zhao, 1998) rather than human being to scaffold students' learning. In recent years, with the boom of internet-based distance education, there are increasing interests in the use of scaffolding in distance learning environment.

Since it was first introduced by Wood et al. (1976) to education, scaffolding has been utilized to teach various content areas, such as literacy (Beed et al., 1991; Palincsar, 1998; Roehler & Cantlon, 1997), math (Ainsworth, Wood, & O'Malley, 1998; Coltman et al., 2002; Lepper et al., 1997), and science (Chang et al., 2001; Davis, 1996; Davis & Linn, 2000; Hmelo & Day, 1999; Hogan & Pressley, 1997; King, 1994; Oliver, 1999). It was also used to foster diverse goals of learning, for instance, language acquisition (Beed et al., 1991), problem solving (Ge & Land, 2003; Oliver, 1999), metacognition (Salmon et al., 1989), and higher order thinking (McLoughlin

& Oliver, 1998; Sharma, 2001). Although it was originally used with young kids, research showed that it is effective among a wide variety of different student population, from young kids (Beed et al., 1991; Coltman et al., 2002; Palincsar, 1998) to middle school students (Chang et al., 2001; McLoughlin & Oliver, 1998; Oliver, 1999), to undergraduate and graduate students (Bean & Stevens, 2002; Kao, 1996; Sharma, 2001); from regular students to students with learning disabilities (Beed et al., 1991; Gaskins et al., 1997; Lepper et al., 1997; Palincsar, 1998). The extensive success of scaffolding indicates its role as successful intervention of learning.

The Roles of Scaffolding

Reigeluth and Moore (1999) classified support for learning into two categories: cognitive support and emotional support. Cognitive support assists students' growth in subject matter. Emotional support influences students' attitude, motivation, and self-confidence towards learning. Scaffolding supports learners both cognitively and affectively (Bean & Stevens, 2002; Dennen, 2004; Lepper et al., 1997). Cognitively, scaffolding can focus learners' attention to relevant information or critical aspects of a problem, leverage cognitive burden, foster higher order thinking, and offer strategies for problem solving (Day, 1983; Gaskins et al., 1997; Stone, 1993; Wood et al., 1976) . Affectively, scaffolding creates unthreatening and engaging environments, in which learners can achieve learning goals that they cannot accomplish by themselves and thus become confident and attach positive feeling to learning.

Cognitive support. For learning to occur it is essential to get learners' attention. According to information processing theory, getting learners' attention is critical to transforming information from sensory memory to working memory. Without attention, information will not be processed or learned. In a new or complex learning environment, for many reasons learners may not be able to focus their attention on information relevant to learning or task at hand. Under this circumstance, scaffolding from teacher or others can draw learners' attention to the task and keep them on the right track. As an unsuccessful example, in Jarvela's (1995) study, the teacher could not get a student's attention from playing Lego pieces to working on the programming task. As a result, he failed to help the student and the learning goal was not achieved.

Scaffolding can also be used to reduce learners' cognitive load (Oliver, 1999) and prevent them from feeling frustrated by difficult tasks (Rosenshine & Meister, 1992). If learners have to struggle with a task all by themselves and keep experiencing failure, they will quickly feel frustrated and may eventually give up. Support from other people or tools can "shoulder some of the intellectual burden" (Jackson, Stratford, & Krajcik, 1996, p. 1) so that learners can focus on more critical components within a task. To leverage students' cognitive load, a teacher can take over part of the cognitive load or provide scaffolding tools, such as cue card (Rosenshine & Meister, 1992). To regulate the difficulty of a task, scaffolder can provide a simplified versions of the task at the beginning and gradually increase the difficulty or divide a complex task into small manageable pieces that learners can handle (Rosenshine & Meister, 1992). However, leveraging cognitive load does not mean taking over all intellectual burden from students. Good instruction should always balance between challenge and support (Roehler & Cantlon, 1997). As students become more competent, it is important to gradually take away support and hand over more responsibility to students. Otherwise, they might either become overly rely on the help or not be able to tackle with the full version of a task.

Scaffolding can also engage learners in learning. In scaffolding, instructors, peers, or technological agents often guide students through the learning process. Learners are more likely to focus on task in guided learning experience (Hmelo & Day, 1999). Interaction with scaffolder often requests learners to verify, elaborate, and summarize their own idea or thinking, and reflect on issues that they will not likely consider by themselves. King (1991) pointed out, when learners have to explain their ideas to others, they need to make their understanding explicit and organized. According to learning theories, such as information processing theory, organizing, elaborating, and reflecting can enhance learning.

In addition to fostering learners' cognitive development, scaffolding can also promote metacognitive growth. Metacognition is the knowledge of what one knows, how one knows, and how to regulate one's learning process. Students with better metacognitive knowledge and skills have better achievement. Many learners, however, do not have enough metacognitive knowledge and skills to learn effectively (Ormrod, 2004). Thus, it is necessary to provide them help to foster their metacognitive development. For example, Davis (1996) designed questions, such as, "Checking Our Understanding" and "How We Spent Time" (p. 10), to guide students through problem solving by monitoring the usage of time and procedure, which they may not be able to do spontaneously. Other researchers (Jarvela, 1995; Kaptelinin & Cole, 2001) also indicate that teacher's scaffolding, such as checking on students' progress or questioning their choice, fostered learners to monitor and regulate their own thinking, which they were not able to do on their own.

Affective support. In addition to cognitive support, scaffolding can offer students emotional support as well (Bean & Stevens, 2002; Hogan & Pressley, 1997; Lepper et al., 1997; Reigeluth & Moore, 1999). In scaffolded instruction, teachers support students by ignoring some errors, providing unthreatening environments, and preventing failure (Bean & Stevens, 2002). With the support, students are willing to participate in instructional activities and are able to perform a task that they cannot do on their own. Through the success they gain confidence (Driscoll, 2000) or attach positive feeling to learning (Lepper et al., 1997). In addition, scaffolding requires shared understanding and shared responsibilities between learner and scaffolder, which have to be achieved through active engagement from both parties. Hogan and Pressley (1997) indicate that teacher's respectful engagement with students' idea undoubtedly created a positive emotional in students about learning.

The Needs for Scaffolding

While scaffolding plays an important role in enhancing student learning, it should be applied only when it is needed. Whether students need assistance is related to the difficulty of an instructional task as well as students' capabilities. Many researchers (Hogan, 1997; Ormrod, 2004; Roehler & Cantlon, 1997) propose that challenging rather than easy tasks promote maximum cognitive growth. Learners tend to lose interests to instructional activities that they can finish easily and feel frustrated with tasks too difficult for them. Ideally, they should be provided with challenging tasks that they cannot finish independently but can accomplish with help from more capable others or tools.

In recent years much attention has been focused on developing learners' higher order thinking skills. However, research findings (Bean & Stevens, 2002; King, 1991; Lin, 2001) consistently show that as a consequence of the mismatch between the difficulty of the task and students' limited competencies, they do not spontaneously engage in higher order thinking. Scaffolding, targeting at filling in the gap with support, has demonstrated effective in fostering the development of higher order thinking skills (McLoughlin & Oliver, 1998; Oliver, 1999; Rosenshine & Meister, 1992; Sharma, 2001).

From another point of view, the fact that not all students can learn effectively indicates their incompetence and needs for help (Puntambekar & Kolodner, 2005). Learning problems may result from lack of cognitive and metacognitive skills (Azevedo, Cromley, Thomas et al., 2003; Rosenshine & Meister, 1992) and these problems can be solved by providing students appropriate support. Rosenshine and Meister (1992) reviewed about 50 studies involving students from third grade to college level. They found that cognitive skills were critical to effective learning and successful teachers often use scaffolding strategies to facilitate cognitive strategy learning. Similarly, scaffolding has been successfully used to help students monitor and regulate their own learning (Azevedo, Cromley, Seibert, & Tron, 2003; Davis, 1996, 2003; Salmon et al., 1989).

Learning problems may also be the result of lack of encouragement or motivation (Jackson et al., 1996), which can be solved through scaffolding as well. For example, students with low self-efficacy tend to give up quickly in the face of difficulty, which further lowers their self-efficacy. Scaffolding these students to accomplish meaningful and challenging tasks may boost their self-efficacy and help create positive feeling towards learning, which in turn improves students' engagement in similar activities (Jarvela, 1995; Lepper et al., 1997).

In addition, the application of some learning philosophies makes scaffolding an essential component of instruction. Historically, the process of learning was perceived as information transmission from teacher to students, wherein students are only passive recipients. However, with the evolvement of diverse learning philosophies, such as social constructivism, students are not recognized as passive recipients anymore. They are actively engaged in instructional activities and also have more responsibility of their own learning. However, students may lack the ability to take over all of the learning responsibilities. As an example, Azevedo, Cromley, Thomas et al. (2003) compared how students learn under three different scaffolding conditions in a hypermedia environment. They found that students without scaffolding did not have an overall plan of learning. They jumped between different types of media without elaborating on the instructional contents. As a result of spending less time to deeply process information, their learning was significantly less than students in the other two groups with some type of scaffolding. It suggests that although some learning theories, such as discovery learning, require students to explore the content on their own, oftentimes students are not yet ready to take over all the responsibilities.

In summary, the mismatch between the difficulty of tasks and students' capability, the fact that not all students can learn effectively, and the nature of some instructional activities validates the needs for scaffolding, especially when the task is new, difficult, and complex. The next section illustrates the theoretical framework of scaffolding, which guides and informs the scaffolding research and practice.

Theoretical Basis of Scaffolding

Wood et al. (1976) did not relate scaffolding with Vygotsky's developmental theory when they first introduced the term scaffolding to educational contexts. However, many researchers believe that the concept of scaffolding is grounded in Vygotsky's developmental theories (Beed et al., 1991; Dabbagh, 2003; Gaskins et al., 1997).

Vygotsky Developmental Theory

Vygotsky was interested in the development of higher mental functions, such as categorical perception, voluntary attention, logical memory, conceptual thinking, and self-regulation of learning (Day, 1983; Gredler, 2001; Lee, 1985). He believes that higher mental functions are acquired through interacting with other people and rooted in social and historical contexts. Therefore, Vygotsky's developmental theory is also referred to as sociohistorical theory. According to Vygotsky, social interaction is translated into psychological functions via "psychological tools", which "direct the mind and change the process of thinking" (Gredler, 2001, p. 241). Language, signs, and symbols are all examples of psychological tools and they are different from culture to culture.

When explaining how social interaction is translated into higher psychological functions, Vygotsky (1978) claims that mental function appears twice in its development: first at the social level and then at individual level; first between people and then inside individual. Higher mental functions develop as the social functions are converted to mental functions. This conversion is mediated through the use of tools and signs. During social interaction, an individual actively modifies the stimulus situation as part of the process of responding to it. Gradually it develops into a sign for use in the individual's mind. This process is called internalization, in which the higher mental functions first go through external stage and then are internalized. Vygotsky (1978) illustrated this process through the development of pointing in a child. Initially the child's grasping is just an unsuccessful attempt. When an adult interprets and acts on it, it becomes a gesture of pointing for the adult. Later the child gradually understands the same meaning as the adult and takes the gesture as a sign for pointing. They thus form a shared understanding of the pointing gesture. As the child transforms the interpersonal activity to intrapersonal activity, internalization occurs. As a result of constant social interaction, higher mental functions develop continuously.

During the development, an individual's higher mental functions are at different levels. Vygotsky claims that what a child can already do is not a good indicator of his or her mental development. He states that students can accomplish more difficult tasks with the assistance of more capable others, which is a more accurate indication of their developmental level. Based on this understanding, he introduced the concept of zone of proximal development (ZPD) and believes that it is a more accurate measure and prediction of learner's cognitive development. According to Vygotsky, the *zone of proximal development* is "the distance between the actual developmental level as determined by independent problem solving and the level of potential development as determined through problem solving under adult guidance or in collaboration with more capable peers" (1978, p. 86).

Later, the “problem solving” ability specified by Vygotsky was expanded to capabilities in any area (Tharp & Gallimore, 1988). Thus, there are three levels of capabilities along the continuum of an individual’s cognitive development: (a) developed capability, that is what an individual can do without others’ help; (b) developing capability, that is what an individual can do with assistance from adults or collaborating with more capable peers, but cannot do without assistance; and (c) underdeveloped capability, that is what an individual cannot do even with assistance. Corresponding to the concept of ZPD, developing capabilities are within an individual’s ZPD.

An individual’s ZPD is not contextually independent. Because of their cultural and personal experience (Tharp & Gallimore, 1988), learners are different in many ways, such as verbal intelligence, logical thinking, scientific intelligence, learning style, prior knowledge, motivation, and epistemological beliefs (Graesser, Bowers, & Hacker, 1997). They also have different ZPDs and vary in how much and which type of scaffolding they need to successfully learn (Hogan, 1997; Hogan & Pressley, 1997).

ZPD and Scaffolding

An important implication of Vygotsky’s theory is that every student is able to learn if appropriate support is provided in their ZPD, that is, students only vary in the amount of help they need for learning to occur (Pressley, Hogan, Wharton-McDonald, Mistretta, & Ettenberger, 1996). With this in mind, then, it is important to know learners’ ZPD before selecting tasks that are in the learner’s ZPD.

Palincsar (1998) described how important it is to know learners’ ZPD from her own research experience. In their research, she and her associates initially wanted to teach children with learning disabilities how to plan and organize writing. However, through their classroom observation at the beginning of the research, they found that the children did not even reach the understanding that the purpose of writing is to communicate. Lacking this understanding, there is no point for them to learn how to plan and organize writing. Under this circumstance, no matter how advanced the original scaffolding strategies and how devoted the teachers might be, they would fail to assist the students effectively, simply because the target skills are beyond the learners' ZPD.

Existing literature (Day, 1983), however, shows that measuring learners' ZPD is more at the theoretical than practical level. Under this circumstance, teachers can make informed guess about learners' ZPDs based on their prior knowledge. Many studies proved that this method is feasible (Fago, 1995; Schunk & Rice, 1993; Wolery, Gast, Kirk, & Schuster, 1988) and could be applied to an individual student as well as classroom settings, where many students' ZPDs need to be estimated.

With learners' ZPDs identified, Vygotsky claims that good instruction as well as scaffolding should occur in the learners' ZPD. However, he pointed out that learning is different from mental development but "should match in some manner with the child's developmental level" (1978, p. 85). More specifically, he indicates that learning precedes development and instruction should occur in learner's ZPD. He further argues that "learning which is oriented toward developmental levels that have already been reached is ineffective" and "the only 'good learning' is that which is in advance of development" (1978, p. 89). Following Vygotsky's thoughts, Bruner (1985) believes that Vygotsky's idea about learning is that individuals enter into a culture via introduction and guidance from more experienced members and the entry point should be within learner's ZPD. If the instruction is below his or her ZPD, the individual has already mastered the skill and may not need support. If the instruction is beyond his or her ZPD, the individual could not finish the task even with others' help and may feel frustrated. Only when a task is within a learner's ZPD could it bring maximum mental development. For a task within a learner's ZPD, however, the individual could not finish it on his or her own and thus needs support from more skilled others or tools. This support could be scaffolding.

As good instruction and scaffolding helped students learn, their ZPDs move forward. Students are now able to finish some tasks in their previous ZPDs independently or accomplish some tasks that fell beyond their ZPDs with scaffolding. To further assist students, scaffolding should match students' changing ZPD. Wells (1999) described this as "aiming at a moving target" (p. 319). Thus, another important feature of scaffolding is its dynamic nature. The dynamic nature of scaffolding has two aspects. First, as learners become more competent at a task, scaffolding should fade. This will give learners increasing chances to accomplish the task on their own. Second, as learners master certain skills, an instructor can raise demands by providing more difficult tasks in the learners' new ZPD and offer scaffolding to the new tasks. Each time when learners need help with a new task the whole scaffolding process begins and repeats. From this viewpoint, scaffolding is helical in nature (Lepper et al., 1997).

Although scaffolding was not connected to Vygotsky's developmental theory when it was first introduced, it fits in the theory very well to a degree that scaffolding and ZPD are frequently mentioned together and even used interchangeably by mistake. To make it clear, Figure 7 lists the relationship between ZPD and scaffolding that has been discussed above.

Features related to ZPD	Influences to Scaffolding
All learners can learn (Assumption).	They only differ in the amount of scaffolding needed for learning to occur.
ZPD is cultural and individual dependent.	Scaffolder should have an understanding of learner's background in order to offer appropriate support.
Learners have different width of ZPD.	Learners with narrower ZPD should be provided with more frequent scaffolding.
Diagnosis of learner's ZPD, which may base on informed estimation, is required before providing scaffolding.	The selection of scaffolding level, frequency, and strategies should be based on the diagnosis of learners' ZPD.
ZPD is dynamic in nature as learner progress along his or her cognitive development.	Scaffolding should fade and more difficult tasks should be presented.
Learners should be continuously presented new activities in their ever changing ZPD.	New scaffolding is needed. Scaffolding is helical in nature.

Figure 7. The relationship of ZPD and scaffolding.

Attributes of Scaffolding

With the theoretical basis identified, it is necessary to explore the basic attributes of scaffolding, including the scaffolding process, the levels of scaffolding, and the types of scaffolding. Following that, two important concepts embedded in scaffolding, which are intersubjectivity and fading, were discussed. Then, the factors that influence the success of scaffolding were examined. Some of the items discussed here were based on face-to-face scaffolding but should shed light on scaffolding application in computer-based environments.

Scaffolding Process

The roles that scaffolding plays in instruction are implemented through scaffolder who can model the task, manage learning environment, and oversee activities (Coltman et al., 2002; Day, 1983). Roehler and Cantlon (1997) conducted a qualitative study in two elementary language classrooms over three years to find out what teachers do in typical scaffolded instructions. Through the analysis of transcripts from audio-taped lessons, they found that teachers scaffolded students' learning by offering explanation, inviting students' participation, verifying and clarifying students' understandings, modeling desired behavior, and inviting students to contribute clues.

Many researchers attempted to illustrate the process in which these activities occur during scaffolding. The processes they proposed vary in complexity and thoroughness. Wood et al. (1976) proposed the first scaffolding process as they introduced the metaphor of scaffolding to education. Later, other researchers (Hammond, 2001; Kearn, 2000) also proposed the process of scaffolding. The scaffolding processes are summarized in Figure 8 and organized in the time order that they were proposed. It should be noted that the process proposed by Kearn's (2000) was originally designed to help students develop social competence and is expanded here to serve as a generic scaffolding process.

As a summary, Hogan and Pressley (1997) reviewed the essential elements of scaffolding: Pre-engagement; establishing a shared goal; actively diagnosing the understanding and needs of the learners; providing tailored assistance; maintaining pursuit of the goal; giving feedback; controlling for frustration and risk; assisting internalization, independence, and generalization to other contexts. They suggest that these strategies should be used as general guidelines rather than fixed steps.

Author(s)	Steps	Explanation
Wood et al.	Recruitment	Attract and maintain learners' interests.
	Reducing degree of freedom	Simplify a task by reducing steps needed to finish it.
	Direction maintenance	Keep learners on the right track.
	Marking critical features	Highlight important and relevant information.
	Frustration control	Control the difficulty of the task so learners will not be very stressful.
	Demonstration	Demonstrate how to deal with the task.
Kearn	Gathering information	Listen to student's question or observe their behaviors in order to understand which kind of problem they have.
	Defining the problem	Is it caused by lack of prior knowledge, learning skill, or motivation?
	Setting a goal	What do you expect the students to be able to do?
	Selecting strategy	Think about several ways to facilitate students and select one strategy to help students.
	Evaluation	Get feedback from students and confirm if it works.
	Iteration	Based on the feedback of students, provide further facilitation or set a higher goal for them.
Hammond	Building the field	Teachers design activities and lead students on knowledge understanding and developing new skills.
	Modeling	Teachers explicitly explain their thinking and action while demonstrating it.
	Joint construction	Teacher and students work together to achieve shared understanding and responsibility of the task at hand.
	Independent construction	More responsibilities are shifted to students and students take control over the task while teacher gradually withdraws support.

Figure 8. Scaffolding Processes (adapted from Hammond, 2001; Kearn, 2000; Wood et al., 1976).

Levels of Scaffolding

Beed et al. (1991) classified scaffolding into five levels. From concrete to abstract, they are: full modeling, assisted modeling, elements cueing, strategy cueing, and general cueing. Figure 9 is a summary of these levels and their forms. Examples for each scaffolding level are provided, in which a teacher scaffolds students to use the Table function in Microsoft Word.

Levels of Scaffolding	Forms	Examples
Level E: full modeling	The teacher models the complete performance and use verbal explanation to identify the elements of the strategy being used.	The teacher demonstrates how to insert a table on the computer and explain it simultaneously. "Under Table menu, select Insert, then Table. Select how many rows and columns you want and click on OK."
Level D: assisted modeling	Students are encouraged to participate in the teacher modeling process.	At the beginning of a class, the teacher can ask "We learned how to insert a table in last class. Can you tell me how to do it?" The students respond to the question and the teacher will follow their answer and demonstrate it on the instructor's computer.
Level C: elements cueing	The teacher identifies the elements of strategy to help learners finish the task.	As one student has difficulty with it, the teacher will cue him "Did you try the Insert function under Table menu?"
Level B: strategy cueing	The teacher identifies the name of the strategy but not the specific elements of the strategy.	As one student has difficulty, the teacher will cue him "Did you try the Table menu and see what you can do?"
Level A: general cueing	The teacher only provides a general verbal cue, which is not task specific.	As one student has difficulty, the teacher will cue him "What should you try?"

Figure 9. Levels of Scaffolding (adapted from Beed et al., 1991).

In addition to learners' ZPDs, the level of scaffolding also varies based on other factors, such as task difficulty and learners' developmental level. In general, the more difficult a task, the more concrete the scaffolding should be. The less advanced a student's developmental level, the more concrete the scaffolding should be. Research findings support the above statements. For example, Oliver (1999) investigated the effect of students' epistemological beliefs on their use of scaffolding tools in a computer-based scientific learning environment. The findings indicate that more explicit and direct scaffolding are more effective for younger students, while open-ended scaffolding with general cueing is more effective for older students. Support also comes from

Zhao's (1998) study, in which he employed computer-based scaffolding program to teach eight graders mathematics. Results from his study demonstrate that students with higher ability relied less on the scaffolding tools and used them less than low ability students.

Types of Scaffolding

To conceptualize the different types of scaffolding, researchers put labels on them. For example, Hannafin, Land, and Oliver (1999) classified scaffolding into four categories based on its function: conceptual scaffolding, metacognitive scaffolding, procedural scaffolding, and strategic scaffolding. Conceptual scaffolding provides learners guidance about what to consider. For example, Bean and Stevens (2002) used prompts to guide pre-service teachers to reflect the instructional content. One example is "Chapter two talks about the culturally pluralistic society in which we live, teach, and learn. Discuss both the challenges and benefits that arise from working with children of diverse background" (p. 210). Metacognitve scaffolding supports learners to monitor and regulate their own learning. For instance, Davis (1996) used "Checking Our Understanding" and "How We Spent Time" questions to guide students to monitor their understanding of the scientific projects and how they spent time. Procedural scaffolding helps learners on how to use resources and tools provided by the learning environment. As an example, Ge and Land (2003) provided the general process of problem solving to help students solve computer programming problem. Strategic scaffolding offers learners a repertory of alternative techniques and tips. For example, in Azevedo, Cromley, Thomas et al.'s (2003) study the tutor gave a student hint on how to illustrate his idea clearer by saying "It will be easier to understand if you make a drawing" (p. 27).

Other researchers classified scaffolding into different types based on their understanding or research needs. For example, Beed et al. (1991) categorized scaffolding as incidental scaffolding and strategic scaffolding. Azevedo, Cromley, Thomas et al. (2003) used content scaffolding and procedural scaffolding in their study. In addition to the four categories proposed by Hannifin et al. (1999), McLoughlin (2002) expanded the scaffolding categories to include orientation, coaching, eliciting articulation, task support, and expert regulation. Jackson, Krajcik, and Soloway (1998) classified scaffolding as supportive scaffolding, reflective scaffolding, and intrinsic scaffolding.

Different types of scaffolding may take different forms, such as, questioning, analogy, demonstration, feedback, modeling, cognitive structuring, and task structuring (Oliver, 1999; Tharp, 1993; Tharp & Gallimore, 1988). These forms are also known as scaffolding strategies. Among all the means of scaffolding, questioning is the best studied strategies, which was discussed in detail later in the relevant research part. In addition to questioning, other strategies are also used in scaffolding. For example, in modeling the more capable person or agent demonstrates how to accomplish a task (Jackson et al., 1996) while during thinking aloud the teacher describes how she or he will work on a task and labels each step of the process, which can later be used as hints or cues to students (Roehler & Cantlon, 1997). Two or more scaffolding strategies can be used together in one instruction. For instance, in Oliver's (1999) study, he provided several forms of scaffolding, including job aids documents, activity hints, evidence hints, and worksheet to assist students with scientific problem solving. Hogan and Pressley (1997) claim that putting individual instructional strategies together should produce effects greater than the sum of them. Research is needed to prove this synergetic effect.

The next section explores two concepts that embedded in the metaphor of scaffolding: intersubjectivity and fading. Following that, the factors influence scaffolding are discussed.

Intersubjectivity

According to Vygotsky, learning is based on sharing of cultural knowledge and is a process that individual enters a culture via the introduction and guidance of more capable members. For scaffolding to occur, the dyad has to reach intersubjectivity through interaction. *Intersubjectivity* refers to the shared understanding of the task objectives, its procedure, and conditions of participation as well as shared responsibility and shared effort between the two individuals who work together on a task (Driscoll, 2000). While shared understanding between learner and scaffolder is well accepted by researchers, few of them mentioned shared responsibility and shared effort in their study, although these two aspects might have been achieved during the scaffolding process.

Learning has both cognitive and affective aspects, without "interaction that express mutual respect, trust and concern" (Wells, 1999, p. 333) it will not be successful. Thus, it is important to achieve intersubjectivity between learner and scaffolder (Greene & Land, 2000; Palincsar, 1998). Without shared understanding of a task, each partner's responsibility, and their shared efforts, learners may not understand the importance of the task and why they should accomplish it. As a result, they may not engage in learning. Jarvela's (1995) study illustrated such a case. In her qualitative study, the researcher studied the interaction between teacher and students while an experienced teacher scaffolded seventh graders with computer-based problem solving using Legologo. When there is joint effort and participation from both parties, the teacher could scaffold the learners effectively. Contrarily, in one of the scaffolding sessions, a student did not know why he should carry out the programming task. He just focused on constructing the Lego pieces. There was no shared understanding between the teacher and the student about the goal of the task, the role of the learner, and how he should participate. Consequently, the teacher failed to get the student involved in the instructional activity and failed to help him. Jarvela went on indicating that in addition to getting learners involved in learning, shared understanding and responsibility can also keep students focused on an instructional task.

While it is important to establish intersubjectivity, it takes time and effort to reach it. Kaptelinin and Cole (2001) proposed a three-stage development of intersubjectivity through a research, in which they wanted to study how the social context would influence children's learning and development. In their study, they paired children with college students in computer-based games and found that there were three stages in the development of intersubjectivity: pre-intersubjectivity, intersubjectivity, and post-intersubjectivity. During the pre-intersubjectivity stage, the two individuals in each dyad have their own goals, which may not be the same. In their case, the children wanted to play computer games while the college students needed to learn more about children development and finish course requirements. At this stage intersubjectivity is not yet established. The children and college students needed to work collaboratively to achieve their goals. During the intersubjectivity stage, the group members need to coordinate each others' efforts effectively and share their emotions, be it positive or negative, to reach intersubjectivity. As an example of changing from pre-intersubjectivity to intersubjectivity, one college student began to describe their activities as joint effort by using "we" to refer to the team. In the post-intersubjectivity stage, intersubjectivity has already been established. However, individuals may or may not adopt the group experience in their individual or other collective activities. As an example of adoption in their study, some children began to take responsibility to coordinate group activity, which was originally accomplished by the college students.

As another example, Jarvela (1995) studied qualitative features of teacher-student interaction in a technology-rich learning environment. In her study, the participants were involved in a relatively abstract and complex task—programming Lego unit as washing machine. She found that building intersubjectivity between teacher and students in abstract and complex environment is different from in cultural abundant environment, such as in traditional apprenticeship. She did not offer an explanation of the possible reasons since she thinks that we do not understand the role of abstract learning task in collaborative learning environment. While more research is needed to explore the effect of a task's nature on the establishment of intersubjectivity, based on the discussion above, one reason for her finding might be that it needs time and effort to establish intersubjectivity. In traditional apprenticeship, the apprentices are normally given a long time to gradually learn various skills, while in classroom-based setting students and teacher only have very limited time to reach a shared understanding of a task.

Building intersubjectivity in the essence is establishing good communication between different parties involved in scaffolding (Stone, 1993). Researchers suggest the following strategies can be used to build intersubjectivity: (a) building shared understanding by repeating learners' idea, adding clarity to their ideas, requiring students to verify, and expanding and refining their statements; (b) setting a positive emotional tone during scaffolding, such as, using eye contact and other body language to show a respect, listening, accepting attitude, or showing interests in learners' thoughts and feeling; (c) designing activities to meet diverse learning interests by allowing learners to make choices or incorporating learners' understanding into the activity; (d) fostering success at the beginning of the activity; (e) providing enough time to develop shared understanding and shared emotion; and (f) cultivating more sophisticated epistemological beliefs, such as offering students chances to explore the dynamic nature of knowledge (Kaptelinin & Cole, 2001; Ormrod, 2004; Palincsar, 1998; Shuster, 2000).

Although some researchers (Greene & Land, 2000; Palincsar, 1998; Wells, 1999) advocated the importance of intersubjectivity in face-to-face scaffolding, it has not yet been implemented in contexts where tools, including computer-based tools, serve as scaffolding. Thus, it remains unclear if establishing intersubjectivity, which is an integral component of Vygotsky's developmental theory, would make tool-based scaffolding more effective.

Fading

During scaffolding, as learners become more competent, scaffolding should be gradually removed and learners should take over more responsibilities. This process is fading. Fading involves both reducing the amount and decreasing the level of scaffolding, that is, moving from providing more concrete scaffolding to more abstract scaffolding (Beed et al., 1991; Day & Cordon, 1993; Fago, 1995; Riley, 1995). Fading is a gradual process. During the internalization process even though students begin to assist their own learning through self-talk or inner speech, their performance is not totally developed yet. They may still need help from more capable others in the form of hints, suggestion, or feedback (Tharp & Gallimore, 1988).

Although some researchers (Chang et al., 2002; Day & Cordon, 1993; Kao, 1996) think that fading is an essential part of scaffolding process, not all studies in scaffolding involved fading. Instead, like many instructional interventions, scaffolding is treated as a one-time shot. To identify the difference between scaffolding with and without fading, Roehler and Cantlon (1997) classified scaffolding into two categories: permanent scaffolding and temporary scaffolding. In permanent scaffolding, the supports to learners always present. In temporary scaffolding, the aids to students fade as students become more competent. These two scaffolding are also known as fixed scaffolding and adaptive scaffolding respectively.

Although scaffolding practices without fading have been proved effective in assisting students' learning (Chang et al., 2001; Ge & Land, 2003), fading is important for several reasons. First, when learners become more skillful at a task, they need less assistance (Day & Cordon, 1993). Unnecessary support from others may interfere with learners' thinking process and potentially harm their performance if learners have already internalized the information and it becomes part of their fully developed capabilities (Tharp & Gallimore, 1988).

Second, without fading learners may over-rely on scaffolding, be it from human scaffolder or scaffolding tools (Kao, 1996). Jarvela's (1995) study confirms this statement. She studied the interaction between teacher and students based on cognitive apprenticeship model. In her study, an experienced teacher scaffolded seventh graders with computer-based problem solving using Legologo. No fading was used. Results from this study showed that students were relatively passive and not able to take responsibility of learning. Some students even became more and more dependent on the teacher's guidance.

Third, fading allows learners gradually take over more responsibility and gives them chances to increasingly regulate their own learning, which helps them become more self-regulated. The ability to self-regulate one's own learning is a critical attribute of life-long independent learners and is particularly important to distance learners who need to plan and monitor their own learning. Research results support this argument. Azevedo, Cromley, Thomas et al. (2003) investigated the effect of different scaffolding interventions on students' performance and self-regulation behavior in hypermedia learning environment. They randomly assigned 53 undergraduates to one of the three scaffolding conditions: no scaffolding (NS), adaptive process scaffolding (APS), and adaptive content and process scaffolding (ACPS). Students in the control group did not get any type of support during learning. Students in the APS group got procedural support from the tutor to self-regulate the different learning phases. In addition to the procedural scaffolding that the APS students got, students in the ACPS group also got adaptive content scaffolding from the tutor. Data from pretest, posttest, and transcript of verbal protocol were collected. The results showed that students in the APS and ACPS group effectively improved their mental model. However, students in the ACPS group over-relied on tutor to regulate their learning by seeking helps while students in the APS group regulated their learning through planning, monitoring their own understanding, and used strategies to handle task difficulties. Students in the NS group were less effective in improving mental model and varied a lot in self-regulation behavior, but they presented more interests in the topic than the other two groups.

Moreover, researchers relate fading to knowledge and skill transfer. For example, Day and Condon (1993) claimed that providing support when students need it and ceding it as students become more skillful are two essential components of faster learning and better transfer. This is confirmed by a study from Renkl et al. (2002), who studied the effect of fading in problem finding and found that fading helped students perform better in near-transfer tasks.

In summary, fading is important in scaffolding although it has not been widely integrated into scaffolding studies. Unnecessary support to learner may interfere with learning and cause over-dependency on scaffolding. Use of fading, on the other hand, can facilitate learners to be self-regulated.

Influencing Factors

Enough evidence has shown that well-designed scaffolding can systematically and dynamically facilitate learning based on the characteristics of a learner, the nature of the subject or task, and the learning environment (Beed et al., 1991; Davis & Linn, 2000; Palincsar, 1998). However, factors that influence the effectiveness of scaffolding remain in scattered pieces. Having an integrated view about the factors can help us understand research studies and expand the use of scaffolding to different contexts. The following section summarizes the essential features of instruction, scaffolder, and learner from the perspective of effective scaffolding.

Instruction

Effective instruction should occur in learners' ZPD and balance between challenge and scaffolding (Roehler & Cantlon, 1997; Vygotsky, 1978). To match learners' level of cognitive development, scaffolding should occur in learners' ZPD (McLoughlin, 2002). As an example, in Jarvela's (1995) study, the teacher made use of two types of modeling to assist students: global modeling, in which the teacher modeled before the whole class; and situation-specific modeling, in which the teacher interacted with a pair of students. The situation-specific modeling was more effective in showing the thinking and planning process of problem solving. Two reasons may account for the effectiveness. First, situation-specific modeling was more relevant to students and thus could attract their attention. Second, situation-specific scaffolding was tailored to help each dyad and thus better matched the students' developmental level.

Scaffolder

Lepper et al. (1997) studied how expert human tutors scaffold learning in mathematics among elementary school students who need substantial remediation. They found that expert tutors do exist. They can foster learning among a variety of students with different initial achievements. As a result of the tutoring, students' socio-emotion also improved significantly. At the beginning of the tutoring sessions, the students had low-achievement and self-efficacy. At the end of the tutoring session, they felt confident about themselves and would like to take more challenges in the subject matters.

Expert scaffolders are not only content expert but also know how to present contents in a way that it is easy for learners to understand. Effective scaffolder must be very competent with the subject matter (Hogan & Pressley, 1997; Lepper et al., 1997; Pressley et al., 1996). Only when the scaffolders know the curriculum very well could they be able to identify which kind of problem or misunderstanding students might have and offer help accordingly. In addition, during scaffolding it is quite normal that the initial support to students might not work and another attempt is needed. This requires that the scaffolders are able to dynamically assess students' learning and provide appropriate support, which is also based on their in-depth knowledge of the curriculum.

Effective scaffolders must also have a variety of pedagogical expertise (Lepper et al., 1997; Tharp & Gallimore, 1988). Pedagogical expertise includes managing classroom and behavior, supervising students' activities, monitoring and assessing students' progress, providing students feedback, and knowing how to help students when they have trouble (Pressley et al., 1996; Tharp & Gallimore, 1988). Effective scaffolders should also have insights into individual learners, i.e., understand what the learners already knows, what level they can reach with help, and what their misconceptions are (Hogan & Pressley, 1997; Pressley et al., 1996). Pedagogical expertise is normally accumulated through years' of teaching experience.

Effective scaffolders also know how to get learners engaged in learning by both initiating and sustaining their interests. Hogan and Pressely (1997) claim that good scaffolding is more than teachers helping students using small sequences. Instead, it is a very complex collaboration process, which requires shared understanding and effort between teacher and students. They further propose that the communication quality and values that the two parties attach to scaffolding will greatly influence the success of scaffolding.

Effective scaffolders have a wide range of scaffolding strategies, know when and how to use them, and are ready to use them to support learners (e.g., Palincsar, 1998). Scaffolding is student-dependent and context-sensitive. Students with different level of cognitive development need different scaffolding strategies. Under different contexts, for example, one-on-one help or a whole class setting, different scaffolding strategies are required. In addition, when one strategy fails to facilitate students, the scaffolder should be able to use another strategy to try again. All these factors require that effective scaffolders have a variety of scaffolding strategies and know how to apply them.

Effective scaffolders must be sensitive and responsive when they interact with students (Hogan & Pressley, 1997). Good scaffolders should be very patient, positive, caring, and persistent in order to find out and provide the right level of support that a student needs. They should expect that errors may occur during students' practice and be ready to offer feedback. In this way, students will be able to know their current performance and adjust their future performance accordingly (Gredler, 2001). In addition, good scaffolders should show their great care about students.

Lepper et al. (1997) summarized the characteristics and strategies of successful tutors using the acronym INSPIRE. The meaning and explanation of the acronym is listed in Figure 10. Among the characteristics and strategies, Intelligent, Nurturant, and Encouraging are part of the characteristics of a good scaffolder. Others are good scaffolding strategies.

As a summary, Hogan (1997) stated that "good tutors set out to boost students' confidence, sense of ability to meet challenges, curiosity, control, and self-efficacy as well as help them to learn" (p. 4). However, effort from scaffolder alone would not make scaffolding effective. Learners and their characteristics may also influence the success of scaffolding. The next session explores what previous studies have found out about the features of learner in effective scaffolding practices.

Characteristics/Strategies	Explanation	Category
Intelligent	Teachers are knowledgeable at subject matter, general and subject specific pedagogical knowledge.	Characteristics
Nurturant	Teachers are supportive and nurturant during interaction with students.	Characteristics
Socratic	Teachers use Socratic questions to make learning active and constructive.	Strategy
Progressive	Teachers gradually increase demands and expect progress from students.	Strategy
Indirect	Teachers express expectation and feedback (both positive and negative) in indirect ways.	Strategy
Reflective	Teachers greatly employ articulation and especially encourage students to articulate.	Strategy
Encouraging	Teachers make great effort to encourage and motivate students to work hard, enjoy work, and feel challenged, empowered, and curious about the subject.	Characteristics

Figure 10. Characteristics and strategies of successful scaffolders (Adapted from Lepper et al., 1997).

Learner

Jarvela (1995) conducted a qualitative research to study the interaction between scaffolder and learner. Based on her findings, she points out that it is important to establish intersubjectivity between teacher and students. She further indicates that students must commit to their own learning in order to achieve intersubjectivity and successful learning. Students' willingness to participating in the instructional activity greatly influences if they will actively interact with teacher during scaffolding, which in turn affects the effectiveness of scaffolding. For those students who have interests in the task, they will try to understand the task objectives, procedure, and their responsibility. Consequently, it is easy to establish shared understanding of a task between them and the teacher. In addition, they are more persistent in the face of difficulty and at the absence of external regulation. In contrast, for those students whose interest in the task was unstable, their interaction with teachers also varied. Every now and then the scaffolding may or may not work for them.

Students' epistemological beliefs also influence scaffolding and learning. If students believe that they are able to solve the problem by making effort, then they are likely more persistent with the task and learning (Ormrod, 2004). Oliver (1999) studied how students use computer-based scaffolding tools during problem solving and found that students with naïve epistemological beliefs quickly generated one or two solutions and believed that they were good enough and then stopped. On the contrary, students with expert-like epistemological beliefs understood that it took effort to generate more appropriate solutions and they were more persistent to create alternative solutions. Consequently, students with expert-like epistemological beliefs performed better in problem solving than their peers with naïve epistemological beliefs.

Students' experience in traditional classroom may interfere with their performance in scaffolded instruction. In traditional classroom environment, students often interpret mistakes negatively rather than taking them as necessary steps to the construction of knowledge and thinking. Pressley et al. (1996) suggest that teachers should explicitly let students know that making mistakes is part of learning process and teachers' prompt and hints to students is not a sign that students are not competent. In this way, students will feel safe to participate in the instructional activities.

Limited experience with instructional content and strategies used in scaffolding may also influence students' performance in scaffolded instruction. Graesser and Person (1994) used student-generated question to enhance learning in research methods and algebra. The research findings showed that the quality of students' questions positively influenced their achievement. In their studies, both college students and seventh graders tended to ask shallow, short answer questions because of their limited knowledge in the content area. In addition, as a result of lack of training, students did not know how to ask quality questions, which require higher order thinking skills, such as analysis, synthesis, or evaluation, from the answerer.

To sum up, learners' characteristics and their previous experiences, such as their knowledge in the subject matter, their point of view on making mistakes, their knowledge on scaffolding strategies, and their epistemological beliefs, may influence the effectiveness of scaffolding and consequently the success of learning.

Limitations of Scaffolding

While scaffolding is effective in enhancing students' learning, Pressley et al. (1996) argues that scaffolding is only part of effective instruction and it has limitations that restrict itself from being a general instructional intervention. For example, scaffolding requires scaffolder keep trying to support a student until she or he makes progress. However, during classroom instruction, it is not realistic for teachers to do that because they have to work with many students at the same time. In order to teach certain amount of contents in limited time, they have to select a relatively efficient way to promote learning in all students (Graesser & Person, 1994).

Scaffolding is also a demanding form of instruction (Pressley et al., 1996). Many requirements of effective scaffolders, such as being an expert of certain subject matter and having a full range of pedagogical expertise, normally need years' of teaching experience. Pressley et al. further indicate that the fact that some teachers can use scaffolding effectively does not mean that all teachers have such ability and that some students can benefit from scaffolding is not an indication that all students would benefit from it.

Furthermore, even expert scaffolders may not always perform very well. Human being is not always stable under all circumstances. As a result, the success of scaffolding may vary from case to case. In Jarvela's (1995) study, she reported that half of the students did not benefit from the scaffolding of an experienced teacher. Although the researcher offered some explanations of the result, she failed to notice the inconsistent performance of the teacher across the scaffolding sessions—some supports provided by the teacher were not appropriate, which should have contributed to the failure of scaffolding.

In summary, although scaffolding is effective to facilitate various learners with different learning goals in diverse learning environments, it also has limitations. Understanding both its effectiveness and limitations helps us have a thorough view of scaffolding.

Tools as Scaffolder

In addition to human being, artifacts, such as book, video, computer program, can also serves as means to supporting leaning. With the advance of technology and their application to education, there are more and more interests in the use of technology, including computer-based technologies, to scaffold student learning.

Comparing with human scaffolders, artifact-based scaffolding has advantages and disadvantages. As an example of advantages, computer-based scaffolding tools can utilize various multimedia, which make it possible to meet the needs of learners who have different learning styles or at different developmental levels. For instance, in Jackson et al.'s (1996) research, one student, different from other students, preferred to use "table view" than "text view" when they were given the chance to view data in different formats. Moreover, the interactive functions built in the computer programs can facilitate students' thinking. In Jackson et al.'s study, the simulation function of Model-It allowed students to see the dynamic change in the ecosystem and thus facilitated them to construct models. Additionally, the artifact-based scaffolding can be designed visually appealing in order to attract students' interest and engage them in learning.

In addition to the media advantages, scaffolding based on artifact does not involve human being. For example, computer-based scaffolding systems utilize computer and programs, which never get tired. Scaffolding as an effective teaching strategy demands a lot of time, energy and commitment from the scaffolder. Human may get tired but artifact will not. Moreover, artifact will not convey negative emotion to students. Good scaffolders must be very patient, positive, caring, and persistent in order to find out and provide the right type and level of scaffolding that a student needs. In reality, it is not realistic to require a human to do so all the time. Furthermore, artifact can be made available all the time so that students can get access to support at any time.

Artifact-based scaffolding also has disadvantages. First of all, at present it is still a challenge to develop an artifact, including a computer program, which can act as human scaffolder to assess students' learning and provide appropriate scaffolding based on the result of the assessment. Second, when tools or strategies rather than human beings are used as scaffolding, students should receive training and practice in the tools before they can utilize them to facilitate learning (Hmelo & Day, 1999). Otherwise, they may not benefit from the scaffolding. For example, Oliver (1999) studied how students use computer-based tools to facilitate problem solving within open-ended science learning environment. Results from the study showed that students could not use the computer-based tools effectively. Oliver suggests that students should be trained to use the scaffolding tools effectively. Similarly, in Hmelo and Day's (1999) study, medical students did not fully understand how they should work with the simulation system, which was designed to scaffold them. Findings from King's (1991) and Kao's (1996) study also confirm the importance of practice in helping learners internalize what offered in scaffolding.

Third, although artifact-based scaffolding will not bring negative feeling to learners, they are not able to take care of students' social, affective, and motivational needs either (Lepper et al., 1997). Last, artifact-based scaffolding, such as computer-based scaffolding system, which is developed by software developers may not match instructional goals. Hmelo and Day (1999) point out that the teaching faculty and the development team should work cooperatively to make sure that the computer-based scaffolding systems match the instructional goals and objectives.

Research in Scaffolding

This section is a review of previous research on scaffolding with a focus on the effectiveness of various scaffolding strategies or tools. The review is organized into different themes. It is hoped that the review would inform the design of this study and provide explanations for the research findings.

Scaffolding versus No Scaffolding

Research on the effect of scaffolding yields mixed results although most researchers claim that scaffolding is effective in enhancing students learning. The majority of the studies that compare instructions with and without scaffolding reveal that scaffolding can support various learners with different learning goals (Chang et al., 2001; Ge & Land, 2003; King, 1991; Salmon et al., 1989). For example, Chang et al. (2001) utilized an expert concept map structure to scaffold seven grade students in biology study. They compared two computer-based concept mapping methods, “construct-by-self” and “construct-on-scaffold”, with “paper-and-pencil” method. In the “construct-by-self’ method, students build concept maps on their own while the computer program provided them with evaluation results and corresponding hints for feedback. In the “construct-on-scaffolding” approach, in addition to the feedback, an incomplete expert concept map was also provided, within which some nodes and links were set as blank. The results showed that “construct-on-scaffold” is more effective in enhancing biology learning than the other two methods and the two computer-based procedures are more helpful to assist students completing the concept maps. Results from King (1991) and Salmon et al.’s (1989) study also revealed that scaffolding could significantly improve students' performance in problem solving and reading comprehension.

However, a study by Azevedo, Cromley, and Seibert (2004) demonstrated contradictive findings from other studies. Azevedo and associates investigated the effect of different scaffolding conditions on students' mental model improvement in the study of circulatory system. A total of 51 undergraduate students were randomly assigned to one of the three scaffolding conditions: adaptive scaffolding (AS), fixed scaffolding (FS), and no scaffolding (NS). Students in the AS group received an overall learning goal as well as dynamic and adaptive support from a tutor. The supports involved both learning of circulatory system and regulation of the learning process. Students in the FS group received the same overall learning goal but not dynamic and adaptive scaffolding. Instead, they received a list of ten domain-specific questions that were developed to help them understand the circulatory system. Students in the NS group did not get any help but learned the instruction totally on their own. Results of the study indicated that with scaffolding from the tutor, students in the AS group significantly changed their mental model. However, fixed scaffolding was not effective in improving students' mental model. There was no significant difference between students in fixed scaffolding group and no scaffolding group in terms of mental model improvement.

The mixed findings suggest that not any scaffolding can facilitate learning. For example, research on fixed scaffolding has produced mixed results. Next, the effect of scaffolding with and without fading was reviewed.

Fading or Not

Researchers have studied how to gradually withdraw scaffolding, such as prompts, and the effect of fading on students' performance and performance maintenance (McDowell, 1982; Odom, 1992; Schunk & Rice, 1993). One characteristic of previous research in fading is that it often involved participants with some types of learning deficits or disabilities (Caverly, 1997; Demchak, 1990; Odom, 1992; Schoen & et al., 1988; Schunk & Rice, 1993; Wolery et al., 1988). Only a few studies used more general learner groups to explore the effect of fading (Atkinson, Renkl, & Merrill, 2003; Renkl et al., 2002). These studies generated mixed results. Most of them revealed that use of fading in scaffolding is superior to scaffolding with no fading in terms of student learning. For example, Renkl et al. (as cited in Atkinson et al., 2003) studied the effect of fading in problem finding. They found that fading helped students perform better in near-transfer tasks. Similarly, McDougall & Brady (1998) used a Self-Management Treatment Package, which included audio cues and self-recording forms, to help fourth graders with and without learning disabilities to self-manage their math learning. The researchers gradually increased the audio cue interval and removed the self-recording forms after some sessions. The results of the study revealed that, except for one of the five participants, the fading methods helped students improve their math performance and increase time engaged in tasks. Other studies also support the effectiveness of fading in improving students' performance, such as summarization ability (Chang et al., 2002) and social interaction level (Odom, 1992). However, some research findings showed that although instruction with faded scaffolding was more effective than scaffolding only instruction, statistically it was not more effective than instruction without scaffolding (McDowell, 1982).

It is not yet clear what caused the inconsistency. A possible reason is that fading was not effectively utilized in the instruction. Riley (1995) reviewed previous studies and found that the main problem with fading was that when scaffolding was removed too quickly, learners failed to perform a task at the same level as when they had scaffolding. To overcome this setback, some researchers combined fading with another scaffolding approach. The studies generated positive outcomes. Based on one of their previous studies, Atkinson, Renkl and Merrill (2003) compared the effect of instruction with fading with instruction with both fading and self-explanation prompt on college students' performance in problem solving. The results showed that the combined method is more effective than the fading alone method in both near and far transfer tasks and did not require additional time on task. In another research, Schunk and Rice (1993) combined fading with strategy-value feedback in their study. Fifth graders who had reading skill deficiencies participated in the 12-session study. They (N=44) were randomly assigned to four treatment groups: control group, fading only group, feedback only group, and fading plus feedback group. All groups received the same reading strategy instruction and practices for the first four sessions. In the following sessions, students in the control group kept receiving the same scaffolding as before. Students in fading only group and fading plus feedback group received gradually decreased scaffolding. Students in the feedback only and fading plus feedback group received strategy-value feedback, which link their success in reading with the correct strategy using practice. Two weeks after completing the treatment, all students took a maintenance test in comprehension. The findings revealed that the students with fading plus feedback group outperformed all their peers in strategic application. In addition, the two groups with faded scaffolding achieved better scores in reading comprehension than the other two groups without faded scaffolding. Similarly, in another study by Puntambekar and Kolodner (2005), a whole unit that was designed to help students learn essential skills for finishing the project was faded after students mastered the skills. But prompts from teacher and peers were used as a continuing support at a lower level. Based on the studies above, it is promising to combine one type of faded scaffolding with other scaffolding strategies given that students need practice and time to internalize the skills and strategies they just learned through scaffolding.

An important issue in fading is the fading schema, that is, when and how scaffolding should be faded. Ideally, scaffolding should be faded to match student's developmental level. However, it is difficult to keep assessing the continuous change of students' developmental level in classroom settings or other learning environments, including computer-based instruction. Although artificial intelligence or other computer programs can be developed to dynamically evaluate learners' developmental level and provide corresponding scaffolding, it is not practical for general use because of the high demand of programming capabilities.

As an alternative, predefined fading schema, in which the fading of scaffolding is accomplished through an informed guess rather than actual assessment of learners' developmental level, was utilized and achieved success. For example, Sedig, Klawe, and Westrom (2001) used scaffolding with fading to assist middle school students with two-dimensional transformation geometry. In their study, the scaffoldings were at three different levels. The first level has 14 puzzles with full scaffolding. The second level included 10 puzzles and the scaffolding ghost images were taken out. The third level had eight puzzles with fewer visual aids. Their study showed that embedding scaffolding (in their case, visual feedback of the targeted rotation, hint, and snap-in feature) into the direct concept manipulation interface significantly promoted reflective cognition and thus enhanced students' learning. In another study by Schunk and Rice (1993), they also utilized predefined fading to help students learn reading skills. In the 12-session treatment period, two students groups with fading received gradually decreased scaffolding. In the first four sessions, they received full scaffolding, that is, verbalize aloud the steps of a reading strategy. From the fifth session, the teacher told the two groups that they would begin to whisper the strategy. The teacher demonstrated how to do that and then students practiced it in session six to eight. At the beginning of the ninth session, the teacher reminded the two groups to say the steps silently to themselves rather than whispering them and students practiced it in session 10 to 12. The findings indicated that students in the two groups with fading outperformed their peers in the other two groups without fading on a comprehension maintenance test.

In summary, scaffolding research that involves fading also generated mixed result. But it is promising to provide students with another format of feedback or hint as the major scaffolding is withdrawn. Research in fading schema indicated that predefined schema can be effective.

The Scaffolders

Originally, the role of scaffolder was accomplished by teachers or parents. Compared with situations where peer as scaffolder, students expressed that information from teacher had greater academic validity (Pressley et al., 1996). Survey from students also showed that in addition to teachers' encouragement, which generated positive emotion towards learning, they felt that they were more engaged in mindful talk when they interacted with teacher instead of peers (Hogan & Pressley, 1997). Teachers also vary in their ability as scaffolder. Lepper et al.'s (1997) study shows that expert tutors do exist. Comparing with their peer teachers, they scaffold students more effectively in both cognitive and emotional aspects.

In addition to teachers, according to Vygotsky, more capable peers can also serve as scaffolder. However, there are mixed findings on the effect of peers as scaffolder in improving learning (Brown & Palincsar, 1989; Pressley et al., 1996). Some researchers (Brown & Palincsar, 1989; Pressley et al., 1996) argue that peer scaffolding does not promote learning and problem solving in weaker students. For instance, Pressley et al. (1996) argue that when students with mixed ability work together, more capable students may dominate the interaction and limit weaker students to benefiting from participation.

Different from Pressley et al., other researchers (Brown et al., 1993; Graesser et al., 1997) believe that unskilled scaffolder can be effective. For example, Graesser et al. (1997) utilized unskilled tutors to scaffold students' learning and achieved success. Through studying the techniques that unskilled tutors used under naturalistic condition, the researchers found that unskilled tutors did not use the model-scaffolding-fading model and Socratic methods, which are regards to be ideal tutoring strategies. However, they did find some strategies that unskilled tutors used in tutoring sessions were unique to the tutoring sessions or presented much higher frequency than classroom-based instructions. They proposed that these strategies, such as using a lot of examples, eliciting explanatory reasoning, and collaborating with student during problem solving, may contribute to the success of unskilled tutors. These findings are important since they lay the ground to use peer and non-human-based approach, such as tools, to scaffold student's learning.

One characteristic of the non-human-based scaffolding is that the scaffolding is embed in tools or learning environments, for example, scaffolding tools, such as flash cards; scaffolding strategies, such as prompt or question stems (Davis, 2003); or artificial pedagogical agent, such as computer program (Azevedo, Cromley, Thomas et al., 2003; Oliver, 1999; Salmon et al., 1989). As to the legitimate of tools as scaffolder, Wells (1999) believes that like speech in face-to-face interaction, these artifacts can also deliver meaning and facilitate those individuals who can understand them to construct meaning and engage in higher order thinking, such as, making explanation, establishing argument, making prediction, comparing and evaluating solutions, articulating thinking, and verifying their own understanding. Thus, they can also be used to mediate learning in ZPD. As an example, Davis and Linn (2000) utilized "sentence-starter" to help students plan and reflect on science project. King (1991) employed index card with general questions to guide students through problem solving process.

The success of human and non-computer-based tools as scaffolder shed light on providing scaffolding through computer-based scaffolding systems. Recently, computer-based scaffolding tools have been developed and achieved some success (Chang et al., 2001; Guzdial & Kehoe, 1998; Jackson et al., 1996). Technology-based scaffolding systems can support learners' representing idea and constructing knowledge, which they are not able to do on their own. For example, Salmon et al. (1989) used computer as reading partner to facilitate junior high school students with reading comprehension. Findings from this research showed that students with computer-based metacognitive scaffolding tools outperformed control groups on both near transfer (reading comprehension) and far transfer (essay writing) tasks. As another example, Jackson et al. (1996) used a ScienceWare Model-It to support high school students, who were not familiar with either modeling or computer-based models, to construct, verify, and analyze computer-based ecosystem models. The results showed that two thirds of the groups in the class constructed good quality models with the help of the software, which allowed them to build and test their models with built-in visual simulation and other functions. The software facilitated students who had no computer modeling experience to construct and test models, which they could not accomplish on their own. However, there was no control group in this study, so we do not know if computer-based scaffolding is superior to other instructional interventions in teaching students modeling.

Questioning as a Scaffolding Strategy

Use of scaffolding tools, especially in asynchronous learning environments, essentially changes the interaction between learner and human scaffolder to learner and scaffolding tools. To achieve the same goals, scaffolding tools should imitate what a human scaffolder do in scaffolding. With this in mind, many researchers employed questioning in scaffolding to simulate the communication process. Questioning involves using questions to guide and support students' learning by making implicit understanding explicit (Puntambekar & Kolodner, 2005). In education, questioning has been widely used to engage and motivate students, activate their prior knowledge, focus their attention, guide their learning, provide them chances of practice, control and maintain a productive learning environment, and examine learning results (Hunkins, 1972; Wilen, 1986).

There are different ways to classify questions based on which types of cognitive process they are targeted to elicit (Dillon, 1988; Hunkins, 1972; Wilen, 1986). For example, Wilen (1986) introduced the concept of convergent and divergent questions. Convergent questions require that students "analyze and integrate given or remembered data" to get to an "expected end result". Divergent questions require that students generate information in a "data-poor situation" to form "a new direction or perspective on a given topic" (p. 13). Steinbrink (1985, as cited in Dillon, 1988) proposed descriptive, policy, opinion, and futures questions. Hunkins (1972) categorized questions as knowledge, comprehension, application, analysis, synthesis, and evaluation questions based on Bloom's taxonomy of educational objective. Dillon (1988) classified questions as closed and open-end questions, factual and opinion questions, lower and higher order thinking questions.

Taken Dillion's classification as an example, the most general close-ended questions are yes or no questions or multiple choice questions. Close-ended questions do not need learners to construct answer and normally only measure learning outcomes at lower levels, such as knowledge or comprehension level. In contrast, open-ended questions require learners to construct answers and often involve higher order learning outcomes, such as analysis, synthesis, or evaluation (Graesser & Person, 1994). Although scaffolding can facilitate various learning goals, it is particularly useful for learning of higher order thinking skills (Rosenshine & Meister, 1992). Open-ended questions can provide a context in which learners interact with instructional content, software, peers, and instructor. They can also focus students' attention, activate prior knowledge, make thinking explicit, encourage reflection and elaboration, and even act as model questions that learners should ask themselves in future studies (Hmelo & Day, 1999; King, 1991, 1994). However, even with open-ended questions students may still try to give short answers (e.g., Hmelo & Day, 1999). To avoid this tendency, it is necessary to set criteria and be specific about the requirements.

Questioning has been used in various studies that involved different learning goals, various audiences, and diverse learning environments. For example, Ge and Land (2003) used questioning to enhance college students' performance in computer-based problem solving. Davis and Linn (Davis, 2003; Davis & Linn, 2000) used questioning to foster scientific learning among middle school students in Knowledge Integration Environment (KIE). Hmelo and Day (1999) embedded questions in computer-based simulation to scaffold medical students to acquire clinical diagnosis skills. King (1991) trained fifth graders to use guided questioning to solve math problems.

Depending on the nature of the task and the instructional objectives, questioning can take various forms. For example, Davis (2003) used question stems, such as "Our evidence critiques will be useful later because…", "The scientific ideas for this evidence involve…", "Right now, we're thinking…" (p. 100-101), and so on. King (1991) provide questions parallel to a problem solving model that involves planning, monitoring, and evaluating. Some of the questions she used include "What is the problem? What are we trying to do here?", "Are we using our plan or strategy? Do we need a new plan? Do we need a different strategy?", "What worked?", "What didn't work" (p. 309), and so on. Hmelo and Day (1999) used contextual questions to foster students to make explanations, craft and verify predictions, and connect the clinical signs with underlying scientific mechanisms. They identified some of the following question for this purpose, such as “What is the significance of the mammogram results?”, “What would you expect to happen to Mrs. Buchanan if she only had surgery? Why? ” (p. 155). As another example, Vanlehn et al. (2000) designed a natural language dialogue in a computer-based tutoring system to engage students in explicating their actions. For example: “Could you say something like ‘I applied <a principle> to <object> because I wanted <goal>’?” Then students can use it like “I applied Newton’s Second Law to the car because I wanted to find its acceleration” (p. 481).

When using questioning to scaffold students’ learning, it is often teachers who propose questions (e.g., Ge & Land, 2003; Hmelo & Day, 1999). Some researchers (e.g., Graesser & Person, 1994; King, 1991) explored using student-generated question to support learning. Results from King’s (1991) study revealed that students trained with questioning strategies outperformed their peers who had no such training in problem solving. In her study, King developed index card with guided questions, which could direct students through the cognitive process and develop metacognitive skills. She classified the questions into three categories, which parallels to a problem solving model that could guide students think more explicitly during the process. A total of 46 fifth grade students were randomly assigned to same sex pairs. The same-sex pairs were then randomly assigned to one of the three conditions to ensure gender balance among the conditions—guided questioning, unguided questioning, and control group. Dyads in guided questioning group were trained to use the index card to ask and answer each other’s questions during problem solving. Dyads in unguided questioning group were told to ask and respond to their partners’ questions. Dyads in control group did not receive training on questioning techniques and were not instructed to ask and respond to partners’ questions. Results from her research indicated that student dyads trained with guided questioning outperformed their peers in unguided questioning or control group on both a new computer-based problem solving task and the written format of a problem solving test. However, students in the unguided questioning group did not perform better than their peers in the control group. This suggests that only telling students to ask each other question is not effective in enhancing their performance because students are not trained to ask questions, not to say good questions that can elicit higher order thinking rather than hard facts memorization.

Another study confirms the importance of question quality. Graesser and Person (1994) studied the characteristics of questioning in tutoring and compared them with classroom instruction. They found that questions from students were about 240 times as frequent in tutoring as in classroom; and tutors only asked questions slightly more than in classroom situation. However, students' achievement was not related to the frequency of question but positively influenced by the quality of questions that they asked.

The quality of a question also matters when it is the instructors who propose the question. Hmelo and Day (1999) suggested that questions have to be carefully designed in order to effectively scaffold students' learning. In their study, they embedded questions in a computer-based simulation environment to scaffold first year medical students with problem solving. A total of 36 students were recruited as four intact groups. Two groups were randomly selected as experimental groups and the other two groups served as control groups. Students in the experimental groups were trained and given chance to practice with the simulation software, in which contextualized questions were embedded. Students in the control group used regular paper cases similar to the experimental groups. The researchers compared the number of observations and inferences made by students in the two groups. The results showed that there was no significant difference of the number of observations and inferences that students could recall. But there was a significant difference of the percentage of critical observations made by the two groups. This suggests that embedding questions in simulation can lead students' focus on important information. But it did not effectively promote connecting symptoms with general scientific mechanism in students. The success was limited. Two reasons may account for the limited success. First, there was a discrepancy of understanding between the program developer and the subject expert. Second, the questions were not specific enough to force students to connect the clinical information with its underlying science mechanisms.

In short, questioning as a scaffolding strategy has attracted a lot of interests. Research shows that the quality of question positively influences the effectiveness of scaffolding. Previous research suggests that specific questions should be asked to guide student's thinking.

Conclusion

Research indicates that compared with novices in a field, experts organize information around major concepts and have a more integrated view about a subject topic. Consequently, they can easily retrieve information from long term memory and apply it to various contexts (Bransford et al., 1999). Concept mapping, grounded in meaningful learning theory (Novak & Gowin, 1984), requires students to "organize and link data in a logical way" (All et al., 2003, p. 311) and thus could help students better organize information and see the underlying structure of knowledge (Cliburn, 1990; Ferry et al., 1997; Novak & Gowin, 1984). However, concept mapping is not a simple task. Many learners felt that it was difficult to build a concept map. Among the difficulties that students have with concept mapping, constructing relationships between concepts is the most difficult (Fisher et al., 1990; Jonassen, 1996; Novak & Gowin, 1984). However, no research has been conducted to scaffold students with concept linking, which is the most difficult task in concept mapping. Thus, it is not clear what may help students with concept linking and if these efforts can improve students' performance in concept linking and other instructional tasks. This study was designed to fill this gap.

To help students conquer the difficulty that they have in concept linking, the reasons behind the problem were first identified, that is, students may not be familiar with relationship phrases and they may have ambiguous understanding of the nature of relationships between concepts (Fisher et al., 1990; Jonassen, 1996; Taber, 1994). Two solutions were proposed accordingly, that is to provide students with relationship phrases and ask them to articulate relationships between concepts. These two solutions are instructional support in nature, which lend themselves to the concept of scaffolding. Scaffolding, as an instructional support, can help students achieve goals or finish tasks that they cannot accomplish by themselves but can do with the help of other people or tools. Scaffolding has been effective in supporting different learners with a variety of instructional tasks, including building concept maps (Chang et al., 2001). Thus, it is promising that the two solutions delivered through scaffolding may help learners build relationships between concepts.

The literature in scaffolding informed the design of the present study. Since scaffolding can be provided through artifact other than human being (Davis, 2003; Oliver, 1999), it could be utilized in learning environments where no face-to-face scaffolding is available, such as a computer-based learning environment in this study. In addition, previous research showed that questioning is an important scaffolding strategy. After examining the two potential solutions, one solution, which is asking students to articulate relationships between concepts, is ideal to be delivered through questioning. Moreover, research utilized questioning as scaffolding suggests that specific questions should be asked to guide students' thinking rather than expecting that they will think in the ways teachers want them to (Hmelo & Day, 1999). So in this study, specific questions were designed to guide students elaborating on relationships between concepts. Scaffolding related studies also indicated that when students become competent at a task, the scaffolding should be removed (Schunk & Rice, 1993; Sedig et al., 2001). Thus, fading of scaffolding was employed in this study.

The scaffolding methods designed to help learners with concept linking may enhance their content comprehension and retention as well. The linking phrase scaffolding, which is designed to help learners better understand the nature of relationships between concepts, and the articulation hint scaffolding, which is designed to help learners articulate the relationships, will engage students to think relationship between concepts explicitly and precisely. Since human beings tend to understanding and remember the things that we link to many other things better (Goodson, 2000), the two scaffolding methods may also enhance students' performance in retention of comprehension. Thus, in this study, the main effects of the two scaffolding methods as well as the interaction effect between them on students' performance in concept linking as well as retention of comprehension were investigated.

In addition, the relationship between students' performance in concept linking and maintenance of content comprehension were also examined to see if students who perform well in concept linking would also have a better retention of the instructional contents. Previous research (Austin & Shore, 1995; Novak & Gowin, 1984) generated mixed results about the relationship of students' performance in concept mapping and other achievement tests. Some researchers (Acton et al., 1994) used traditional achievement scores to judge the validity of the concept map as an assessment tool while others (McGaghie et al., 2004) believe that concept map and other achievement tests measure different knowledge in students. Thus, using traditional measurement, such as multiple choice questions, as criteria to judge the validity of concept map as an assessment tool is fundamentally wrong. With the mixed findings and disagreement, it would be interesting to know if there is positive relationship between students' performance in concept linking and retention of comprehension and how well students' performance in concept linking can predict their performance in retention of comprehension.

Therefore, the research hypotheses of this study are:

H_1: Students who receive *linking phrase scaffolding* (PS) will perform better in both computer-based concept linking and retention of comprehension tests than their peers who do not receive such scaffolding.

H_2: Students who receive *articulation hint scaffolding* (AS) will perform better in both computer-based concept linking and retention of comprehension tests than their peers who do not receive such scaffolding.

H_3: Students who receive *linking phrase and articulation hint scaffolding* (PAS) will perform the best in both computer-based concept linking and retention of comprehension tests.

H_4: There is a positive relationship between students' performance score in computer-based concept linking and retention of comprehension, that is, students who perform well in concept linking task will also perform well in retention of comprehension, and vice versa.

METHODOLOGY

The purpose of this study was to examine the effect of linking phrase scaffolding and articulation hint scaffolding on students' performance in computer-based concept linking as well as retention of content comprehension. Participants worked on two concept mapping exercises after an orientation in concept mapping and CmapTools—a computer-based concept mapping program. While working on a computer-based exercise, students in different groups received different types of scaffolding that were designed to help them build relationships between concepts or/and make the relationships explicit. Students in the *no scaffolding* (NS) group did not receive any type of scaffolding. Students in the *linking phrase scaffolding* (PS) group received relationship phrases as scaffolding. Students in the *articulation hint scaffolding* (AS) group received a hint question as scaffolding, which asked them to elaborate on relationships between concepts. Students in the *linking phrase and articulation hint scaffolding* (PAS) group received both types of scaffolding. One week after the treatments, as part of the posttest, students engaged in a short web-based instructional episode and built a concept map based on the instruction. No scaffolding was provided to any group during this posttest activity. A week after the concept mapping posttest, students took a retention of comprehension test on the instructional material. It was hypothesized that students in the PAS group would perform the best in the concept linking as well as retention of comprehension tests; that students in the NS group would perform the worst in the two tests; and that the other two groups' performance would fall between the PAS and NS groups.

This chapter presents the methodology that was used to implement the present study. It includes a discussion of the research design, participants, materials and apparatus, procedures, pilot studies, and data analysis techniques that were used to test the research hypotheses.

The Experimental Design

Given the research questions, a quantitative method was employed to examine the main effects of linking phrase scaffolding and articulation hint scaffolding, as well as the interaction effects between them, on students' performance in concept linking and retention of content comprehension. A 2 x 2 experimental design (see Figure 11) was used for research questions 1-3 by examining the effects of (a) linking phrase scaffolding; (b) articulation hint scaffolding; and (c) linking phrase and articulation hint scaffolding on students' performance in concept linking and retention of content comprehension. In addition, the relationship between students' performance in concept linking and retention of content comprehension was also investigated. The independent variables of this study were the two different scaffolding strategies: linking phrase scaffolding and articulation hint scaffolding. The dependent variables were students' performance scores in concept linking and retention of comprehension tests.

	Articulation Hint Scaffolding	
Linking Phrases Scaffolding	Yes	No
Yes		
No		

Figure 11. The 2 x 2 Experimental Design.

Participants

Participants of this study were undergraduate students enrolled at Virginia Polytechnic Institute and State University (Virginia Tech). One professor was contacted for student recruitment since he was teaching two undergraduate courses with a large number of student enrollments: 618 students in the Drug Education class and 501 students in the Personal Health class. Recruitment from the Drug Education class started in the middle of March 2006. Later, to get more participants, students attending the Personal Health class were also recruited at the beginning of April 2006. For both classes, the professor first announced the recruitment notice in class and then on course websites. The recruitment notice included the following information: the purpose of this study, the eligibility criteria, brief procedures, benefits from participation, compensation for participation, location of the research, the researcher's contact information, and how to participate in the study.

Students were offered course credits for participation. However, the crediting mechanisms were different between the two classes. Upon completion, students in the Personal Health class would receive 15% of their final score; students in the Drug Education class would have one of their lowest test scores removed. Participation of this study was on a volunteer basis. Students in both classes could participate in alternative research project(s) to earn the same course credits. They could drop the study at any time. However, course credits were only offered with completion of the study.

All volunteers electronically signed an informed consent form through *survey.vt.edu*. Since concept maps constructed by students might be used in publications at a later time, they were asked to give permission for this use. The study was approved by the Institutional Review Board (IRB) at Virginia Tech. The approval letter is included in Appendix A.

A total of 144 students participated in the study with 134 of them finishing all three sessions. From this pool, 18 students were eliminated because they did not finish the sessions on schedule. The remaining 116 students were participants of this study. Data collected from them were used for analysis. The participant's age was between 18 to 25 years old. Among them, 45 were female and 71 were male; 92 were from the Drug Education class and 24 were from the Personal Health class. Both classes had students from freshman to senior. Of all participants, 22 were freshmen, 40 were sophomores, 14 were juniors, and 40 were seniors. They were studying in about 50 majors. The majority of participants had English as their first language while 10 of them did not. Participants distributed to the following ethnicities: Asian 11, Black/African American 15, Hispanic/Latino 7, multiracial 2, other 1, and White/Caucasian 80.

Although participants of this study were not randomly selected from the general pool of undergraduates at Virginia Tech, their gender and ethnicity composition to some degree reflected the undergraduate population at Virginia Tech. Table 1 demonstrates the gender and ethnicity composition of participants of this study and the undergraduates at Virginia Tech at large. The undergraduate demographic information was based on 21,567 enrollments in Fall 2005 (Office of Institutional Research and Effectiveness at Virginia Tech, 2006).

Table 1

Gender and Ethnicity Percentage of Participants and Undergraduates at Virginia Tech (VT)

	Participants of This Study (%)	Undergraduates at VT (%)
Gender		
Female	38.8	41.2
Male	61.2	58.8
Ethnicity		
Asian	9.5	7.0
African American	12.9	5.0
Hispanic/Latino	6.0	2.2
White/Caucasian	69.0	74.3

Materials and Apparatus

Materials used in this study included the Pre-Treatment Survey, the web-based tutorials, the treatments, the concept linking posttest, and the retention of comprehension posttest. For the convenience of discussion, they are classified into three categories: pre-treatment material, treatment materials, and post-treatment materials.

The Pre-Treatment Material

The pre-treatment material is the web-based Pre-Treatment Survey (see Appendix B), which included two sections: demographic information and self-rated questions. Data from this Pre-Treatment Survey were collected through the online survey program *survey.vt.edu*.

The first part of the survey was designed to collect the participants' demographic information, including year in school, gender, age range, ethnicity, major of study, and native language. The second part of the survey consisted of ten questions, in which the participants were asked to self-rate their knowledge and skills. The first four questions dealt with their knowledge and skill in general computer operation, concept mapping, CmapTools, and computer-based concept mapping programs. The other six questions were about the anatomy and function of the human heart. On a scale from 1 to 5, the participants were asked to self-rate their knowledge from *very little 1* to *very much 5* in the following six statements: "I know the difference between diastolic and systolic pressure," "I can explain how blood circulates through the body," "I know the different layers of membranes and muscle of the heart," "I can explain the diastolic and systolic phase," "I know which part of the heart sends blood to the lungs," and "I know which part of the heart provides blood for the entire body."

The Treatment Materials

Based on the time order that they were employed, the four components of the treatment materials were: a web-based introductory tutorial on concept mapping, a paper-and-pencil-based concept mapping exercise, a web-based tutorial on CmapTools, and a computer-based concept mapping exercise with treatments. The different groups went through the same tutorials and exercises except that they received different scaffolding treatments when they worked on the computer-based concept mapping exercise.

Concept mapping tutorial. The purpose of this tutorial is to teach participants the basic concepts about concept mapping. Based on relevant literature review (All et al., 2003; Chmielewski & Dansereau, 1998; Sturm & Rankin-Erickson, 2002), the concept mapping tutorial included the following contents: definition and components of a concept map, example concept maps, example concept map structures, and procedures to build a concept map. To motivate learning, the benefits of using concept maps were also introduced briefly.

Researchers (Novak & Gowin, 1984; Taber, 1994) suggested that the idea of concept mapping should be introduced using a topic that students are familiar with. In that way, they can focus on concept map construction rather than content comprehension. In addition, the examples should advance from simple to complex. These strategies were adopted in the development of this tutorial. From simple to complex, example maps on units of measurement in mathematics, the animal classification, and social bookmarking were used. See Appendix C for a sample screen capture of this tutorial.

Paper-and-pencil exercise. This task was designed with two purposes in mind: first, allow participants to experience concept mapping using paper and pencil so that they could obtain a basic understanding of the concept mapping process; second, provide students a chance to compare the traditional mapping method with the more current computer-based approach. After reading a 130-word text on nutrition, each participant constructed a concept map using paper and pencil. The text was abridged from *Human Nutrition* (Worthington-Roberts, 2005). It was retrieved from Microsoft Encarta on the Microsoft Student 2006 DVD. Permission to use the article was acquired through email from the Encarta/MS Student Editorial Director on January 25, 2006. This text was selected because the text introduces the basic categories of nutrients and the relationships between concepts are stated clearly. Thus, it is easy for beginners to construct a concept map based on the contents. See Appendix D for the paper-and-pencil exercise.

CmapTools tutorial. Immediately after the paper-and-pencil exercise, participants proceeded to a web-based tutorial on CmapTools , a computer-based concept mapping application. There are various computer-based concept mapping programs available on the market, including SemNet, Learning Tool, TextVision, Inspiration, and Cmap. Among them Cmap was chosen since it is freeware and very easy to learn (Jonassen, 1996). Cmap has two versions. CmapTools is the client version, which was free for downloading at http://cmap.ihmc.us/download/. CmapServer is the server version, which is free for educational purposes upon approval. CmapTools version 4.0 was used in the present study.

CmapTools was developed by Hunter and Stahl in cooperation with Dr. John Novak. CmapTools is now associated with the Institute for Human and Machine Cognition (IHMC). As a freeware product, it is very easy to use (Jonassen, 1996). The software has a built-in help system that guides users through the basic functions. For example, when a user opens a new file, in the middle of the blank map, text shows "double-click to create a concept". When a user follows this instruction, a rounded rectangular box will appear with a sign of two arrows above it and some text on its right. The text reads "click and drag arrow to make a link, double click to edit text". A user then can choose either input/change the name of a concept or create a link from this concept.

For the purpose of this study, the participants did not need to know all the functions of CmapTools. To save participants' time and make the participation less time-demanding, a web-based tutorial was developed. This tutorial only addressed the basic functions and steps that would be required in this study, such as creating a new file, adding concepts, linking concepts, adding arrows to linking lines, annotation, and saving a file. Each function was addressed on one screen with illustrating screen captures of the software and texts. Including the introduction part, this tutorial consisted of nine screens. See Appendix E for screen captures of this tutorial.

The Treatments. After completing the CmapTools tutorial, participants worked on one exercise on concept mapping. In this computer-based exercise, the participants constructed concept maps in CmapTools based on *Human Nutrition*, the same text that they used in the paper-and-pencil exercise. All participants received the text of *Human Nutrition*, instructions for the exercise, and scaffolding treatments, which were delivered through paper printouts to allow easy access during computer-based concept mapping.

While the exercise was the same among all participants, different groups received different scaffolding treatments (see Appendices F to I) while working on the exercise. Students in the control group did not receive any scaffolding. Students in the PS group received a list of relationship phrases, which were recommended by Jonassen (1996) and Fisher (1990), as scaffolding. The phrases were classified into different categories to reflect the nature of relationships. Students in the AS group received a hint question, which asked them to articulate relationships between concepts, as scaffolding. Students in the PAS group received both link phrases and articulation hint as scaffolding.

In addition to labeling relationships between concepts using words or short phrases, which is a standard practice in concept mapping, participants in the AS and PAS groups were also instructed to state each corresponding relationship in a full sentence using the annotation function of CmapTools. Annotation allows users to write down notes or comments in CmapTools. It can be minimized to save space or expanded to show the contents. This design was informed by Taber's (1994) study. In her study, Taber asked students in the remedial physics class to label numbers on the linking lines and then use full sentences to explain the propositions. This method had three advantages. First, when a concept map gets very complex, this labeling method would give students more space to work. Second, the full sentence description of propositions allowed her to better understand students' misconception(s) since students had to clearly state relationships between concepts. Third, without making marks on the map she could provide students feedback through the sentence explanation. With readability and map grading in mind, however, in this study students in the AS and PAS groups were asked to label relationships with linking words or phrases rather than numbers. They were then required to put an annotation beside each corresponding link. Compared with using numbers to link concepts, this method is more natural to concept mapping practice. In addition, it allowed a map grader to judge the linking words or phrases without opening the annotation notes.

Feedback has been used in concept mapping exercises to facilitate students' learning. Chang et al. (2001) and Conlon (2004) reported that students had positive feeling about feedback in concept mapping tasks. The software-based feedback in both studies, however, required computer programming skills to compare a student map with a referent map and is not practical for this study. As an alternative, in this study a referent map was provided through a web page. After finishing the computer-based concept mapping exercise, the participants were instructed to compare their maps with the referent map to see what they did well and what they could improve in later exercises (Acton et al., 1994; Chang et al., 2001; McGaghie et al., 2004).

The Posttest Materials

The posttest materials consisted of an instruction on the heart and two posttests—a concept mapping test and a retention of comprehension test. One week after the web-based tutorials and treatment, the participants took a concept mapping test in which they first studied the human heart through a web-based instruction and then built a concept map based on the contents. One week after the concept mapping test, students took a web-based maintenance test in comprehension.

Instructional material. The instruction material is an instructional set that taught participants the anatomy and functions of the human heart. It is a revised version of the original material developed by Francis M. Dwyer (in Lamberski, 1972). Permission to use the instruction was acquired from Dr. Dwyer through email on September 27, 2005. The original instruction has approximately 2000 words on 21 slides. The researcher constructed a concept map based on the contents and found that the first half of the instruction, which has about 1000 words, contains enough information for the purpose of this study. As such, Slides 2-10 from the original instruction were used in this study. To further eliminate those contents that are not closely related to other contents in the material, part of Slide 2 and 3 and the entire Slide 5 were removed. By doing this, the challenging level of the task was reduced. In the end, the instructional material for this study has a total of 790 words on 8 slides. See Appendix J for sample screen capture of this instruction.

Based on Vygotsky's developmental theory, many researchers (Hogan, 1997; Ormrod, 2004; Roehler & Cantlon, 1997) believe that challenging rather than easy tasks promote maximum cognitive growth. Learners tend to lose interests to instructional activities that they can finish easily and feel frustrated with tasks too difficult for them. Ideally, they should be provided with challenging tasks that they cannot finish independently but can accomplish with help from more capable others or tools. In other words, the ideal instructional activities should fall into a student's zone of proximal development. It was hoped that by reducing the original contents, constructing a concept map about the heart would be an ideal instructional activity to the participants.

Over the years, Dwyer (1978) and associates conducted a series of studies to investigate the effects of different graphic presentations on students' learning. They claim that different visual aids have various degrees of realism, which is a construct of how similar the graphic representation is to the real object. Graphics with black and white simple line drawings has a lower realism than its counterpart with color and shade drawings or photograph. Their research findings showed that too low or too high of realism would negatively influence student's learning. In this study the researcher tried to avoid these situations. Thus, the version of instruction using simple line drawing color figures and color texts was used. This instruction is ideal for the purpose of this study in that the major concepts were labeled with different colors while each concept in the text and its corresponding human heart part in the line drawings were labeled with the same color. In this way, the major concepts were emphasized by the colored texts and figure labels, which helped direct learners' attention to important concepts and corresponding parts in the figures.

Concept mapping test and its instruction. Based on the heart instruction, participants took a concept mapping test, in which they constructed a concept map in CmapTools. While constructing the map, they were able to refer to the instructional material as well as the concept mapping and CmapTools tutorials that they went through last week. However, no scaffolding offered in last week's treatment was provided to any group. This design was based on previous research on fading of scaffolding. Researchers (Chang et al., 2002; Day & Cordon, 1993; Kao, 1996) believe that fading is an essential part of a scaffolding process. When learners get more competent at a task, scaffolding should be gradually removed. Unnecessary scaffolding may interfere with learners' thinking processes and make them overly rely on the scaffolding.

Similar to the instructions provided in the treatment, instruction on the concept mapping posttest was also provided through paper printout in Appendix K. The instruction required the participants to finish the task in CmapTools. To reduce the task difficulty and make it less time consuming, participants could start with an existing CmapTools file — heart.cmap. In this file, 25 concepts were provided, with some concepts in the middle of the map to reflect the basic anatomy of the heart. Other concepts were listed on the right side of the map (see Appendix L).

This design was informed by Ruiz-Primo's (2004) Concept Mapping Tasks Model and other relevant studies. Ruiz-Primo differentiates concept mapping tasks by their "degree of directness" (p. 3). A "high-directed" concept mapping task provides more information to learners than its "low-directed" counterpart. Along the degree of directedness continuum, the tasks with the highest directedness are those "fill-in-map" tasks, including filling in concepts and/or links. The tasks with the lowest directedness are those free construction tasks in which students construct a map with no provision of concept, linking phrase, or structure. Based on the degree of directness, concept mapping tasks vary in difficulty. The selection of a task should be based on the nature of subject content, its difficulty level, and learners' capability and prior knowledge in both the content area and concept mapping. Although free construction may offer more information about students' understanding and knowledge structure in an area, it might be too difficult for them. In this study it was expected that participants would not be familiar with concept mapping and the human heart topic, which was proved to be true through the results of the Pre-Treatment Survey. Thus, to control the difficulty of the concept mapping test, concepts were provided.

Concept map grading. To quantify concept maps, a revised scoring system that was based on the scoring schema from Novak and Gowin (1984) and other researchers (Austin & Shore, 1995; Conlon, 2004; Jonassen, 1996) was established before data collection. In this system, four components of a concept map would be evaluated: concepts, propositions, hierarchy, and cross links. However, with preliminary analysis of participants' concept maps from the posttest, it was found that three components of this system could be removed. First, in this study, the concepts were provided to the participants. Although some students did not use the provided concepts or not all of them, the differences generated from this component were very limited. Second, based on the content of the instructional material as well as participants' concept maps, it was found that no cross link existed. Third, the only hierarchies in this topic were between the heart, the left/right half, and the left/right auricle and ventricle, which most of the participants could identify. Therefore, scores from these three components would not differentiate participants' performance in concept linking. The only component left for assessment would be the proposition score.

To evaluate the propositions, a referent map was used. A referent map, also known as an expert map, is often used to compare a student's map with an expert map. Different from the scoring systems based on Novak and Gowin (1984), referent map-based assessment does not focus on counting the number of valid components in a map (Stoddart et al., 2000). A referent map is often created when the topic is the same among students and there are predictable relationships between concepts. Since the topic in this study was the same across learners and the relationships between concepts were predictable, a referent map was created. Different from other studies, in which the referent maps were created by teachers, experts, or groups of experts (Stoddart et al., 2000), here the referent map was created based on the maps from the participants. During the preliminary stage of concept map grading, about one third of participants' maps were reviewed. By summarizing those maps, a referent map was created to include as many valid propositions as possible. Afterwards, a senior undergraduate majoring in Biology at Virginia Tech, who was very familiar with the topic of the human heart and would serve as an independent rater, was consulted about the appropriateness of the referent map. He approved it.

To score relationships in the referent map as well as students' maps, a weighted scoring method was adopted. As reviewed in the literature, scoring systems based on Novak and Gowin's (1984) schema ignore that within a given topic some relationships are more critical than others. To differentiate the importance, Chang et al. (2005) developed a weighted measurement system in which a teacher can assign a weighted index from 0 to 1 to each proposition, with important propositions receiving higher weighted indices and less important propositions receiving lower weighted indices. As a general rule, the criteria introduced by Stoddart et al. (2000) were used to determine each weighted index in a map. Stoddart et al. suggest that statement or linkage that answers “why” and “how” questions indicates sophisticated understanding and should be assigned a high weighted index. On the contrary, factual statement or linkage that answers “what” questions should receive a low weighted index. Following these general rules, the linkages illustrating how blood circulates through the body were assigned high weighted indices of 0.8 or 1.0. Propositions that state the part of the body and their location relationships were assigned low weighted indices of 0.4 to 0.6. By doing this, the importance of each proposition was reflected in quantity. Appendix M shows the weighted indices assigned to the referent map.

In addition to the weighted index, factors like the quality of linking phrases and the linking directions should also be considered. The quality of linking phrases, to a great degree, indicates learners’ understanding of the propositions. Chang et al. (2005) used three levels to indicate if a proposition is learned, partially learned, or unlearned. A revised scale was developed for this study to evaluate students’ understanding of a relationship. Thus, a correct and accurate linking phrase gets 4 points; an acceptable but not accurate linking phrase gets 3 points; a vague and less acceptable linking phrase gets 2 points; a linking phrase that barely describes the relationship gets 1 point; a link without linking phrases gets 0.5 point; a linking phrase that does not make sense at all does not get any points. As a result, the score of a proposition is determined by two factors: the weighted index that reflects the importance of a relationship and the quality of the linking phrase that describes the nature of a relationship. Multiplying the weighted index by the quality score of linking phrase will generate the score of a proposition. In Figure 12, both Map A and B would get

0.8 x 4 + 1.0 x 2 = 5.2 points for the propositions in them.

Except symmetric links, relationships between concepts are directional (see Appendix G for symmetric and asymmetric linking phrases). For example, Figure 12 shows two concept maps extracted from this study. Although arrows in the two maps point to different directions, both maps are correct since the linking directions matched the corresponding linking phrases. When there is a mismatch between them, however, no point should be granted since it indicates that there is a misunderstanding in the participants.

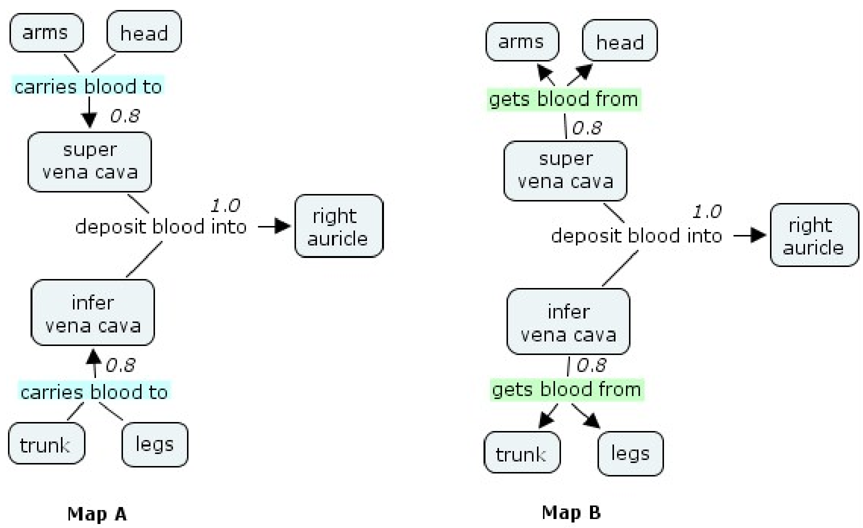

Figure 12. Match between Linking Direction and Linking Phrase.

During the quantifying process, to ensure that no relationship would be left out, unexamined, or calculated multiple times, a grading matrix was developed based on a previous study. Clariana (2006) used a link array to represent relationships between concepts. In the link array, all concepts were arranged both along rows and across columns in a spreadsheet. If there is a relationship between two concepts, then the crossing cell of the corresponding row and column was labeled 1. Otherwise, it was labeled 0. Based on this method, a spreadsheet was developed in Microsoft Excel. In this spreadsheet, all concepts were arranged both along rows and across columns. To keep the grading consistent, a concept across columns were treated as the starting point of a relationship while a concept along rows was treated as the ending point of a relationship. The crossing cell is the score of a proposition generated from multiplying the weighted index by the quality score of a linking phrase. To make it easy to trace the grading process for any possible error or adjustment, the multiplying formula was put into the Excel file, which automatically generated the resulting scores. Appendix N is the screen capture of this scoring matrix.

The researcher and another independent rater graded the concept maps based on the scoring system. The independent rater was a senior undergraduate majoring in Biology at Virginia Tech. He participated in the undergraduate pilot study and was familiar with both concept mapping and the subject topic. Before scoring the maps, the researcher trained the independent rater about the scoring system. The inter-rater reliability was calculated through reliability analysis (Howell, 2002) using scores from both graders. The interclass correlation coefficient was 86.3%. A student's concept linking score was the mean score rated by both the researcher and independent rater.

Comprehension test. The comprehension test consists of 24 multiple choice questions adopted from Francis Dwyer's study (in Lamberski, 1972). Accompanying the human heart instruction, Dwyer and his colleagues developed four types of criteria to measure students' learning. The four criteria are: a Drawing test, an Identification test, a Terminology test, and a Comprehension test. The Drawing test and the Identification test measure students' visual learning. Considering the extra time they will require from students and their limited contribution to evaluating students' comprehension performance, they were not used in this study. The Terminology test consists of 20 multiple choice questions that assess students' understanding of the terms and their meanings. These terms are the major concepts related to the human heart. The

Comprehension test also consists of 20 multiple choice questions that evaluate students' understanding of the heart functions (Dwyer, 1978). The KR-21 Reliability Coefficient of the Terminology test and the Comprehension test are 0.81 and 0.88 respectively (Dwyer & Moore, 1991). Since only the first half of the original instruction was used in this study, original test questions that are related to the second half of contents were removed. In the end, 12 questions from the Terminology test and 12 questions from the Comprehension test were used in this study as the comprehension test (See Appendix Q).

Based on the test theory (Pedhazur & Schmelkin, 1991), removing test items from its original set will lower the reliability coefficient. Thus, the reliability coefficient of the new comprehension test was analyzed based on participants' scores. The result showed that the reliability coefficient of the comprehension test was 0.7851, which is higher than the acceptable value of 0.70.

Procedure

Before coming to this study, volunteers needed to sign up through a web page. In the web page, they provided their names and email addresses and selected which one of the two classes (Personal Health and Drug Education) they were in. They then chose the dates and times that they would be able to participate in the study. The study consisted of three sessions with one week interval between each of them. After signing up, the volunteers received a confirmation email informing them the dates, times, and place of this study. One day before each of their study session, they received another email reminder about the study.

The participants were randomly assigned to one of the four treatment groups using a free web-based program called the *Research Randomizer* (available at http://www.randomizer.org). To make the number of participants in each group as even as possible, a "blocked design" (Urbaniak

& Plous, 1997) was used. With blocked design, every group of four volunteers was considered as one block and they were randomly assigned to one of the treatment conditions. This method avoids assigning significantly uneven numbers of participants to different conditions. It also permits data collection to begin before knowing the total number of participants. In this study, the recruitment was carried out over one month. Some earlier participants already finished the study before later participants signed up for it. The "blocked design" made this possible.

Since no name, email address, or other personal identifier was allowed to track students' performance, each participant was assigned a Study ID from 001 to 144 based on the order that they came in for the first session of the study. They used the Study IDs throughout the study.

The research was conducted in a PC lab. Participants were required to finish all procedures in the lab. Before the study, 20 PCs were set up with CmapTools installed on each of them. The procedures employed in this study are summarized in Figure 13 and explained in texts. The estimated time for completing each session is labeled.

Week 1	Pre-treatment Survey	demographic information; self-evaluation			
	Tutorial	web-based tutorial on concept mapping			
	Exercise	paper-and-pencil exercise on concept mapping			
	Tutorial	web-based tutorial on CmapTools			
	Treatment	computer-based concept mapping with treatment			
		Tx 1 (NS)	Tx 2 (PS)	Tx 3 (AS)	Tx 4 (PAS)
Week 2	Instructional Materials	web-based instruction on the human heart			
	Posttest 1 (Concept Mapping)	Ob_1	Ob_2	Ob_3	Ob_4
Week 3	Posttest 2 (Comprehension)	Ob_5	Ob_6	Ob_7	Ob_8

Figure 13. Research Procedures.

Week 1 (1 hour and 10 minutes)

During the first session, the participants first read and signed the Informed Consent form and then took the Pre-Treatment Survey. Following that, they went through the web-based tutorials on concept mapping and finished the paper-and-pencil exercise. Next, they took the web-based tutorial on CmapTools. After that, they worked on a computer-based concept mapping exercise under different treatments. After finishing the exercise, participants were instructed to go to a web page to look at the referent map as feedback.

Week 2 (1 hour)

When participants came to the second session, the web-based instruction was opened for them. Participants studied the anatomy and functions of the heart. They then built a concept map based on the instructional material. Heart.cmap, a CmapTool file with 26 concepts, was provided to the participants. No group received any scaffolding in Week 2.

Week 3 (20 minutes)

A week after the concept mapping test, participants took a web-based comprehension test in *survey.vt.edu*. After logging in, participants first filled in their Study ID and then answered 24 multiple choice questions on the heart. By clicking on the Submit button, their answers were stored on the server and available for data analysis.

Pilot Studies

Before implementing the experiment, the entire study was piloted in two separate sessions. The focus of the pilot studies was to evaluate the general appropriateness of the instructional contents and the experimental procedure. The first pilot study involved five female graduate students from the Instructional Design and Technology program at Virginia Tech. Except one native English speaker, the other four graduates were international students with English as a second language. The second pilot study involved four undergraduate students: two females and two males. They were all native English speakers. The graduate session was conducted one week before the undergraduate session. Based on the observation and feedback from the first pilot study, the study procedure and contents were revised for the second pilot study.

Because of the time constraint, students in both pilot studies finished all three sessions of study in one session, but not three consecutive weeks as designed for the official study. The same randomization procedure used in the final study was employed to assign both pilot groups into four treatment conditions. Before the pilot studies it was not sure if students could finish all tasks within the allocated two and half hours. The researcher, thus, recorded the approximate time needed by each student to finish each individual task. It was found that four out of five graduates and all undergraduates could finish the tasks within the predefined time. In general, it took undergraduates less time to accomplish the activities than their graduate counterparts.

This two-session design has its advantages. It allowed the researcher to make necessary changes after the first pilot study. Therefore, the pilot study used for undergraduates, who were the target participants of the study, could be as similar to the official study as possible. As a result of this design, all changes were made based on the graduate pilot study.

One revision was made right before the first pilot study. In the original design, CmapServer was planned, which would allow participants to upload CmapTools files to a server. However, right before the graduate pilot study, it was found that this function did not work properly although it was tested to work fine in another situation. Thus, this step was cancelled. As an alternative, students were asked to save the files to their local computers. The researcher then used a USB drive to transfer the files. This revised method was then used in the undergraduate pilot study and the official study.

One change was made onsite during the first pilot study. The original design consisted of two computer-based concept mapping exercises to ensure mastery of CmapTools. However, it was found that after one hour into the study students could only finish one computer-based exercise. If they continued working on the second exercise, they would not be able to finish the study within the designated time. Thus, each volunteer was inquired if she felt that she had already learned the CmapTools software and felt confident to use it for concept mapping. All volunteers responded positively. So the second computer-based exercise was removed. The two pilot studies and the official study proved that all students could use CmapTools to build a concept map after one computer-based exercise. Appendix O is an example concept map built by a participant.

Another major revision was made after the first pilot study. In the original treatments, students in the AS and PAS groups were provided a hint question, which asked them to elaborate on the relationships between concepts. In the first pilot study, students in these two groups were requested to label the linking lines with a unique number starting from one and then use the annotation function in CmapTools to state the relationships in full sentences. This method was informed by Taber's (1994) study. However, it was found that this method caused confusion in participants. In the concept mapping posttest, all students were asked to label the relationships between concepts using linking words or phrases so that the relationships could be evaluated without expanding corresponding annotations. Had Tabor's method been used, the treatments would be the only time that students in the AS and PAS groups needed to use a number to link concepts. To avoid the confusion, in the second pilot study as well as the official study, students were asked to label the relationships using linking words or phrases.

At the end of both pilot studies, volunteers were given a paper-based evaluation form (Appendix P) for feedback. Eight questions were asked about the clarity of the instruction and experimental procedure, students' perception about the difficulty of Concept mapping, and the usefulness of providing concepts and basic structure in the posttest. Students could also make comments about the interface design, grammar issues, or any other problem under the "Additional comments" section. Results of the feedback indicated that volunteers agreed that the instruction and procedures of the study were clear; the tutorials provided enough information for them to learn concept mapping and CmapTools; they did not think building a concept map was too difficult; and providing concepts and basic structure on the heart helped them build the concept map.

Data Analysis

The following information was collected from each participant: demographic information; self-rated knowledge and skill on computer operation and concept mapping; group membership (NS, PS, AS, or PAS); concept mapping test score; and retention of comprehension test score. The statistics program SPSS 14 was used for the quantitative data analysis. The alpha level for all analyses was set at .05 ($p \leq .05$).

The primary purpose of the analysis was to answer the research questions of the study:

1) Does *linking phrase scaffolding*, which provides students with linking phrases, positively affect students' performance in constructing relationships between concepts and retention of content comprehension?
2) Does *articulation hint scaffolding*, which requires students to explicitly state relationships between concepts, positively affect students' performance in constructing relationships between concepts and retention of content comprehension?
3) Does *linking phrase scaffolding and articulation hint scaffolding* positively affect students' performance in constructing relationships between concepts and retention of content comprehension?
4) Is there a positive relationship between students' performance in concept linking and retention of content comprehension tests?

The first three questions were answered by using two factorial Analysis of Variance (ANOVA) to compare the concept mapping scores and the comprehension scores. The main effects of the two scaffolding methods as well as the interaction effects of them were examined. The fourth question was answered by conducting a Pearson's correlation analysis (Howell, 2002) to find out if there is a positive relationship between students' concept linking performance and their retention of comprehension performance.

RESULTS AND DISCUSSION

The purpose of this study was to determine if different types of scaffolding would affect students' performance in computer-based concept linking and retention of comprehension. This chapter reports the general descriptive data, the scores of each dependent variable, and the results of the statistical analysis that was carried out to test the research hypotheses. It finishes with a summary and conclusion section.

Volunteers were randomly assigned to different groups using the blocked design to ensure the number of participants in each group was as equal as possible. However, there were still different numbers of participants in each group for several reasons. First, ten volunteers dropped out during the study. Second, some volunteers did not finish the sessions on schedule. Participants in this study were required to finish three sessions in three consecutive weeks with one week interval between each session. Eighteen volunteers did not follow the schedule. They finished all three sessions, but data collected from them were not used for analysis. Third, in the treatment some participants in the AS and PAS group did not follow the articulation hint instruction of writing down relationships using full sentences. Those participants were adjusted to the NS and PS groups based on whether or not they received the linking phrase scaffolding. The adjustment was determined by checking participants' concept maps in the treatment exercise. In the end, of the 116 participants, 30 were in the NS group, 35 were in the PS group, 25 were in the AS group, and 26 were in the PAS group. Since unequal numbers of participants in each treatment condition will influence the result of factorial Analysis of Variance (ANOVA), the Type III Sum of Square, which is based on the weighted means of each cell, is reported below (Howell, 2002).

Results of Analysis

Data collected from the Pre-Treatment Survey, concept linking test, and retention of comprehension test are presented in the following section. The analysis results are also reported.

Results of the Pre-Treatment Survey

In addition to gathering participants' demographic information as reported in the previous chapter, participants in this study were also asked to self-rate their knowledge and skill in the following areas: general computer operation, concept mapping, CmapTools, and the anatomy and function of the human heart. This study required the completion of web-based tutorials and other computer-based activities, so it was expected participants would have a basic familiarity with general computer operation. In addition, it was expected that the majority of participants would have limited knowledge of concept mapping and CmapTools so that the effects of the treatments could be examined without being influenced by their prior knowledge in these areas. It was also hoped that most participants would not be very familiar with the anatomy and function of the heart so that their prior knowledge would not affect the comprehension test.

For each question, the participants selected a number from 1-5, with 1 as *very limited* and 5 as *very proficient*, to represent their self-rated knowledge and skill. The results showed that almost all participants were confident about their basic computer operation skills except three who rated their skills as low (1 or 2 on a scale of 5). No participants rated their knowledge in concept mapping as very proficient. About 10% (n = 12) of participants rated their knowledge in concept mapping as relatively high with a score of 4; the rest of participants distributed about equally into the other three categories, with 26.7% (n = 31), 32.8% (n = 38), and 30.2% (n = 35) in scores 1 to 3 respectively. Most participants did not have a high level of knowledge in CmapTools. Only two participants rated that they had a relatively high level of knowledge in CmapTools with a score of 4 or 5. For the rest of the participants, 75% (n = 87) rated their CmapTools knowledge as low (score = 1), 11.2% (n = 13) as relatively low (score=2), and 12.1% (n = 14) as medium (score = 3).

Compared with CmapTools, the participants had a higher knowledge level in other computer-based concept mapping software, with 57.8% (n = 67), 19.0% (n = 22), 15.5% (n = 18), 4.3% (n = 5), and 3.4% (n = 4) rated their score from 1 to 5 respectively. Answers from these self-rated questions revealed that generally participants of this study had basic computer operation skills; some of them had some knowledge in concept mapping and used computer-based concept mapping software before; almost all of them had very limited experience with CmapTools.

In the rest of the Pre-Treatment Survey, the participants self-rated their knowledge in the heart on a scale from 1 to 5, with 1 as *very little* and 5 as *very much*. For five questions, at least 89% of the participants rated their knowledge below 3. Only one question received a rating above 3 from 22.1% of participants. This question asked participants to explain how blood circulates through the body. Participants' total score on the six questions ranged from 5 to 29 (out of a possible 30). The mean of the self-rated knowledge on the heart was 11.0 and the median was 9.5. The histogram in Figure 14 showed that the scores were negatively skewed, which means that the majority of the participants did not know the subject topic very well. In summary, results of the Pre-Treatment Survey indicated that participants in this study had the expected knowledge and skill in general computer operation, concept mapping, and the human heart.

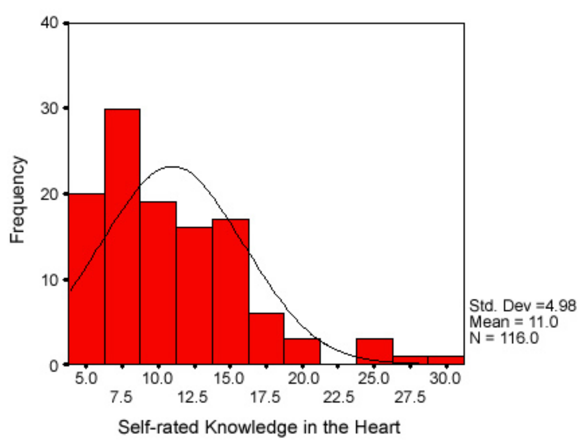

Figure 14. Participants' self-rated knowledge of the heart.

Concept Linking and Comprehension Test Scores

Participants' scores in the concept linking posttest ranged from 7.2 to 117.7. Table 2 shows the means, standard deviations, and total scores for each treatment group.

Table 2

Means and Standard Deviations for the Concept Linking Test

Linking Phrase		Articulation: No	Articulation: Yes	total
No	Group Name	NS	AS	
	M	61.6950	61.3080	61.5191
	SD	18.5502	17.6648	17.9867
	n	30	25	55
Yes	Group Name	PS	PAS	
	M	62.9614	64.3942	63.5721
	SD	21.5041	14.5638	18.7331
	n	35	26	61
Total	M	62.3769	62.8814	62.5987
	SD	20.0497	16.0705	18.3322
	n	65	51	116

Participants' scores in the retention of comprehension test were the total number of questions that they answered correctly. The scores ranged from 2 to 22 (out of a possible 24). Table 3 shows the means, standard deviations, and total scores for each treatment group.

Table 3

Means and Standard Deviations for the Retention of Comprehension Test

		Articulation		
Linking Phrase		No	Yes	total
No	Group Name	NS	AS	
	M	10.2333	9.4800	9.8909
	SD	4.4542	4.6915	4.5366
	n	30	25	55
Yes	Group Name	PS	PAS	
	M	9.6286	9.6154	9.6230
	SD	4.9055	4.7504	4.7999
	n	35	26	61
Total	M	9.9077	9.5490	9.7500
	SD	4.6762	4.6747	4.6586
	n	65	51	116

When there are unequal numbers of participants in different treatment conditions, the robustness of ANOVA will be influenced and it is necessary to examine the assumptions of ANOVA. Thus, in this study the three assumptions of ANOVA were tested. The first assumption of ANOVA refers to the homogeneity of variance among groups. Table 4 shows that for both the concept linking and retention of comprehension tests the Levene Statistic was not significant ($\alpha >$

0.05), which means that there were comparable variances among the different treatment groups and the homogeneity requirement was met.

Table 4

Results of Levene's Test for Homogeneity of Variance

	Levene Statistics	df1	df2	Sig.
Concept Linking Scores	1.297	3	112	.279
Comprehension Scores	.060	3	112	.981

The second assumption of ANOVA is the normality, which means that participants' scores for each treatment condition should distribute normally around their means. Figure 15 and 16 demonstrated the distribution of the dependent measurements—concept linking scores and retention of comprehension test scores among different groups. The normal curves among different groups were similar, which indicate that the normality assumption was met.

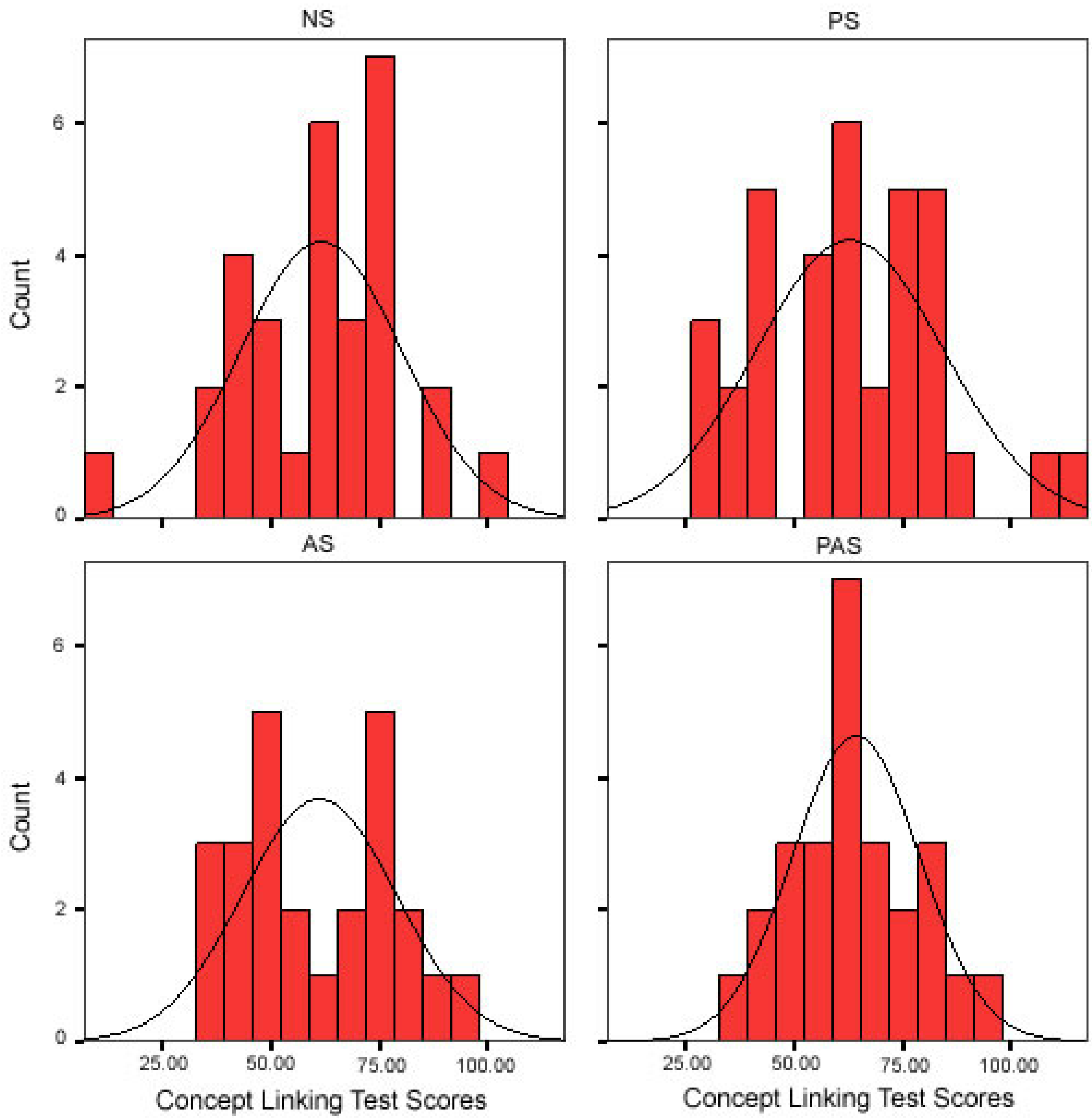

Figure 15. Distribution of concept linking scores among different groups.

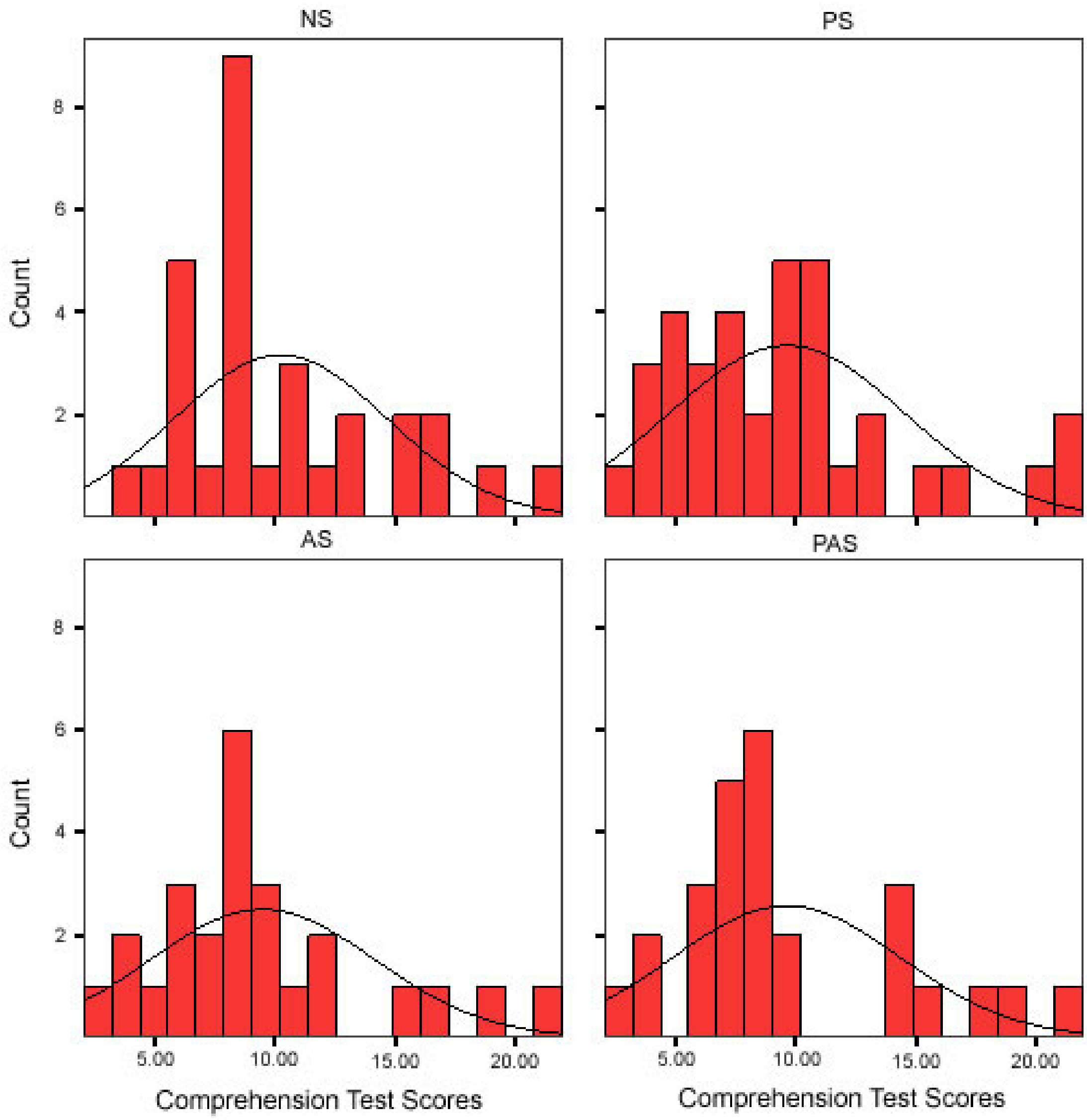

Figure 16. Distribution of comprehension scores among different groups.

The third assumption of ANOVA is independence of observation, which means that the observations within each treatment are independent of one another and knowing how one participant in a group performs will not inform how another participant in the same group may perform. This was addressed by randomly assigning participants to groups (Howell, 2002). Therefore, none of the three assumptions of ANOVA was violated and it is valid to use factorial ANOVA in this study.

Results of the factorial ANOVA of the concept linking scores indicated that there was no significant difference among the different treatment groups. More specifically, there was no significant main effect of either the linking phrase scaffolding, $F(1,112) = .393$, $p > .05$ and the hint question scaffolding, $F(1,112) = .023$, $p > .05$ on students' performance in computer-based concept linking. There was also no significant interaction between these two types of scaffolding, $F(1, 112) = .069$, $p > .05$. Table 5 demonstrates the results of the factorial ANOVA of the concept linking test.

Table 5

Summary of ANOVA Table of the Concept Linking Test

Source	df	Type III Sum of Squares	Mean Square	F
PS	1	134.973	143.973	.393
AS	1	7.792	7.792	.023
PS * AS	1	23.593	23.593	.069
Error	112	38493.227	343.690	

Results of factorial ANOVA of the comprehension scores indicated that there was no significant difference among the different treatment groups. More specifically, there was no significant main effect of either the linking phrase scaffolding, $F(1,112) = .071$, $p > .05$ and the hint question scaffolding, $F(1,112) = .189$, $p > .05$ on students' performance in retention of comprehension. There was also no significant interaction between these two types of scaffolding, $F(1,112) = .176$, $p > .05$. Table 6 demonstrates the results of the factorial ANOVA of the comprehension test.

Table 6

Summary of ANOVA Table of the Comprehension Test

Source	df	Type III Sum of Squares	Mean Square	F
PS	1	1.570	1.570	.071
HS	1	4.186	4.186	.189
PS * HS	1	3.903	3.903	.176
Error	112	2485.932	22.196	

Result of the Pearson's correlation indicates that there was a positive relationship between students' performance in computer-based concept linking and retention of comprehension ($\gamma = 0.447$, $p < 0.01$).

Hypotheses Tests

The testing results of each hypothesis are reported in the following section followed by a discussion of the results.

Hypothesis 1

Students who receive linking phrase scaffolding (PS) will perform better in both computer-based concept linking and retention of comprehension tests than their peers who do not receive such scaffolding.

To test this hypothesis, mean scores from both the concept linking and retention of comprehension tests were compared. Results showed that in the concept linking test students in the linking phrase scaffolding groups (PS and PAS) scored higher (*M* = 63.57, *SD* = 18.73) than their peers (NS and AS) who did not receive such scaffolding (*M* = 61.52, *SD* = 17.99). However, this difference was not significant. The results of the factorial ANOVA did not support the hypothesis that participants in the linking phrase scaffolding group would perform better than their peers who do not receive such scaffolding in computer-based concept linking, F (1,112) = .393, $p > .05$.

Researchers (Fisher et al., 1990; Jonassen, 1996) proposed that providing students with linking phrases would help them construct relationships between concepts. However, no empirical study has been conducted to examine this potential effect. Although in several studies (Brandt et al., 2001; Chang et al., 2001) a list of linking phrases was provided to learners, the focus was to leverage the cognitive load but not help learners construct relationships between concepts. Thus, it was unknown if providing linking phrases, as suggested by Fisher et al. and Jonassen, would help learners construct relationships between concepts. Results of this study did not support the hypothesis that providing linking phrases would help learners build relationships between concepts.

Results from the retention of comprehension test showed that students in the linking phrase scaffolding groups (PS and PAS) scored lower (*M* = 9.62, *SD* = 4.80) than their peers (NS and AS) who did not receive such scaffolding (*M* = 9.89, *SD* = 4.54). However, this difference was not significant. The results of the factorial ANOVA did not support the hypothesis that participants in the linking phrase scaffolding group would perform better than their peers who do not receive such scaffolding in retention of comprehension, $F(1,112) = .071$, $p > .05$. The linking phrase scaffolding employed in this study had no effect on students' performance in retention of comprehension.

Previous research in concept mapping focused on the effects of concept mapping on students' academic performance and generated mixed results. Some studies (Chang et al., 2001;

Chmielewski & Dansereau, 1998; Uzuntiryaki & Geban, 2005) showed that concept mapping could positively improve information acquisition and retrieval, changing of misconception, and academic performance. Other studies (Brandt et al., 2001; Sturm & Rankin-Erickson, 2002), however, revealed that concept mapping was not always effective in promoting student's learning. No study, however, examined if helping students build relationships between concepts, which was deemed to be the most difficult task in concept mapping (Fisher et al., 1990; Jonassen, 1996), would help them better understand the nature of relationships between concepts and thus enhance retention of comprehension. Findings from the present study did not provide evidence that providing linking phrases as scaffolding could help students better maintain their comprehension.

Hypothesis 2

Students who receive articulation hint scaffolding (AS) will perform better in both computer-based concept linking and retention of comprehension tests than their peers who do not receive such scaffolding.

To test this hypothesis, mean scores from both the concept linking and retention of comprehension tests were compared. Results showed that in the concept linking test students in the articulation hint scaffolding (AS and PAS) groups scored higher (M = 62.88, SD = 16.07) than their peers (NS and PS) who did not receive such scaffolding (M = 62.38, SD = 20.05). However, this difference was not significant. The results of the factorial ANOVA did not support the hypothesis that students in the articulation hint scaffolding groups would perform better than their peers who do not receive such scaffolding in computer-based concept linking test, F (1,112) = .023, $p > .05$.

Taber (1994) believes that learners may not completely and accurately reflect relationships between concepts if they only connect concepts with linking phrases. They may have the illusion that they understand the relationships while, in fact, they do not. This is especially true for learners who have low metacognitive capabilities (Driscoll, 2000). To avoid this, Taber (1994) and Ferry et al. (1997) asked students to elaborate on relationships between concepts using full sentences. One student in Ferry's study reflected that explaining relationships between concepts using full sentences helped her better understand how concepts relate to each other. This claim, however, was not based on empirical research. Thus, it has not been established whether asking students to articulate relationships between concepts would enhance their concept linking performance. Results of this study did not support the hypothesis that asking students to articulate relationships between concepts would help them with concept linking.

Results from the retention of comprehension test showed that students in the articulation hint scaffolding (AS and PAS) groups scored lower (M = 9.55, SD = 4.67) than their peers (NS and PS) who did not receive such scaffolding (M = 9.91, SD = 4.67). However, this difference was not significant. The results of the factorial ANOVA did not support the hypothesis that participants in the articulation hint scaffolding group would perform better than their peers who do not receive such scaffolding in the retention of comprehension test, $F(1,112) = .189$, $p > .05$. The articulation hint scaffolding employed in this study had no effect on students' performance in both concept linking and retention of comprehension.

Similar to the linking phrase scaffolding, no study has been conducted to examine if helping students articulate relationships between concepts would help them better understand the nature of relationships and consequently the overall information. Findings from the present study did not provide evidence that articulation hint as scaffolding could help students better comprehend and maintain subject contents.

Hypothesis 3

Students who receive linking phrase plus articulation hint scaffolding (PAS) will perform the best in both computer-based concept linking and retention of comprehension tests.

Results of the factorial ANOVA of the concept mapping posttest did not support the hypothesis that participants in the linking phrase combining articulation hint scaffolding group would perform the best in the four treatment groups. There was no significant interaction effect between linking phrase scaffolding and articulation hint scaffolding on students' performance in computer-based concept linking, $F(1,112) = .069$, $p > .05$.

Results of the factorial ANOVA of the retention of comprehension test did not support the hypothesis that participants in the linking phrase combining articulation hint scaffolding group would perform the best in the four treatment groups. There was no significant interaction effect between linking phrase scaffolding and articulation hint scaffolding on students' performance in retention of comprehension, $F(1,112) = .176$, $p > .05$.

No study has been conducted to examine if linking phrase scaffolding combining articulation hint scaffolding would help students construct relationships between concepts and better maintain information reorganized through concept mapping. Findings from the present study did not provide evidence that there was an interaction effect between these two types of scaffolding. In summary, participants in this study performed equally well in the concept linking and retention of comprehension tests no matter which kind of treatments they received.

Hypothesis 4

There is a significant correlation between students' performance score in computer-based concept linking and retention of comprehension, that is, students who perform well in concept linking task will also perform well in retention of comprehension, and vice versa.

Result of the Pearson's correlation analysis indicated that the correlation between students' performance in computer-based concept linking and retention of comprehension was significant ($\gamma = 0.447$, $p < 0.01$). This result supported the hypothesis that participants' performance in concept linking and retention of comprehension would have a positive correlation. Students' performance in concept linking is a significant predictor of their retention of comprehension performance. About 20.0% (γ^2 = 20.0%) of variability in students' retention of comprehension test is related to their concept linking performance.

The use of concept map as an alternative assessment of students' learning has attracted a lot of interests. Acton et al. (1994) argued that to qualify as an assessment tool, concept maps should reliably predict students' performance in other standard achievement tests. However, other researchers (Kinchin, 2000, 2001; McGaghie et al., 2004) believe that the different tests assess different knowledge in students. Thus, it is inappropriate to use other assessment methods as criteria to evaluate the validity of concept map as an assessment tool. Although disagreement exists, research findings revealed that there is a high correlation between students' performance in concept mapping and some testing measures (Austin & Shore, 1995; Chang et al., 2005). For example, Austin and Shore's study showed that some quantitative indicators for assessing concept map have a high correlation (0.71-0.82) with students' performance in multiple-step problem solving. Chang et al. (2005) used closeness index and similarity index to evaluate concept maps and found that these two indices had significant correlation with students' achievement scores (γ =

0.48 and $\gamma = 0.63$ respectively).

Researchers (Jonassen, 1996; Kinchin, 2000; Novak & Gowin, 1984) believe that concept mapping is a complex process and requires deep information processing. To construct a concept map, students need to identify and classify concepts, clarify relationships between them, and reorganize information into a visual format. This process encourages knowledge synthesis and organization, which promotes information comprehension and retention (Ausubel, 1978). Therefore, students who perform well in concept linking should have a good understanding of a subject topic and should perform well in retention of comprehension.

Conclusion

This study was based on a literature review in two areas: concept mapping and scaffolding. Concept mapping is believed to be one method that can help students establish a systematic and integrated knowledge structure. However, concept mapping involves various higher order thinking skills and students often find it difficult. Among the various difficulties that students have, it is the most difficult to construct relationship between concepts. Researchers (Ferry et al., 1997; Fisher et al., 1990; Jonassen, 1996; Taber, 1994) suggested that providing learners with linking phrases and asking them to articulate relationships between concepts might help them conquer this difficulty. However, before this study, there was no empirical data available to help determine if these two methods would work.

Scaffolding, as an instructional support can focus learners' attention to critical aspects of a problem, leverage cognitive burden, foster higher order thinking, and offer strategies for problem solving (Day, 1983; Gaskins et al., 1997; Stone, 1993; Wood et al., 1976). Scaffolding has been effective in helping learners accomplish various tasks.

To fill the gap in relevant research, this study was designed to explore the effects of linking phrase and articulation hint, delivered as scaffolding, on students' performance in computer-based concept linking and retention of comprehension. The researcher expected that learning linking phrases would help learners recognize words and phrases that are used to connect concepts; explicitly stating relationships between concepts would help learners monitor and achieve better understanding of the relationships. However, results from this study indicated that students performed equally well with or without the different types of scaffolding. In other words, the different scaffolding methods were not effective in improving learners' performance in concept linking as well as retention of comprehension. This echoes the statement from All et al. (2003) that "helping students formalize concept links is one of the most challenging tasks in teaching" (p. 311).

While it is possible that participants' performance in concept linking was a result of their incompetence in CmapTools, this possibility was excluded through observation and participants' maps. The researcher observed the participants through the study and found that all participants were able to build concept maps in CmapTools after the web-based tutorials and exercises. The maps constructed by the participants supported the observation.

Riley (1995), after reviewing previous studies, found that it takes time for students to learn scaffolding strategies or tools. If the scaffolding is withdrawn too fast, students can not internalize what provided in the scaffolding as part of their thinking. It is possible that scaffolding methods in this study were removed too fast and that this prevented the participants from mastering them. Other researchers (Hmelo & Day, 1999; Kao, 1996; King, 1991; Oliver, 1999) also argue that to succeed in scaffolding, students need to master the strategies or skills offered in scaffolding. Thus, it is suggested that in future studies students should be provided more time to practice the different scaffolding methods to see if that would generate any significant effects.

In addition to exploring the effects of scaffolding on students' performance, this study also examined the correlation between students' performance in computer-based concept linking and retention of comprehension. Since concept map was introduced as a way to detect change in students' understanding (Novak & Gowin, 1984), it has attracted a lot of interest. In spite of the disagreement among researchers about using other standard tests as criteria to evaluate the validity of concept map as an assessment tool, the results of this study indicate a positive correlation between students' performance in concept linking and retention of comprehension. This suggests that students' performance in concept linking can be used to help predict their performance in retention of information, which was acquired and reorganized through concept mapping.

In another way, this study responded to the call from Ruiz-Primo and Shavelson (1996), who argued that "research on students' facility in using concept maps, on training techniques, and on the effect on teaching is needed if concept map assessments are to be used in classroom and in large-scale accountability systems" (p. 569). Because of the scarcity of similar research, the researcher suggests that more studies should be conducted to explore ways to help students build quality relationships between concepts and thus form a systematic and integrated view of a particular subject matter.

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APPENDIX A: INSTITUTIONAL REVIEW BOARD APPROVAL

Virginia Tech
VIRGINIA POLYTECHNIC INSTITUTE
AND STATE UNIVERSITY

Institutional Review Board

Carmen Green
IRB Administrator
Research Compliance Office
1880 Pratt Drive, Suite 2006(0497), Blacksburg, VA 24061
Office: 540/231-4358; FAX: 540/231-0959
email: ctgreen@vt.edu

DATE: January 31, 2006

MEMORANDUM

TO: John K. Burton Teaching and Learning
Deyu Hu EDCI

FROM: Carmen Green

SUBJECT: **IRB Exempt Approval:** "The Effects of the Scaffolding on the Performance of Students in Computer-based Concept Mapping" IRB # 06-035

I have reviewed your request to the IRB for exemption for the above referenced project. I concur that the research falls within the exempt status. Approval is granted effective as of January 31, 2006.

Virginia Tech has an approved Federal Wide Assurance (FWA00000572, exp. 7/20/07) on file with OHRP, and its IRB Registration Number is IRB00000667.

cc: File

A Land-Grant University - Putting Knowledge to Work
An Equal Opportunity/Affirmative Action Institution

APPENDIX B: THE PRE-TREATMENT SURVEY

Pre-Treatment Survey

Welcome to the study. Thank you for participating. It will take you less than 10 minutes to finish this survey. Please answer each question. Thank you!

Part I. Demographic Information

1. My study ID is: (Please see the package you received from the researcher)

2. I am a _________.
- a. freshman
- b. sophomore
- c. junior
- d. senior
- e. master's student
- f. doctoral student

3. I am a _________.
- a. female
- b. male

4. My age range is _________.
- a. under 18
- b. 18-25
- c. 26-35
- d. 36-45
- e. 46 and above

5. I am majoring in

6. English is my native language.
- Yes.
- No.

7. My ethnicity is:
- American Indian/Alaskan Native
- Asian
- Black/African American
- Hispanic/Latino
- Multiracial
- White/Caucasian
- Other

Part II. Rate Your Knowledge and Skills

Please check the statements that apply to you.

8. Please rate your skill and proficiency in general computer operation:
○ weak 1 ○ 2 ○ 3 ○ 4 ○ strong 5

9. Please rate your knowledge and skills in concept mapping:
○ weak 1 ○ 2 ○ 3 ○ 4 ○ strong 5

10. I am familiar with CmapTools (a computer-based concept mapping program).
○ Disagree ○ Tend to disagree ○ Undecided ○ Tend to agree ○ Agree

11. I am familiar with one or more computer-based concept mapping software.
○ Disagree ○ Tend to disagree ○ Undecided ○ Tend to agree ○ Agree

12. I know the difference between diastolic and systolic pressure.
○ Very little 1 ○ 2 ○ 3 ○ 4 ○ Very much 5

13. I can explain how blood circulates through the body.
○ Very little 1 ○ 2 ○ 3 ○ 4 ○ Very much 5

14. I know the different layers of membranes and muscle of the heart.
○ Very little 1 ○ 2 ○ 3 ○ 4 ○ Very much 5

15. I can explain the diastolic and systolic phase.
○ Very little 1 ○ 2 ○ 3 ○ 4 ○ Very much 5

16. I know which part of the heart sends blood to the lungs.
○ Very little 1 ○ 2 ○ 3 ○ 4 ○ Very much 5

17. I know which part of the heart provides blood for the entire body.
○ Very little 1 ○ 2 ○ 3 ○ 4 ○ Very much 5

[Submit]

APPENDIX C: SAMPLE SCREEN FROM THE CONCEPT MAPPING TUTORIAL

Concept Mapping Study

Concept Mapping Tutorial

Introduction

This is a tutorial on concept mapping. Including this page, this tutorial has two screens. After finishing the tutorial, you will construct a concept map using paper and pencil.

After finishing this tutorial, you should be able to:

1. Explain **what** is a concept map;
2. State and identify the **components** of a concept map;
3. List the basic **types** of concept maps;
4. Describe the **process** of constructing a concept map; and
5. Draw a simple concept map.

During this tutorial, you need to:

1. Understand the contents of this tutorial;
2. Draw a concept map using paper and pencil.

Go Back Continue

APPENDIX D: THE PAPER-AND-PENCIL CONCEPT MAPPING EXERCISE

Concept Mapping Study

Paper-and-Pencil Exercise

Please read the paragraphs below and then draw a concept map based on the contents. *Please use the paper and pencil provided to you.*

Nutrients are classified as essential or nonessential. Nonessential nutrients are manufactured in the body and do not need to be obtained from food. Examples include cholesterol, a fatlike substance present in all animal cells. Essential nutrients must be obtained from food sources, because the body either does not produce them or produces them in amounts too small to maintain growth and health. Essential nutrients include water, carbohydrates, proteins, fats, vitamins, and minerals.

An individual needs varying amounts of each essential nutrient, depending upon such factors as gender and age. Specific health conditions, such as pregnancy, breast-feeding, illness, or drug use, make unusual demands on the body and increase its need for nutrients. Dietary guidelines, which take many of these factors into account, provide general guidance in meeting daily nutritional needs.

After you finish, please write down your **study ID** (e.g. 065 or 118) on the top of the map and keep it with you. You will need it later in this session.

Go Back   Continue

APPENDIX E: SAMPLE SCREENS FROM THE CMAPTOOLS TUTORIAL

Concept Mapping Study

CmapTools Tutorial

1 of 9

Introduction

This tutorial teaches you how to use CmapTools, a computer-based concept mapping software. Including this page, this tutorial has nine screens. Please go through them all and then finish the exercise following the instructions.

After finishing this tutorial, you should be able to:

1. Create a new Cmap file;
2. Add concepts to a Cmap file;
3. Add links between concepts ;
4. Save a concept map;
5. Add arrows to linking lines; and
6. Add annotations to a Cmap file.

During this tutorial, you need to:

1. Understand and practice the contents in this tutorial;
2. Draw a concept map using CmapTools.

Go Back Continue

Concept Mapping Study

CmapTools Tutorial

2 of 9

Learning Instruction

CmapTools is a computer-based concept mapping program provided by the Institute of Human and Machine Cognition (IHMC). You can download this freeware, from this URL http://cmap.ihmc.us/download/ for later use. But for the purpose of this study, it has been downloaded and installed on the computer you are now using.

While you go through this tutorial, please *follow the steps* in this tutorial in CmapTools. In this way, you can practice what is addressed in this tutorial while you are reading. Remember, you need to switch between this Web browser and CmapTools to finish this tutorial. Now let us launch CmapTools by going to the **Desktop** and click on the "**CmapTools**" shortcut.

Go Back Continue

APPENDIX F: TREATMENT FOR THE NS GROUP

Concept Mapping Study Week 1 Session

This instruction is for the CmapTools Exercise, which is the last task of the Week 1 session.

CmapTools Exercise

Group A

My Study ID is _________

Please return this packet back to the researcher after you finish this exercise.

General Instruction:

1. Read this instruction thoroughly before you begin the task.
2. Use CmapTools to construct a concept map based on the paragraphs on page 2, which are the same as the paper-and-pencil exercise you have done. You can refer to your finished map in the paper-and-pencil exercise.
3. **Always label the nature of relationships between concepts.**
4. Always save your concept map file during the construction process.

1

Computer-based Concept Mapping Exercise

Instruction:

1. Name your file as "nutrients_#". # is the Study ID assigned to you and it is on page 1. For example, if your Study ID is 007, then your file name should be nutrients_007.

Nutrients are classified as essential or nonessential. Nonessential nutrients are manufactured in the body and do not need to be obtained from food. Examples include cholesterol, a fatlike substance present in all animal cells. Essential nutrients must be obtained from food sources, because the body either does not produce them or produces them in amounts too small to maintain growth and health. Essential nutrients include water, carbohydrates, proteins, fats, vitamins, and minerals.

An individual needs varying amounts of each essential nutrient, depending upon such factors as gender and age. Specific health conditions, such as pregnancy, breast-feeding, illness, or drug use, make unusual demands on the body and increase its need for nutrients. Dietary guidelines, which take many of these factors into account, provide general guidance in meeting daily nutritional needs.

Worthington-Roberts, Bonnie. "Human Nutrition." *Microsoft® Student* 2006 [DVD]. Redmond, WA: Microsoft Corporation, 2005.

-- STOP HERE --

After you finished this exercise,
please see the back of this page for more instruction.

Thank you!

Now, you have finished the task. Please take a look at the concept map constructed by the researcher at this URL:

https://filebox.vt.edu/users/dhu/Cms/tutorials/cmtref.htm

You do not need to make any change of your concept map. Just compare the two maps and see where you did well and where you can improve in later exercises.

You finished today's session. Before you leave, please ask the researcher to check that you have the files in the correct folders.

Thank you!

APPENDIX G: TREATMENT FOR THE PS GROUP

This instruction is for the CmapTools Exercise, which is the last task of the Week 1 session.

CmapTools Exercise

Group B

My study ID is _________

Please return this packet back to the researcher after you finish this exercise.

General Instruction:

1. Read this instruction thoroughly before you begin the task.
2. Use CmapTools to construct a concept map based on the paragraphs on page 2, which are the same as the paper-and-pencil exercise you have done. You can refer to your finished map in the paper-and-pencil exercise.
3. **Always label the nature of relationships between concepts.**
4. Always save your concept map file during the construction process.

Computer-based Concept Mapping Exercise

Instruction:

1. On **page 3**, there are lists of commonly used ***Relationship Phrases***, please study the lists and apply them in your concept map where it is appropriate.
2. Name your file as "nutrients_#". # is the study ID assigned to you and it is on page 1. For example, if your study ID is 007, then your file name should be nutrients_007.

Nutrients are classified as essential or nonessential. Nonessential nutrients are manufactured in the body and do not need to be obtained from food. Examples include cholesterol, a fatlike substance present in all animal cells. Essential nutrients must be obtained from food sources, because the body either does not produce them or produces them in amounts too small to maintain growth and health. Essential nutrients include water, carbohydrates, proteins, fats, vitamins, and minerals.

An individual needs varying amounts of each essential nutrient, depending upon such factors as gender and age. Specific health conditions, such as pregnancy, breast-feeding, illness, or drug use, make unusual demands on the body and increase its need for nutrients. Dietary guidelines, which take many of these factors into account, provide general guidance in meeting daily nutritional needs.

Worthington-Roberts, Bonnie. "Human Nutrition." *Microsoft® Student* 2006 [DVD]. Redmond, WA: Microsoft Corporation, 2005.

-- STOP HERE --

After you finished this exercise,
please see the back of the last page for more instruction.

Thank you!

Relationship Phrases

Symmetric Relation Phrases

is opposite of	is same as	has sibling
is independent of	has synonym	is equal to
is near to	is equal to	is similar to
is opposed to		

Asymmetric Relation Phrases

Inclusion Relations

has part/ is part of	includes/is included in	is composed of
contains/is contained in	has example/is example of	has instance/is instance of
has member/is member of		

Characteristic Relations

has characteristic /is characteristic of		has attribute/is attribute of
has property/is property of	has type/is type of	has kind/is kind of
defines/is defined by	describes/is described by	models/is modeled by
denotes/is denoted by	implies/is implied by	has advantage/is advantage of
has disadvantage/is disadvantage of		has function/is function of
has size/is size of	is above/is below	is higher than/is lower than
has precursor/is precursor of	has state/is state of	is near

Action Relations

causes/is caused by	uses/is used by	solves/is solution for
exploits/is exploited by	decrease/is decreased by	increases/is increased by
destroys/is destroyed by	impedes/is impeded by	influences/is influenced by
determines/is determined by	enables/is enabled by	absorbs/is absorbed by
acts on/is acted on by	consumes/is consumed by	converted from/converted to
designs/is designed by	employs/is employed by	evolves into/is evolved from
generates/is generated by	modifies/is modified by	originates from/is origin of
provides/is provided by	requires/is required by	provides/is provided by
sends to/receive from	inserts on	attach to/is attachment for
flexes/is flexed by	extends/is extended by	adducts/is adducted by
elevates/is elevated by	dilates/is dilated by	stabilizes/is stabilized by

Process Relations

has input/is input to	has output/is output of	occurs at site/is site of
has result/results from	has subprocess	has process/is process in
proposes/is proposed by	depends on/has dependent	concludes/is concluded by
empties into	receives from	gives arterial blood to
gets arterial blood from	precedes/follows	has step/is step on
has stage/is stage in		

3

Now, you have finished the task. Please take a look at the concept map constructed by the researcher at this URL:

https://filebox.vt.edu/users/dhu/Cms/tutorials/cmtref.htm

You do not need to make any change of your concept map. Just compare the two maps and see where you did well and where you can improve in later exercises.

You finished today's session. Before you leave, please ask the researcher to check that you have the files in the correct folders.

Thank you!

APPENDIX H: TREATMENT FOR THE AS GROUP

Concept Mapping Study | Week 1 Session

This instruction is for the CmapTools Exercise, which is the last task of the Week 1 session.

CmapTools Exercise

Group C

My study ID is _________

Please return this packet back to the researcher after you finish this exercise.

General Instruction:

1. Read this instruction thoroughly before you begin the task.
2. Use CmapTools to construct a concept map based on the paragraphs on page 2, which are the same as the paper-and-pencil exercise you have done. You can refer to your finished map in the paper-and-pencil exercise.
3. **Always label the nature of relationships between concepts.**
4. Always save your concept map file during the construction process.

1

Computer-based Concept Mapping Exercise

Instruction:

1. In addition to labeling linking lines with relationship words or phrases, also use the annotation function (hint: right-click your mouse and select **Annotate…**) of CmapTools to state the relationships between concepts with full sentences. For example: North America is part of the American continent. Please put each annotation beside its corresponding link in the map.
2. Name your file as "nutrients_#". # is the study ID assigned to you and it is on page 1. For example, if your study ID is 007, then your file name should be nutrients_007.

Nutrients are classified as essential or nonessential. Nonessential nutrients are manufactured in the body and do not need to be obtained from food. Examples include cholesterol, a fatlike substance present in all animal cells. Essential nutrients must be obtained from food sources, because the body either does not produce them or produces them in amounts too small to maintain growth and health. Essential nutrients include water, carbohydrates, proteins, fats, vitamins, and minerals.

An individual needs varying amounts of each essential nutrient, depending upon such factors as gender and age. Specific health conditions, such as pregnancy, breast-feeding, illness, or drug use, make unusual demands on the body and increase its need for nutrients. Dietary guidelines, which take many of these factors into account, provide general guidance in meeting daily nutritional needs.

Worthington-Roberts, Bonnie. "Human Nutrition." *Microsoft® Student* 2006 [DVD]. Redmond, WA: Microsoft Corporation, 2005.

-- STOP HERE --

After you finished this exercise,
please see the back of this page for more instruction.

Thank you!

Now, you have finished the task. Please take a look at the concept map constructed by the researcher at this URL:

https://filebox.vt.edu/users/dhu/Cms/tutorials/cmtref.htm

You do not need to make any change of your concept map. Just compare the two maps and see where you did well and where you can improve in later exercises.

You finished today's session. Before you leave, please ask the researcher to check that you have the files in the correct folders.

Thank you!

APPENDIX I: TREATMENT FOR THE PAS GROUP

This instruction is for the CmapTools Exercise, which is the last task of the Week 1 session.

CmapTools Exercise

Group D

My study ID is _________

Please return this packet back to the researcher after you finish this exercise.

General Instruction:

1. Read this instruction thoroughly before you begin the task.
2. Use CmapTools to construct a concept map based on the paragraphs on page 2, which are the same as the paper-and-pencil exercise you have done. You can refer to your finished map in the paper-and-pencil exercise.
3. **Always label the nature of relationships between concepts.**
4. Always save your concept map file during the construction process.

Computer-based Concept Mapping Exercise

Instruction:

1. On **page 3**, there are lists of commonly used ***Relationship Phrases***, please study the lists and apply them in your concept map where it is appropriate.
2. In addition to labeling linking lines with relationship words or phrases, also use the annotation function (hint: right-click your mouse and select **Annotate…**) of CmapTools to state the relationships between concepts with full sentences. For example: North America is part of the American continent. Please put each annotation beside its corresponding link in the map.
3. Name your file as "nutrients_#". # is the study ID assigned to you and it is on page 1. For example, if your study ID is 007, then your file name should be nutrients_007.

Nutrients are classified as essential or nonessential. Nonessential nutrients are manufactured in the body and do not need to be obtained from food. Examples include cholesterol, a fatlike substance present in all animal cells. Essential nutrients must be obtained from food sources, because the body either does not produce them or produces them in amounts too small to maintain growth and health. Essential nutrients include water, carbohydrates, proteins, fats, vitamins, and minerals.

An individual needs varying amounts of each essential nutrient, depending upon such factors as gender and age. Specific health conditions, such as pregnancy, breast-feeding, illness, or drug use, make unusual demands on the body and increase its need for nutrients. Dietary guidelines, which take many of these factors into account, provide general guidance in meeting daily nutritional needs.

Worthington-Roberts, Bonnie. "Human Nutrition." *Microsoft® Student* 2006 [DVD]. Redmond, WA: Microsoft Corporation, 2005.

-- STOP HERE --

After you finished this exercise,
please see the back of the last page for more instruction.

Thank you!

Relationship Phrases

Symmetric Relation Phrases

is opposite of	is same as	has sibling
is independent of	has synonym	is equal to
is near to	is equal to	is similar to
is opposed to		

Asymmetric Relation Phrases

Inclusion Relations

has part/ is part of	includes/is included in	is composed of
contains/is contained in	has example/is example of	has instance/is instance of
has member/is member of		

Characteristic Relations

has characteristic /is characteristic of		has attribute/is attribute of
has property/is property of	has type/is type of	has kind/is kind of
defines/is defined by	describes/is described by	models/is modeled by
denotes/is denoted by	implies/is implied by	has advantage/is advantage of
has disadvantage/is disadvantage of		has function/is function of
has size/is size of	is above/is below	is higher than/is lower than
has precursor/is precursor of	has state/is state of	is near

Action Relations

causes/is caused by	uses/is used by	solves/is solution for
exploits/is exploited by	decrease/is decreased by	increases/is increased by
destroys/is destroyed by	impedes/is impeded by	influences/is influenced by
determines/is determined by	enables/is enabled by	absorbs/is absorbed by
acts on/is acted on by	consumes/is consumed by	converted from/converted to
designs/is designed by	employs/is employed by	evolves into/is evolved from
generates/is generated by	modifies/is modified by	originates from/is origin of
provides/is provided by	requires/is required by	provides/is provided by
sends to/receive from	inserts on	attach to/is attachment for
flexes/is flexed by	extends/is extended by	adducts/is adducted by
elevates/is elevated by	dilates/is dilated by	stabilizes/is stabilized by

Process Relations

has input/is input to	has output/is output of	occurs at site/is site of
has result/results from	has subprocess	has process/is process in
proposes/is proposed by	depends on/has dependent	concludes/is concluded by
empties into	receives from	gives arterial blood to
gets arterial blood from	precedes/follows	has step/is step on
has stage/is stage in		

Now, you have finished the task. Please take a look at the concept map constructed by the researcher at this URL:

https://filebox.vt.edu/users/dhu/Cms/tutorials/cmtref.htm

You do not need to make any change of your concept map. Just compare the two maps and see where you did well and where you can improve in later exercises.

You finished today's session. Before you leave, please ask the researcher to check that you have the files in the correct folders.

Thank you!

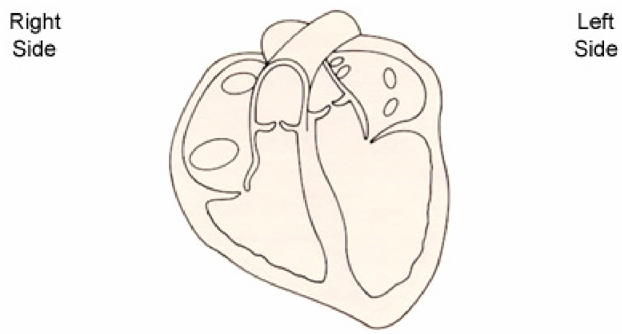
APPENDIX J: SAMPLE SCREEN FROM INSTRUCTION ON THE HEART

Concept Mapping Study

The Human Heart

1 of 8

Intorduction



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, as shown in the above diagram. Likewise, the left side of the person's heart would be illustrated on the right side in the above diagram.

The human heart is a hollow, bluntly conical, muscular organ. Its pumping action provides the force that circulates the blood through the body.

Go Back Continue

APPENDIX K: INSTRUCTION FOR THE CONCEPT MAPPING POSTTEST

Concept Mapping Study | Week 2 Session

Read this instruction thoroughly before you begin this session.

Concept Mapping on the Heart

My study ID is _________

Today's Date ___________(mm/dd/yy)

General Instruction:

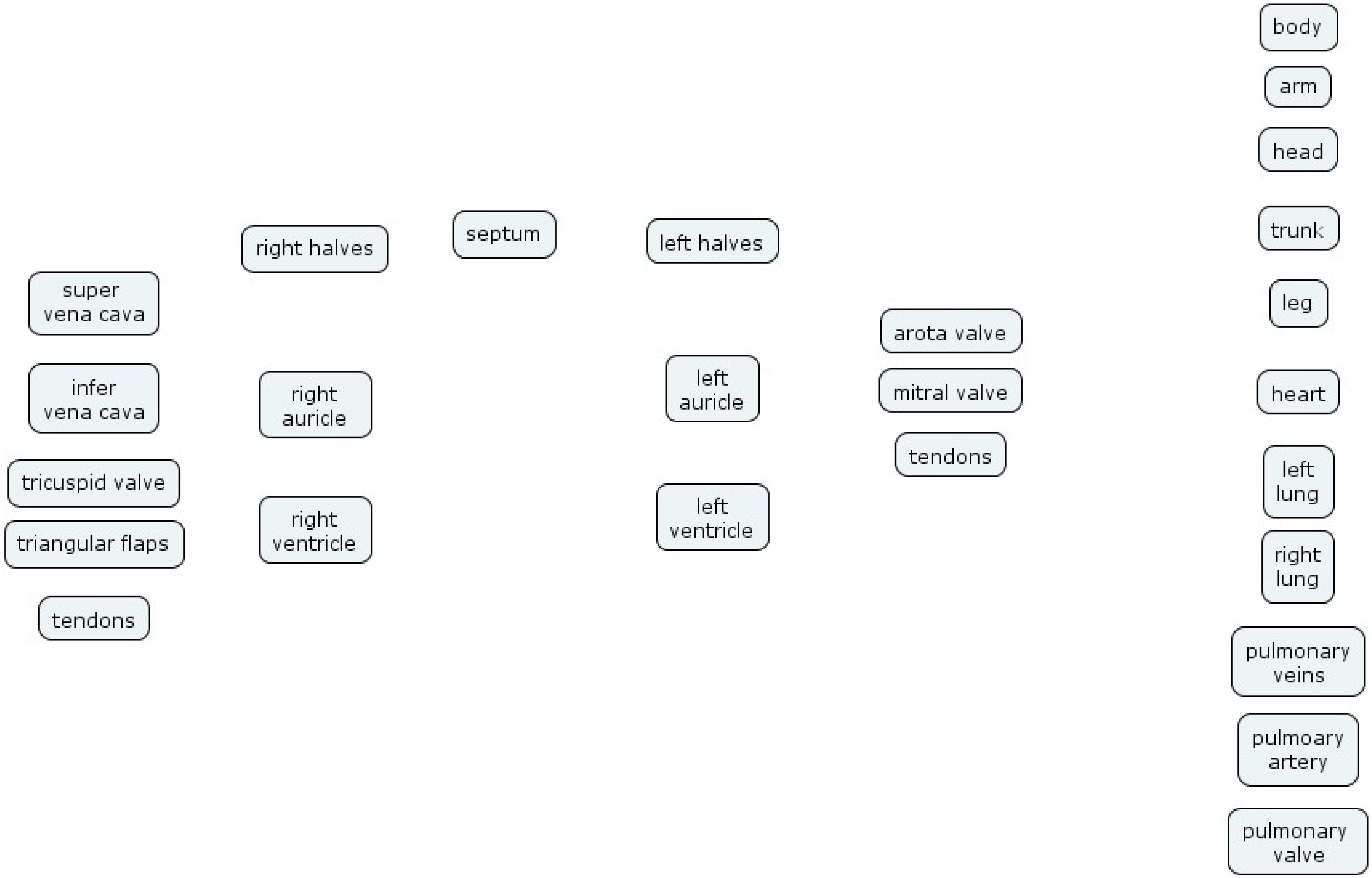
1. Read the web-based instructional tutorial on the heart and then build a concept map based on the contents. Some major concepts are provided to you in the Cmap file named "heart", which you can locate by opening the CmapTools software and look under the **My Cmaps** folder. If you have trouble finding this file, please let the researcher know.
   In the middle of the map, a basic anatomy structure of the heart is given with corresponding parts (concepts) listed on the left and right sides. On **the very right of the map** is a list of concepts that you may need in your concept map. Feel free to use or discard the given structure and/or concepts. You can also add additional concepts as needed.
2. Use CmapTools to finish this task. If you need to review the concept mapping tutorial and CmapTools tutorial that you learned last week, you can locate a link to the Table of Contents of these two tutorials at the first page of today's tutorial.
3. **Always label the nature of relationships between concepts.**
4. Always save your concept map file during the construction process.
5. Rename your file as "heart_#". # is the study ID assigned to you. For example, if your study ID is 007, then your file name should be heart_007. If you can't remember your study ID, please let the researcher know.

Before you leave, please ask the researcher to check that you have the file with right name in the correct folder.

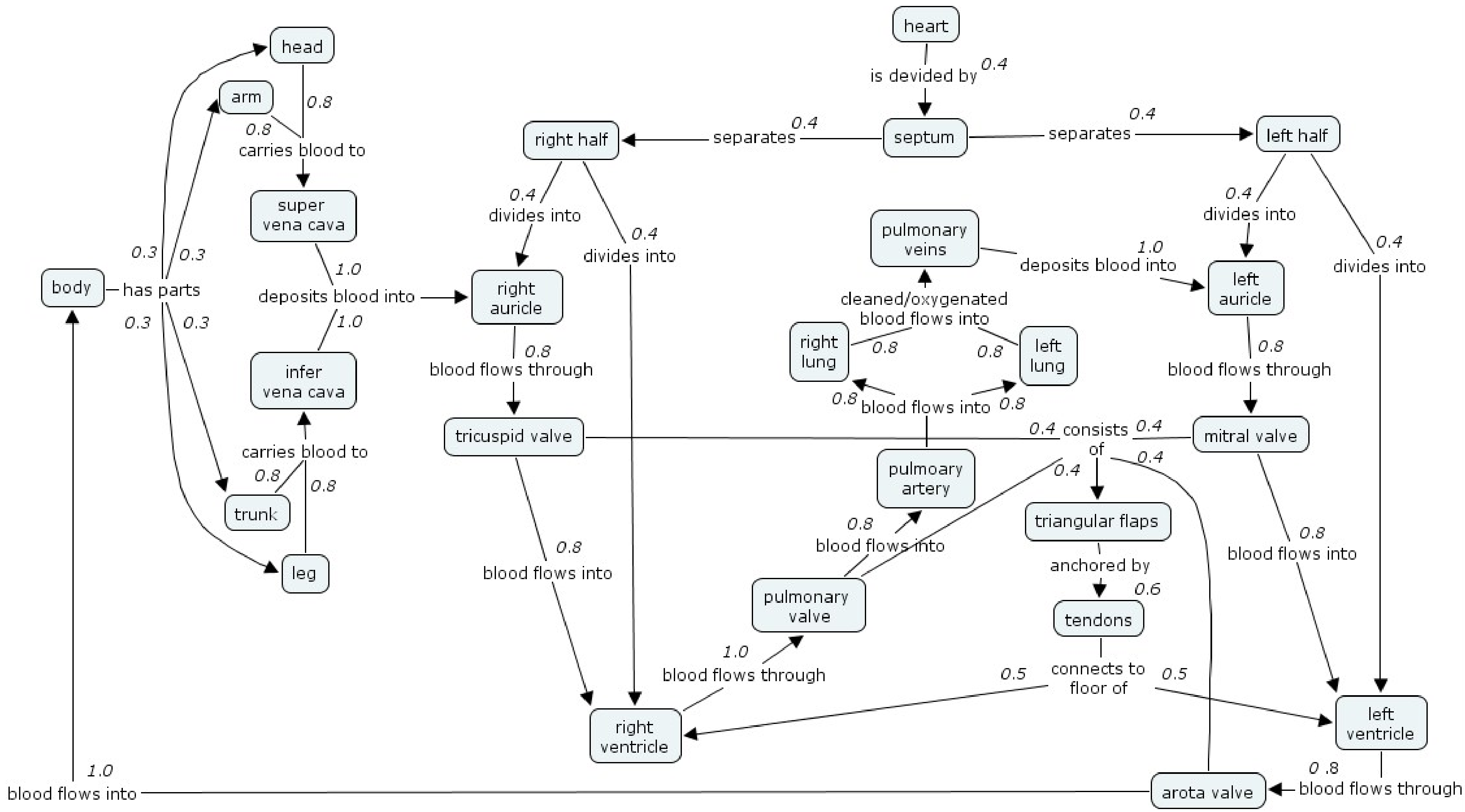
Thank you!

Please return this page back to the researcher before you leave.
See you next week!

APPENDIX L: HEART.CMAP



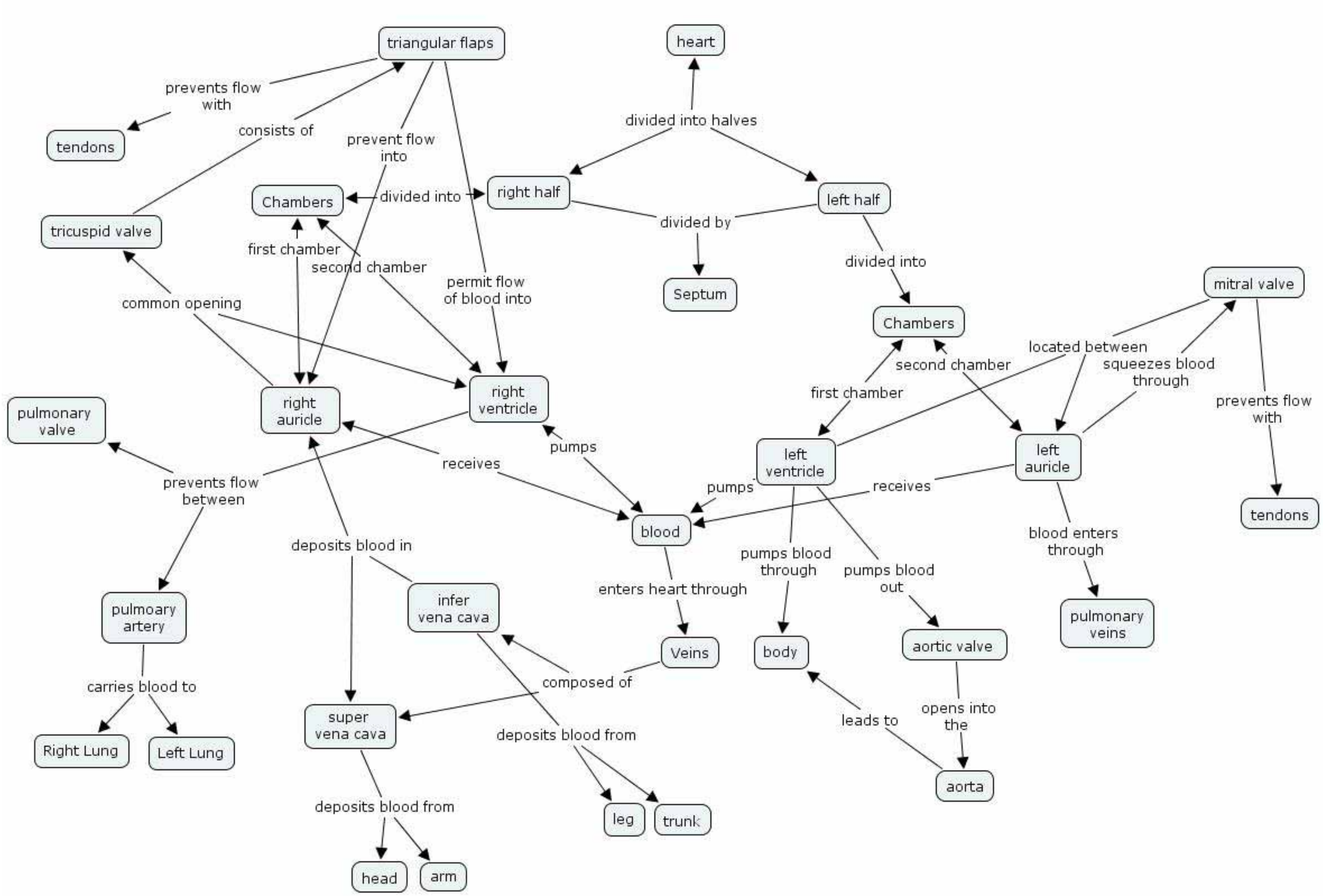
APPENDIX M: THE REFERENT MAP



APPENDIX N: THE SCORING MATRIX

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	
1	J001	body	arm	head	trunk	leg	heart	left lung	right lung	pulmonary veins	pulmonary artery	pulmonary valves	septum	right halves	right auricle	right ventricle	super vena cava	infer ve
2	body																	
3	arm																	
4	head																	
5	trunk																	
6	leg																	
7	heart																	
8	left lung																	
9	right lung																	
10	pulmonary veins																	
11	pulmonary artery																	
12	pulmonary valve																	
13	septum																	
14	right halves																	
15	right auricle																	
16	right ventricle																	
17	super vena cava																	
18	infer vena cava																	
19	tricuspid valve																	
20	triangular flaps																	
21	tendon																	
22	left halves																	
23	left auricle																	
24	left ventricle																	
25	aorta valve																	
26	mitral valve																	
27	tendon																	
28	subtotal	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	

APPENDIX O: AN EXAMPLE CONCEPT MAP BUILT BY A PARTICIPANT



APPENDIX P: FEEDBACK FORM FOR THE PILOT STUDIES

Evaluation for Concept Mapping Study

Thanks for participating! Your feedback is greatly appreciated!

Please select the answers apply to you:

	Disagree	Tend to Disagree	Tend to Agree	Agree
1. The procedure is clear				
2. The instruction is not clear				
3. The concept mapping tutorial provides enough information				
4. The CmapTools tutorial does not teach me the functions I need to build a concept map				
5. CmapTools is too difficult to learn.				
6. Building a concept map is too difficult for me.				
7. Providing the concepts helped me build the heart map.				
8. Providing the basic structure impeded me from building the heart map.				

Additional comments:

APPENDIX Q: THE POST-TREATMENT COMPREHENSION TEST

Post-treatment Test and Survey

Thank you for participating in the study. This is the last task you need to finish for this study. It will take you about 30 minutes to finish this survey.

My study ID is:

Part I: Comprehension/Recall Test

In the following multiple-choice questions, select the answer which you feel best answers the question. Select the radio button before it. Please remember to click on the "Submit" button to submit your answers.

1. 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

2. The __________ is (are) the strongest section(s) of the heart.

- a. left ventricle
- b. aorta
- c. septum
- d. right ventricle
- e. tendons

3. When blood returns to the heart from the body, it enters the __________.

- a. right auricle
- b. pulmonary valve
- c. left ventricle
- d. right ventricle
- e. pulmonary artery

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

- a. veins
- b. arteries
- c. vena cava
- d. tendons
- e. valves

5. Blood passes from the left ventricle out the aortic valve to the __________.

- a. lungs
- b. body
- c. aorta
- d. pulmonary artery
- e. left auricle

6. 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

7. 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

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

- a. septum
- b. valves
- c. arteries
- d. veins
- e. tendons

9. The __________ is the common opening between the right auricle and the right ventricle.

- a. mitral valve
- b. tricuspid valve
- c. semi-lunar valve
- d. pulmonary valve
- e. aortic valve

10. The __________ is a 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

11. 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 valve
- e. ventricles

12. 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

13. Which valve is most like the tricuspid in function?

- a. Pulmonary
- b. Aortic
- c. Mitral
- d. Superior Vena Cava

14. When blood is being forced out the right ventricle, in which position is the tricuspid valve?

- a. Partially open
- b. Partially closed
- c. Open
- d. Closed

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

- a. pulmonary veins
- b. pulmonary artery
- c. superior vena cava
- d. cardiac artery

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

- a. mitral valve
- b. pulmonary veins
- c. pulmonary artery
- d. aorta

17. 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

18. 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

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

- a. closed
- b. open
- c. partially closed
- d. confined by pressure from the right auricle

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

- a. superior and inferior vena cavas
- b. pulmonary veins
- c. tricuspid and mitral valves
- d. pulmonary and aortic valves

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

- a. vena cavas
- b. pulmonary veins
- c. pulmonary artery
- d. tricuspid and mitral valves

22. When the blood in the AORTA is exerting a superior pressure on the AORTA VALVE, what is the position of the MITRAL VALVE?

- a. closed
- b. open
- c. partially open
- d. closed by pressure from the right ventricle

23. When the TRICUSPID and MITRAL VALVES are forced shut, in what position is the PULMONARY VALVE?

- a. closed
- b. partially open
- c. open
- d. partially close

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

- a. entering only the vena cavas
- b. being forced out the pulmonary and aortic valves
- c. passing through the tricuspid and mitral valves
- d. being forced through the pulmonary artery