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Saleh Al-Foraih  
*University of Central Florida*



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THE EFFECT OF CURRICULUM ORGANIZATION ON THE ACQUISITION OF  
ABSTRACT DECLARATIVE KNOWLEDGE IN COMPUTER BASED  
INSTRUCTIONS

by

SALEH AL-FORAIH  
M.S. University of Central Florida, 2003  
B.S. King Saud University, 1994

A dissertation submitted in partial fulfillment of the requirements  
for the degree of Doctor of Philosophy  
in the Department of Industrial Engineering and Management Systems  
in the College of Engineering and Computer Science  
at the University of Central Florida  
Orlando, Florida

Spring Term  
2013

Major Professor: Kent Williams

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## **ABSTRACT**

The United States of America has dropped behind many countries in terms of the Science and Engineering university degrees awarded since the beginning of the nineties. Multiple studies have been conducted to determine the cause of this decline in degrees awarded, and try to reverse the trend in US education. The goal of these studies was to determine the proper instructional methods that facilitate the knowledge acquisition process for the student. It has been determined that not one method works for all types of curriculum, for example methods that have been found to work effectively in curriculum that teaches procedures and physical systems often fail in curriculum that teaches abstract and conceptual content. The purpose of this study is to design an instructional method that facilitates teaching of abstract knowledge, and to demonstrate its effectiveness through empirical research.

An experiment including 72 undergraduate students was conducted to determine the best method of acquiring abstract knowledge. All students were presented with the same abstract knowledge but presented in different types of organization. These organization types consisted of hierarchy referred as Bottom Up, Top Down, and Unorganized. Another factor that was also introduced is Graphing, which is a method that is believe to improve the learning process. The experiment was completed in 8 weeks and data was gathered and analyzed.

The results strongly suggest that abstract knowledge acquisition is greatly improved when the knowledge is presented in a Bottom Up hierarchical fashion. On the other hand, neither Graphing nor the Top Down or Unorganized conditions affect learning in these novice students.

This dissertation is dedicated to my parents who established my education career since the beginning of my first day of school. Their prayers and encouragements have an impact toward my life and education.

To my wife, Nada, your patience and understanding of my goal toward my education career was contributed to accomplish this dissertation.

## ACKNOWLEDGMENTS

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I would like to extend my appreciation to the students who participated in the experiment. The outcome of this dissertation would not be reached without their participation.

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## **CHAPTER 1: INTRODUCTION**

The United States of America has dropped behind Europe and Asia in terms of the Science and Engineering (S&E) university degrees awarded since the beginning of the nineties (National Science Board and National Science Foundation, 2002). Even in higher education programs, Europe has produced far more S&E doctoral degrees (54,000) than the United States (26,000) (NSB and NSF, 2002). Multiple studies have been conducted to determine the cause of this decline in degrees awarded, and try to reverse the trend in US education. At the University of Central Florida, an emphasis on reformulating the Industrial Engineering undergraduate education has previously taken place. The goal is to determine the proper instructional methods that facilitate the knowledge acquisition process for the student. It has been determined that not one method works for all types of curriculum, for example methods that have been found to work effectively in curriculum that teaches procedures and physical systems often fail in curriculum that teaches abstract and conceptual content.

There is clearly a gap when it comes to teaching conceptual and abstract knowledge as will be established in the following literature review. The goal of this research is to design an instructional method that facilitates teaching of abstract knowledge, and to demonstrate its effectiveness through empirical research. The hypothesis guiding the present research is that instructional strategies which stimulate students to generate graphical organization of complex concepts will improve learning of abstractions.

The following explicates findings regarding how knowledge is represented, what characteristic make up complex declarative knowledge, instructional strategies and their impact upon knowledge generation and the influence of knowledge organization strategies upon learning.

## **CHAPTER 2: BACKGROUND LITERATURE REVIEW**

### **Instructional Design**

Instructional Technology (IT) has been defined as the theory and practice of designing, developing, utilizing, managing, and evaluating processes and resources for learning (Seels and Richey, 1994). While every step of the above definition is important in the IT process, we will only emphasize the instructional design task in our research. Instructional Design (ID) is defined as the development of instructional content using learning and instructional theory in a systematic process. The main goal of Instructional Design is to enhance the quality of instruction (Alessi and Trollip, 1991). Reigeluth (1999) identified instructional design theory as “a theory that offers explicit guidance on how to better help people learn and develop.” Spector, Polson, & Muraida (1997) define instructional design as the structuring of the learning environment for the purpose of facilitating learning or improving learning effectiveness. Ely (1996) refers to the term instructional design as that used by professionals who work with direct applications of technology in teaching and learning.

In order to enhance the learning experience, instructional designers need to have an understanding of the human cognitive system. The next section will identify different theories about how knowledge is represented in memory.

## **Knowledge Representation**

The most agreed upon types of knowledge representation are declarative and procedural knowledge (Anderson & Lebiere, 1998). Declarative knowledge is factual information that a person knows and can report (Anderson & Schunn, 2000). Declarative knowledge represents the verbal rules, facts, or ideas within a domain of knowledge. On the other hand, procedural knowledge as (Jonassen, Beissner, & Yacci, 1993) described is “the interrelating of declarative knowledge into patterns that represent mental performance.”

### **Procedural Knowledge**

Procedural knowledge is represented by a large number of rule-like (IF-THEN format) units called production rules (Anderson & Lebiere, 1998), which make up the skills acquired through practice. Production rules are the basic units of knowledge for performing a skill, and therefore are more performance-oriented and adhere to specific rules (Anderson, 1983). When a production rule’s conditions are met (the IF part), an action is executed (the THEN part). Learning procedural knowledge depends primarily on the number of opportunities a learner has to use these production rules, therefore the more a student practices using production rules, the stronger the knowledge for these rules (Anderson & Lebiere 1998).

### **Declarative Knowledge**

Chunks are the main elements of declarative knowledge, which are small natural groupings of information. Declarative knowledge can be acquired through perception, instruction, or reading. As an example, “a fish lives in water and uses its fin to move around” can be stored as declarative knowledge.

Another form of declarative knowledge is Complex Declarative Knowledge, which is declarative knowledge that requires processes that are more complicated than the associative processes needed to memorize pairs of words (Chi and Ohlson, 2005). History of the Panama Canal and the structure of the solar system are examples of such complex declarative knowledge.

### **Complex Declarative Knowledge**

Research regarding how one learns complex declarative knowledge is still in its infancy. What is known about complex declarative knowledge has been reviewed by Chi and Ohlson (2005) who have described the basic characteristics of complex declarative knowledge, which are detailed in the following.

#### **Characteristics**

##### ***Size***

One of the main characteristics of complex declarative knowledge is the capacity of the human knowledge base, for which research has been conducted to determine its size. The average college-educated adult knows between 40,000 to 60,000 words while the total words in the English language is larger than 100,000 (Miller, 1996). Other research conducted by Landauer (1986) resulted in estimating how much information a person can remember from a lifetime of learning. It has been estimated that a person will accumulate one million pieces of knowledge by the age of 70 (Landauer, 1986)(Chi and Ohlson, 2005).



Domain specific knowledge has been determined to be in the vicinity of the mental lexicon, on average 50,000 pieces of information for a college educated adult. For example, the number of Chess piece configurations known by master players is estimated to be between 10,000 and 100,000.

During domain specific curriculum construction, it is beneficial to know the size of the knowledge base to be taught to the student. Assimilation of the content will be increased by not overloading the student's capacity. For example, an English language class cannot teach the full Lexicon (100,000 words and more) in one semester, therefore the teacher should size his/her curriculum content accordingly to allow students to learn more effectively.

### ***Organization***

The most important characteristic in our research is how the learner organizes knowledge in memory. Many Scientists have established at least three distinct representational constructs for knowledge organization: semantic networks, theories, and schemas (Chi and Ohlson 2005 and Markman, 1999).

Semantic networks consist of a set of nodes that represent concepts, which are connected by links that represent relations among the concepts (Rodriguez and Watkins 2010). Anderson (1983) also assumed that knowledge forms a semantic network with relational links connecting concepts. Semantic networks that have similar meanings can be grouped by domain. An example of a semantic network, as previously discussed, is the fish example "a fish lives in water and uses its fins to move around". In this example, the concept "fish" would exist as a node and would be linked to attributes such as "lives in water" and "has fins." The concept could then be linked to other concepts, such as "water

creatures,” which would be linked to an additional set of attributes. It is the interconnections between the nodes that give concepts meaning (Jonassen et al., 1993).

Theories on the other hand are “deep” representations in the sense of having a well-articulated center-periphery architecture. This implies that some knowledge elements are more important than others and are organized around a small set of core concepts, the center core concepts consist of the fundamental and abstract while the rest of the elements in that domain are derived and dependent upon the core concepts. For example, the United State constitution would be considered a core concept, while law texts are derived from it and dependent upon it. The constitution is considered the source of the law. Theories may not be an appropriate representation for every domain.

The schema is the third representational type. It represents elements of information depending on how they will later be used (Chi, Glaser, and Rees, 1982). For example, children construct schemas for letters that allow them to classify an infinite variety of shapes, to accommodate different types of hand writing, into a very limited number of categories. Schemas can be thought of as a tool for organizing information, and will be discussed in more detail in the next sections.

Of course knowledge is not represented as only one of these types of organizational structures, but may be organized on multiple levels. Therefore the learning process will impact any pre-existing organization that relates to the knowledge domain to be acquired.

### **Change during Learning**

The question of what happens during the learning process is very essential for this research, as change has to occur to assimilate new knowledge. There are seven

dimensions of change during the learning process as compiled by Chi and Ohlson (2005) that are described hereafter.

### ***Larger size***

During the learning phase, knowledge is acquired, and the size of the knowledge base grows. The size of the relevant declarative knowledge base increases by inferring new facts from prior knowledge, or by integrating new facts with old knowledge and making new inferences from the combination; it is referred to as accretion. It is also the type of cumulative addition of pieces of knowledge as defined by Rumelhart and Norman (1978).

### ***Denser Connectedness***

The more knowledge acquired, the denser the knowledge base becomes. As new pieces of knowledge are added to the knowledge base, more connections are formed, and stronger ties are created. This is apparent when a novice moves through the learning process when acquiring experience to become an expert (Stokes, Kemper and Kite, 1997). Figure 1 and Figure 2 represent a child's knowledge of 20 familiar dinosaurs with his representation of 20 less familiar dinosaurs (Chi & Koeske, 1983, Figures 16.1 and 16.2). One can see that the first figure shows more connections when compared to the second figure, representing denser connectedness for more knowledge.

### ***Increased Consistency***

Consistency is the degree in which multiple assertions embedded in an intuitive theory can be true at the same time. For example, a person who claims that the Earth is round but refuses to sail on the ocean for fear of falling over the edge is inconsistent in

this sense. Thagard (1989, 2000) defined consistency as the lack of contradictions between assertions and hypotheses. Inconsistency triggers cognitive processes that aim to restore consistency.

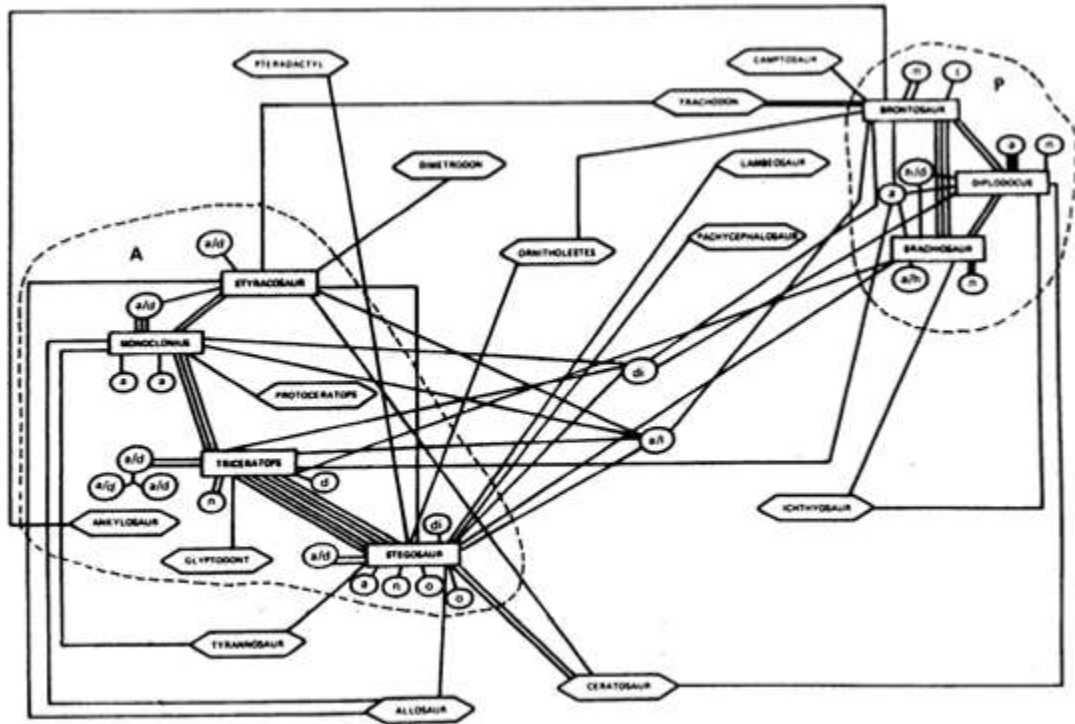


Figure 1 a child's knowledge of 20 familiar dinosaurs (Chi & Koeske, 1983)

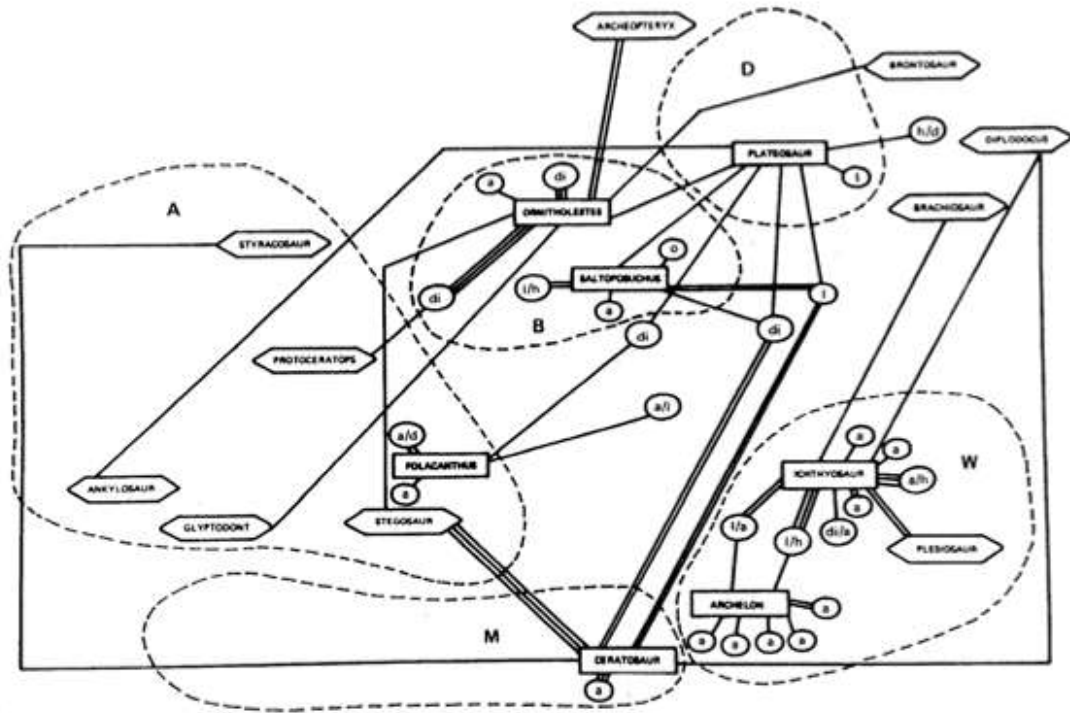


Figure 2 a child's knowledge of 20 less familiar dinosaurs (Chi & Koeske, 1983)

### ***Finer Grain of Representation***

The declarative knowledge base can be expanded via finer levels of detail, referred to as finer grain. As one learns more about something, he/she will understand it at a finer grain, which expands the knowledge base by forcing the movement in one direction rather than another. For example, people appear content to understand the weather at the level of wind, temperature, clouds, humidity, rain, and snow, without re-representing them at a finer level available to the professional meteorologist (Wilson & Keil, 2000).

### ***Greater Complexity***

Another type of changing knowledge structure is needed when the current representation is not sufficient to assimilate the new available knowledge. For example, when a schema is no longer sufficient, the learner, in this case, can respond by creating a more complex schema (Halford, 2005). The change process does not refine the grain of representation, but instead, it creates a more dense knowledge representation.

### ***High Level Abstraction***

Re-representing at higher level of abstraction (using an already acquired abstraction) is another dimension of knowledge change. For example, Chi, Feltovich, and Glaser (1981) showed that experts represent their solutions in terms of the deep principles that would be needed to construct a solution, whereas novices tend to represent the same problem according to their concrete surface components. For example, physicists represent routine physics problems in terms of the deep principles of the law of physics that would be needed to construct a solution. Whereas physics novices (those who have taken one course in college with an A grade) tended to represent the same problems according to their concrete surface components, such as pulleys and inclined planes. The point is that the same problems tend to be represented at different levels of abstraction by two groups that both know the relevant principles.

### ***Shifted vantage point***

Shifting one's point of view can facilitate the learning process. The ability to change point of view grows with the knowledge the student acquires. Studies have confirmed that as children grow and mature, they acquire more knowledge that enables

them to shift perspective (Piaget and Inhelder, 1956). For example, 2-year-old's cannot adjust their speech to the age of the listener, while 8-year-old's can adjust their speech whether they are talking to an adult or another child of their age. In this example, 8-year-old children are capable of shifting their perspective to that of the listeners.

### **Levels of Learning**

There are mainly two common types of learning: surface-level learning, that is, shallow or reproductive, and deep-level learning, that is, meaningful understanding (Marton, Hounsell, & Entwistle, 1984; Entwistle & Entwistle, 1992; Ausubel, 2000). In surface-level learning, students memorize discrete facts (declarative knowledge) without concentrating on understanding the relationships between the facts. On the other hand, in deep-level learning, students focus on properly connecting and organizing knowledge. Mayer (1984, 1987, 1996, 1999) described that the processes of selection, organizing, and integrating are three cognitive processes that are thought to aid in the construction of meaningful knowledge structures.

In the selection process the student focuses attention on pertinent information and brings it to working memory for further manipulation. Organizing is a very important process because it creates internal connections between selected information, and builds information that is coherent and complete. Integrating is the final process that connects newly acquired information to related organized knowledge which already exists in long-term memory. Learning strategies are mechanisms that offer different ways to help learners to organize and integrate new knowledge.

## Learning Strategies

Much research has concluded that proper and effective use of learning strategies can enhance the performance of a student (e.g. Rosenshine, Meister, and Chapman, 1996; Pressley & McCormick, 1995; Zimmerman & Schunk, 2001; Schunk & Zimmerman, 1994). Mayer (1984, 1987, 1996, 1999) asserted that the learning strategies that an instructor or a tutor uses directly affect the effectiveness of the learning experience. Mayer (1996) also suggested that students can use learning strategies to increase the effectiveness of their cognitive processing. Weinstein and Mayer (1986) suggested a set of cognitive strategies that students use to encode, store, organize, and retrieve knowledge. These strategies are classified into three general classes: rehearsal, organization, and elaboration. It is believed that a deeper level of understanding could be achieved by employing elaboration and organizational strategies rather than the rehearsal strategies (Marton et al. 1984).

In the rehearsal strategy, the students can perform any combination of the following processes: repeat material, take selective verbatim notes, underline important material, copy material, and recite material. Marton et al. (1984), Weinstein & Mayer (1986) found that the rehearsal strategy was not effective when students are asked to remember facts and conceptual information, as they scored less on a passage-related, creative problem solving task, than a control group who were asked to use their regular learning strategies. It is believed that rehearsal strategies could be responsible for shallow types of learning as opposed to organization and elaboration strategies.



Organization strategies involve identifying important information, organizing the information in a meaningful way, and setting priorities pertaining to what information should be learned.

The main usage of organizational strategies is to retain information and connect it to previously acquired knowledge (Ausubel, 2000; Cook & Mayer, 1988). The elaboration strategy is the one mostly used as it assists students in building internal associations between new and old stored knowledge. The next section will discuss in detail the elaboration theory.

## **Elaboration Theory**

### **Overview of the Elaboration Theory of Instruction**

The Elaboration Theory attempts to integrate instructional design research findings into a comprehensive set of macro-level methods to be used to improve the way instruction is designed. The theory is primarily concerned with how the ideas are sequenced as opposed to the content of the individual ideas themselves and the examples relating to those ideas (Reigeluth & Stein, 1983; Reigeluth, 1997; Reigeluth, C.M, Merrill, M.D., Wilson, B.G., & Spiller, R.T., 1980). Specifically, sequencing in this case relates to ideas that are fundamental and representational or core principles, which are presented first, that then lead to specifics. In elaboration theory these ideas are called epitomes, and serve as a foundation from which more specific information may be developed. Figure 3 presents an epitome for an introductory course in economics (Reigeluth, 1983).

1. Organizing content

The law of supply and demand

- An increase in price causes an increase in the quantity supplied and a decrease in the quantity demanded.
- A decrease in price causes a decrease in the quantity supplied and an increase in the quantity demanded.

2. Supporting content

The concepts of

- Price
- Quantity supplied
- Quantity demanded
- Increase
- Decrease

Practically all principles of economics can be viewed as elaboration on the law of supply and demand, including those that relate to a monopoly, regulation, price fixing, and planned economics.

Figure 3 Content for an Epitome for a Course in Economics (Reigeluth, 1983)

Reigeluth & Stein (1983) described the elaboration theory by an analogy to a zoom lens, where, the subject is general and fundamental at the beginning. As we zoom in with the lens however, we start to develop details and can pick up specifics about our subject matter. We can also observe the relationships between our wide-angle subject and those details. This principle is called a "cognitive zoom" when applied to elaboration theory. As in the zoom analogy, before one can zoom though, one must first deal with the broader, core aspects of the subject. Elaboration begins with an overview of the simplest and most fundamental ideas of the domain. It is important to note that certain

prerequisites exist for this overview and if the students do not have these prerequisites, then the teacher must provide it.

Elaborative strategies present an excellent opportunity for learners to construct their knowledge about the subject. Having students construct their own representation of knowledge has been shown to have a positive and enduring effect on learning (Chi, M. T., Siler, S. A., Jeong, H., Yamauchi, T., & Hausmann, R. G., 2001; Chi, M. T. H., De Leeuw, N., Chiu, M., & Lavancher, C., 1994; Wong, R. M., Lawson, M. J., & Keeves, J., 2002; King, 1992a). The constructing or generating effect of knowledge is discussed in the next section.

### **Constructing and Generating Knowledge**

Students who relate to the material provided to them by building their own understanding relative to what they already know has been shown to have a significant impact upon learning (Jonassen, 1999). By participating in problem-solving and critical thinking activities that the students find relevant, they are in the process of constructing new knowledge (Mayer, 1999). They are "constructing" their own knowledge by testing ideas and approaches based on their prior knowledge and experience, applying these to a new situation, and integrating the new knowledge gained with pre-existing intellectual constructs (Bruner, 1973). Students can also integrate their approaches with other individuals, other sources of information, or current experience to construct a new level of understanding. Learning is then assessed through performance-based projects rather than through traditional paper and pencil testing. The teacher is thought of as a facilitator

or coach in the constructivist learning approach, as he/she guides the student, stimulating and provoking their critical thinking throughout the learning process (Mayer, 1996).

Jean Piaget, Seymour Papert, Jerome Bruner, Lev Vygotsky, John Dewey, and many more have contributed to the body of knowledge in the field of the theory of constructivism. Designing instruction for constructivist learning and designing constructivist learning environments, are subjects of interest to Mayer (1999) and Jonassen (1999).

Mayer's (1999, 1996) theory emphasizes the design of instruction according to human cognitive processing. By activating three cognitive processes (selecting, organizing, and integrating, SOI) in the learner's mind during interaction, the theory is intended to aid student retention as well as the transfer of knowledge.

The next sections discuss the three cognitive processes known as the SOI model that highlight selecting relevant information, organizing incoming information, and integrating incoming information with existing knowledge.

1. Selection of relevant information by
  - a. Providing a summary.
  - b. Highlighting key information using: headings, italics, boldface, font size, bullets, arrows, icons, underlining, margin notes, repetition, white space, and captions.
  - c. Using instructional objectives.
  - d. Being concise by trying to eliminate irrelevant information.
2. Organize information for the learner using:
  - a. Outlines.

- b. Headings.
  - c. Pointer or signal words.
  - d. Graphic representations.
  - e. Structure text for:
    - i. Comparison.
    - ii. Classification structure.
    - iii. Enumeration or parts structure.
    - iv. Cause/effect structure.
3. Integrate information by applying:
- a. Advance organizers.
  - b. Animation with narration.
  - c. Worked-out examples.
  - d. Elaborative questions.
  - e. Illustrations with captions.

The intent of the theory is to enhance the construction of knowledge while directing the learning process using appropriate prescriptions. This theory is more effective when used in textbooks, lectures, and multimedia environments.

On the other hand Jonassen (1999) presented a theory that uses constructive-learning environments to enhance problem solving and conceptual development. The theory is suitable for learning involving ill-defined or ill-structured problems (those are problems that have not an immediate solution path), where instructions are given as experiences on the problem of interest to the learner. The theory is illustrated in systematic points as follows:

1. Select an appropriate problem, or challenge, for the learner to focus on.

The problem should be:

- a. Interesting, relevant, and engaging, to foster learner ownership.
  - b. Ill-defined or ill-structured.
  - c. Authentic and representative of what learners do.
  - d. Its design should address its context, representation, and manipulation space.
2. Present related cases or worked examples to engage case-based reasoning and enhance cognitive flexibility.
  3. Provide learner-selectable information just-in-time. Also, information relevant to the problem should be easily available and accessible.
  4. Provide cognitive tools that support required skills including:
    - a. Problem representation tools.
    - b. Knowledge modeling tools.
    - c. Performance support tools, and
    - d. Information gathering tools.
  5. Provide conversation and collaboration tools to support discourse communities, knowledge building communities, and/or communities of learners.
  6. Provide social and contextual support for the learning environment.

Demonstrating the performance, coaching during the course of learning, and regulating task difficulties, are additional instructional activities that are provided by the

theory to enhance the learning experience. Overall, the theory presents a framework that integrates many aspects of constructivist learning that can interact and work together.

From the early work of Wittrock (1974), many researchers contributed to what we know today about “construction” or the “generation” of knowledge. The current direction of constructivism is focused on allowing the student to be active and self directed in the learning process (Chi et al., 2001). Laboratory and natural settings have proven that students will remember materials they generated themselves better than materials generated by others (Foos, Mora, & Tkacz, 1994). The generative strategies are more effective if the learner has prior knowledge of the subject matter, as can be explained in terms of schema theory. Schema theory was previously introduced but it will be presented in the next section in the context of the effectiveness of generative strategies.

### **Schema Theory**

A schema is the organization of the student’s knowledge of the world, and it provides him the basis for comprehending, learning, and remembering ideas (Anderson, 1996). Rumelhart (1980) stated that, Schemata are used in interpreting sensory data, retrieving information from memory, organizing actions, determining goals and sub-goals, allocating resources, and guiding the flow of processing in the system. As a result schema theory advocates that a student, with a well-developed schema for a subject, is more likely to benefit from prior knowledge by drawing the elaboration from their own schema (Anderson, 1996). Wong (1985) stated that in order to take full advantage of stored schema knowledge, it is necessary to teach students prior-knowledge-activating mechanisms. Self questioning and forming analogies are mechanisms that can be used to

activate prior knowledge on the student's behalf. According to schema theory, remembering newly learned content in the future is directly related to how effective the student was in relating the new information to prior knowledge.

### **Elaboration Strategies**

The elaboration strategy as introduced earlier helps the student make the new material more meaningful through the expansion of the presented information, by activation of stored information, and integration of the new and old information. There are several strategies that make up the elaboration strategy set, which include generative summarizing, revising, forming analogies, questioning, advance organizers, hypothesizing, justifying, criticizing, reflecting, and predicting (Reigeluth, 1983; Royer & Cable, 1975; King, 1992a; Scardamalia & Bereiter, 1983; Rosenshine et al., 1996; Chi et al., 2001).

Empirical studies have shown that elaboration strategies enhance the outcomes of learning (Pressley, Symons, McDaniel, & Snyder, 1988; Woloshyn, Willoughby, Wood, & Pressley, 1990). Test groups were given the designated elaboration method, and its outcome was compared to a control group using written tests, or multiple choice test performance evaluation methods. The following section is a detailed discussion on the elaboration strategies.

#### ***Generative Summarizing***

Summary writing is a one to two phrase synopsis of text in the student's own words that is written after reading text material (Brand-Gruwel, Aarnoutse, & Van Den Bos, 1998). The activity that takes place when the student is writing-down representative



ideas of their learning experience while trying to reflect on what he/she has already learned, is called generative summarizing. King (1992a) defined a summary as “capture the gist of the piece as well as reduce the material substantially”. There is a fundamental difference between the above definition and the conventional one, where students simply manipulate and delete text to produce a summary (e.g. Ross & Divesta, 1976; Brown & Day, 1983; Reinhart, Stahl, & Erickson, 1986).

Summarizing is considered a knowledge generative process, according to Wittrock & Alesandrini (1990), because the students use their own words and prior knowledge to create the content of the summary text in sentence form. These newly student-created sentences are the essence of the connections between new knowledge and existing knowledge stored in memory. Since the students use their own words, which are associated with previously stored material, it allows them to construct knowledge by activating connections between new and existing knowledge (Wittrock, 1990).

Jacoby (1978) provided another form of generative summarizing by asking students to complete sentences or generate their own sentences using provided keywords, which direct their attention to important segments of the text.

Wittrock & Alesandrini (1990) have shown that summary writing improved learning. They conducted a study where subjects were assigned to one of three groups: summary, analogy, and a control group. While the control group was asked to simply reread each paragraph to control for time, the summary group was asked to read and review a paragraph of text and then write a summary of each paragraph in the space provided in the answer booklet. The students were directed to use their own words in writing the summary, and not to use any terminology from the paragraph, nor to copy

sentences directly from the passage. The analogy group was instructed to write an analogy that relates to their prior knowledge or experience with the content of the text in the form of two sentences. The study found that while both the summary and analogy group scored higher than the control group on a comprehension test, no difference was found between them.

In the Hooper, Sales, & Rysavy's (1994) study, that replicated and extended Wittrock & Alesandrini's experiment, they found that both the summary and analogy group scored higher than the control group. On the other hand, the summary group scored higher than the analogy group in a posttest achievement exam, with an advantage to students working alone as opposed to students working in pairs.

These findings agree with King's (1992b) previous research that compared self-questioning, summarizing, and note-taking review in learning from lectures. Students in the self-questioning and summarizing group were found to recall better than the group of students that only reviewed their notes. The summarizing group out-performed the self-questioning group on an immediate recall test, although they were comparable on a retention test one week later.

Davis and Hult's (1997) study on 79 college students found that the summary group performed better than a control group on an immediate recall test as well as on a retention test 12 days later.

In another study by Radmacher and Latosi-Sawin (1995) compared exam scores of a college class that used summarizing techniques with another class that did not. It was found that the summarizing class scored higher than the control class.

### ***Revising***

Revising is another form of generative process in which one can connect new knowledge with existing knowledge. This is achieved by mapping the words, symbols, and concepts among different subjects, and making new connections between old and new knowledge (Kiewara, 1989). For example, students were asked in a classroom setting to go back to their notes and revise the information content in those notes.

Kiewara (1989) showed that taking notes and revising them will improve learning, but it is not as effective as summarizing or self-questioning. Another study from King (1992b) compared self-questioning, summarizing, and note-taking review and found that students in self-questioning and summarizing groups have better retention of lecture content than students who reviewed their notes. Furthermore, in comparing the summary group and the self-questioning group, King found that the self-questioning performed less well than the summarizing group in instant recall, but they were compatible on a recall test one week later.

### ***Forming Analogies***

The similarity between two things not otherwise alike is called analogy, much like a bird and a plane. It is also called a metaphor or a similarity-based reminding (Eberts, 1994). The difficult part in analogies is to figure out similarities in certain characteristics, relations, and properties between dissimilar things. Analogies are often used to understand information in a novel domain (the target) from a familiar domain (the base). Many researchers define reasoning by analogy as the identification of similarities between disparate domains and the transfer of additional information from the familiar base domain to the novel target domain (Gentner, 1983, 1989; Holyoak & Thagard,

1989). Duit (1991) argued that analogy makes possible the deduction of properties on the basis of reasoning which is made understandable by reflection of the analogue. Eberts (1994) provided the example of the instructor choosing a concrete situation the student is familiar with, and presenting the target information in terms of how it relates to the old familiar information.

Surface and structural reminding are two forms of similarity-based analogies that were identified by Forbus, Gentner, and Law (1994). For example, the analogy between a bicycle and a pair of eyeglasses is based on “dumb” superficial commonalities, and it is called surface similarity, as it does not expose any common “real” properties between the base and the target. On the other hand, when a much deeper similarity is presented, it is called structural reminding. The analogy between an atom and the solar system is a good example of a structural analogy. The atom acts as a miniature solar system because electrons revolve around a nucleus the same way planets orbit the sun.

Forbus et al. (1994) argued that for analogy creation, students should initially access base information in long-term memory, then create a mapping from the base to the new target information, then evaluate the mapping. The above argument resulted in a three stage process to describe analogical learning: access, mapping, and inference (Falkenhainer, Forbus, & Gentner, 1989). Access, which can occur spontaneously or via a prompt from an outside source, takes place when the base is retrieved from long-term memory. The mapping then begins by recognizing structural and surface similarities between the base and target, and aligning the commonalities in the domains (Gentner & Markman, 1997). Alignment and mapping pave the way for the generation of inferences relating to the target. The core of the reasoning process behind the analogy is outlined in

the mapping and inference stages. Many researchers agree that the identification of an appropriate mapping is a critical prerequisite to useful knowledge transfer (Clement & Gentner, 1991; Gentner, 1989; Halford, 1992; Holyoak & Thagard, 1989). Gentner & Toupen (1986) provide an excellent example of structural mapping that outlines three rules for a successful mapping process to occur: (1) the attributes of the objects in the base are dropped, (2) relations between objects in the base tend to be mapped across, and (3) systematic higher order relations are also mapped and isolated relations are discarded. Figure 4 depicts an analogy between the solar system (base) and the hydrogen atom (target). This is assuming that the learner has sufficient prior knowledge about the solar system that the sun is at the center of the solar system and planets revolve around it. Based on Gentner & Toupen's research (1986), when learners look at the analogy for the first time they will:

- Establish the object similarities between the solar system (base) and hydrogen atom (target).
- Discard object attributes, such as the sun is yellow.
- Map base relations, such as “the sun is more massive than a planet;” to the target domain such as “the nucleus is more massive than the electron.”
- Discard isolated relations such as “the sun is hotter than the planets” and map systematic higher order relations such as “the sun is more massive than planets” and “the smaller object (planet) revolves around the sun.”

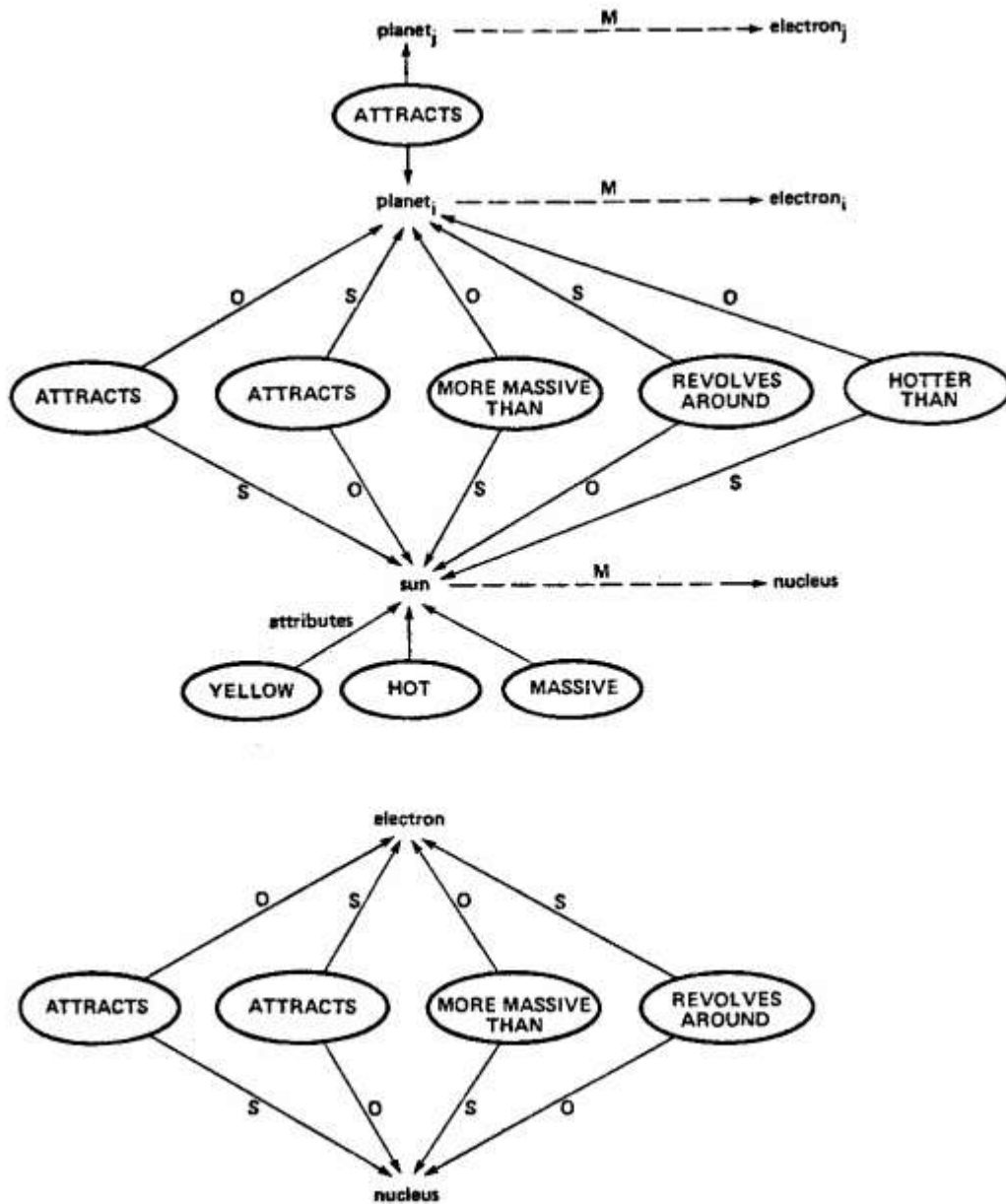


Figure 4 Analogy between the Solar System and Hydrogen Atom

Analogies have always played a key role in the historical development of scientific knowledge (Hesse, 1966). It has also been argued by many that analogy is an effective strategy for learning. Holyoak & Thagard (1995) argued that analogies facilitate

and improve creative discovery, while Nation & Hulme (1996) argued that it improves spelling skills. Solving statistical and mathematical problems were also found to be improved using analogy (Bernardo, 2001; Ross, 1987), (Novick & Holyoak, 1991). Anderson & Thompson, (1989), found that analogy has been shown to be an effective tool for teaching a conceptual understanding of technology such as computer programming. Conceptual knowledge helps people create a higher perspective that generalizes from the specific, and helps solve problems in similar or different situations.

### ***Questioning***

Graesser, Baggett, and Williams (1996) argued that one of the fundamental cognitive components that guide human reasoning is question-driven explanatory reasoning. An explaining strategy that relies on self-questioning, involves prompting students to pose and answer their own questions pertaining to the lesson's content to provoke thinking (King, 1992a). Students are encouraged to explain to themselves what is going on during the learning process by asking questions to help them understand the new text or material. Scardamalia & Bereiter (1984) called these questions "procedural prompts" that cue learners to perform specific ways of transforming what they are studying or writing. For example, there are many ways that students could use these questions as cues such as for the retrieval of related information, or for deep analysis of the new material, or to create connections between different parts of the material.

According to Pressley, M., McDaniel, M. A., Turnure, J. E., & Ahmed, M. (1987) and Wood, Pressley, & Winne (1990) self-generated elaborations, like elaborations produced by learners to answer their own questions, are more conducive to learning than elaborations provided by textbook, a teacher, or any other external source. King (1992a)

believed that students can remember self-made elaborations easier because they are more coherent with their own knowledge and prior experience (i.e. student's own stored organization of information). These elaborations are easier to process and recall since they are personalized and relate to prior meaningful knowledge. They can provide explicit encoding cues for recall because they create more links to what is already known.

Questioning strategies have been investigated extensively across a range of curriculum and across levels of education: in writing (e.g. Scardamalia, Bereiter, & Steinbach 1984), in mathematics (e.g. Schoenfeld, 1985), in science (e.g. Chi et. al., 1994; King, 1994), and in reading comprehension (e.g. Andre & Anderson, 1979). Rosenshine et al. (1996) reviewed the results of 26 studies where students were taught to generate questions and answers to improve comprehension. She found that the outcome of this type of training had a small-to-medium effect on comprehension performance when standardized tests were used as outcome measures.

King (1989, 1991) investigated the effect of what she called a "guided learner-generated questioning strategy" and compared it to three different study strategies: guided peer questioning, unguided small group discussions, and unguided independent review. Students were asked to work alone, and to generate their own question and answers in the guided learner-generated questioning strategy. They were asked to utilize a list of questions to serve as examples. Table 1 presents examples of the generic questions that were used by students in the study and their intended cognitive effect. On the other hand, the guided peer-questioning group employed the same list of questions used by the guided learner-generated questioning group but had to answer peer's questions instead of answering their own questions. Students in the unguided small group



discussions were instructed to talk about the material in a freestyle format, while students in the unguided independent review were simply instructed to review the material alone and try to make sense of it. The results indicated that students in both guided self-questioning and guided peer questioning significantly improved their lecture comprehension compared to the discussion condition and the independent review condition. The discussion group outperformed the independent review group. Furthermore, students in the guided peer questioning group outperformed students in the guided self-questioning group. King (1991) conducted another study on ninth grade high-school students using their regular class lectures this time. The results of this experiment confirmed her previous findings as the results were identical.

Table 1  
Generic questions for the self-questioning group

<b>Questions</b>	<b>Cognitive Effect</b>
Explain why...or Explain how...?	Analysis of processes and concepts
What is the main idea of...?	Discovering the central idea of the text
What makes you think this way?	Justifications of current state of the mind
How would you use...to...?	Integrating prior knowledge to new experiences
What is a new example of...?	Generating new ideas by building on prior experience
Does this make sense so far?	Continued linkage of ideas
What is the difference between... and...?	Compare and contrast concepts
What conclusions can you make about...?	Presenting the conclusion of text being read
How does... affect...?	Evaluating relationships between ideas
What are the strengths and weaknesses of...?	Deep analysis and integration of concepts within the text
What is the best... and why?	Using some criteria to evaluate concepts
How is... related to... that we studied earlier?	Prior knowledge activation and integration with new knowledge

### *Advance Organizers*

Stone (1983) defined an advanced organizer as a short set of verbal or visual information that is presented prior to learning a larger body of content. This term has already been used by Ausubel (1961) to describe the process of linking the upcoming new material with old material in the learner's knowledge base. He defined advance organizers as "appropriately relevant and inclusive introductory materials that are maximally clear and stable. . . introduced in advance of the learning material itself, used to facilitate establishing a meaningful learning set."

Peterson, Glover, & Ronning (1980) also defined advance organizers as conceptual "bridges" from the prior knowledge to the information to be learned. They are hints to the student as a frame of reference that provides hooks or anchors to knowledge previously acquired. They assist the student to remember and apply old information, and also may give the student background information. Compare/contrast structures, Venn diagrams, matrices, or just a written queue card, are examples of advance organizers (Royer & Cable, 1976). Taylor , I. & Taylor (1983) depict a teacher advance organizer as seen in Figure 5.

<p>Review Previous Learning "Okay, let's go over the steps that we discussed yesterday." "Where could you use this at school or at home?"</p> <p>Personalize "What do you think would happen if you used this in...?" "Tell me why you think this is going to help you."</p> <p>Define the Content "That's right, but what's a...?" "What are you going to be learning?"</p> <p>State Expectations "What do you think I am going to do?" "Remember, today you are going to be involved in...."</p>
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Figure 5 Teacher's Sample Cue Card for Using an Advance Organizer

According to Schwartz, N., Ellsworth, L., Graham, L., & Knight, B. (1998) advance organizers could increase learner's comprehension and recall by helping mobilize relevant schema and provide means of organizing new materials. Advance organizers are usually given at the beginning of the lesson but may also be used during the lesson to reinforce and direct student thinking. Examples of advance organizers are stating clear and interesting objectives and expectations, making generalizations, defining terms, reviewing previous learning, and personalizing the learning (Mayer 1979). Mayer (1979), has also provided characteristics of an advance organizer as “(a) a short set of verbal or visual information, (b) presented prior to learning a larger body of to-be-learned information, (c) containing no specific content from the to-be-learned information, (d) providing a means of generating the logical relationships among the elements in the to-be-learned information, and (e) influencing the learners’ encoding process.”

Many researchers have investigated the effectiveness of applying advance organizers, and many of them show that advance organizers help facilitate learning. For

example, Luiten, Ames, and Ackerson (1980) concluded that advance organizers have a “facilitative effect” on the learning process after conducting a meta-analysis of 135 advance organizer studies. An example of these studies is the work done by Ausubel and colleagues (Ausubel, 1960; Ausubel & Fitzgerald, 1961; Ausubel & Fitzgerald, 1962, Ausubel & Youssef, 1963) that was conducted on advance organizers as a series of four experiments. The study emphasized the usefulness of advance organizers as an instructional strategy to improve reading comprehension from text. For instance, Ausubel (1960) exposed 110 undergraduate students to an unfamiliar expository passage about metallurgical properties of metal, and divided them into two groups: experimental and control. Before reading the metallurgical properties of metal passage, subjects in the experimental group read a 500-word advance organizer text that presented the main features of upcoming material. On the other hand, before reading the metallurgical properties of metal passage, the control group read a 500-word historical introduction to steel production that did not reveal any information about upcoming material. The experimental group scored significantly higher than the control group in a multiple-choice posttest.

Videotaped material was also found to help students learn better when used as an advance organizer in-line with written material. For example, Herron (1994) used video to teach French to American college students while investigating the effect of using it as an advance organizer. Two groups of 19 students were used in this study for a semester long course “beginning level French”. In the advance organizer group, the teacher summarized major scenes in an upcoming video segment in chronological order, by providing students with several short sentences written on the board in French. Students

then watched the video in its entirety with no further teacher manipulation of material. In the control group, students watched the video in its entirety without any manipulation of material and without introductory statements by the instructor. Comprehension and retention tests were taken by students to cover the material presented in each of the 10 different videos during the course of the study. The results showed a significantly higher mean score for the students in the advance organizer condition as opposed to the control condition.

Another study was conducted by Herron, Hanley, & Cole (1995) to compare two advance organizers by introducing beginner foreign language students to videos. The first advance organizer is an aural description of major upcoming scenes in the video accompanied by contextually related pictures. The second advance organizer contained only the aural description. The first advance organizer scored significantly higher than the second one and significantly improved the comprehension and retention of information in a French video series.

### ***Hypothesizing and Justifying***

Chi et al. (2001) considered that hypothesizing and justifying constitute more complex, deeper, and a higher level of constructive learning. In order to justify the line of thought and to make a hypothesis, an individual needs to describe a new relation, make an effort to solve a problem, and attempt to understand difficult issues. Therefore, an integration effort needs to be completed by the individual of the new information with established knowledge in his/her existing cognitive structure. Chan, Burits, Scardamalia, and Bereiter (1992), experimented with 109 children from a middle class urban school by asking them to read from two informative texts, one about germs and the other about

dinosaurs, which both consisted of 12 expository statements. They tested four groups with different instructional strategies prior to a thinking aloud session that was common to all groups. The groups were hypothesizing/justifying, know, do not know, and a control group. Groups of three to four students were formed and received training on how to provide thinking ideas about text sentences being read, for half an hour one week before the testing session. Children in all groups learned that deep thinking is the process of describing new relations, making an effort to justify a solution to a given problem, or attempting to understand difficult points. Examples of “thinking ideas” about the text as opposed to “easy ideas.” illustrated the definition of deep thinking. First, children were provided with examples on how to provide thinking ideas such as “I wonder why cats need to sleep that much, maybe they are lazy. Or, maybe it’s the other way around. Maybe they are not lazy. Maybe they use extra energy when they are awake so they get more tired than most animals.” in reaction to the statement “Cats sleep more than any other animal, though scientists don’t know why”. On the other hand, children were taught that an easy idea to the same statement would be “My cat likes to sleep on my pillow”. Once that training was completed, children were given two ideas and asked to assess which one was an easy idea and which one was a thinking idea. The final step is to involve the children in generating their own ideas and assist each other to evaluate these attempts. This completed the training of children to learn to hypothesize/ justify.

The know group was assigned a topic for which the students were asked to tell what they already knew or understood about it. As for the do not know group, students were asked to talk about what they did not know about the topic they were assigned at the beginning of the learning session. During the 15-minute training sessions, the

experimenters met with children individually and asked them to “say out loud everything that comes to your mind as you try to learn from this statement”. The process consisted of the experimenter, initially providing an example and showing the children how to think aloud. Second, the child was asked to think aloud to a statement and the experimenter provided feedback. Finally, the child was asked to practice thinking aloud to two more statements. Of course, the control group students did not receive any special treatment. The testing started with the thinking aloud session, where the experimenter read 12 expository statements to each child, and asked him/her to think aloud after each statement. The statements are reread if the child asked to repeat them or if the experimenter thought the child had not understood them. After the thinking aloud session, recorded interviews were conducted on an individual basis with the students. There were four questions asked during the interview that aimed at assessing recall and fostering knowledge construction:

1. The students were asked to recall everything he/she remembered about the text.
2. The students were asked to summarize the main idea of the text.
3. The students were asked to tell everything new he/she learned about the topic.
4. The students were asked to tell what else he/she would like to know about the topic.

After analyzing the elaborations provided by learners, the team was able to develop a scale with five levels of constructive activities:

1. Pre-factual confabulation (telling isolated words or fragmented phrases which indicate no understanding of the text).
2. Knowledge retelling.
3. Assimilation (telling explicit evidence of comprehension of the text).

4. Problem solving.
5. Extrapolation (telling an extension of knowledge beyond what was given in the text).

The results of the post-test suggested that age is an important factor in the use of the constructive activities. While children in grade 1 tended to focus on surface features, children in Grade 3 showed simple text comprehension by using assimilation learning more frequently. On the other hand, grade 6 children made use of both the simple text comprehension and the problem solving activities to construct deep and meaningful understanding. In addition, there were significant differences in favor of the hypothesizing and justifying group with respect to learning comprehension.

### ***Criticizing, Reflecting, and Predicting***

Similar to hypothesizing and justifying in the previous section, reflecting, criticizing, and predicting are integrative instructional strategies that help construct deep understanding. During the reflecting and criticizing process, learners are asked to rephrase expressions into their own words, which will provide the tutor a mechanism to monitor the student's learning. Furthermore, the tutor will engage the students in critical evaluation of the content being learned by asking them to clarify. The criticizing strategy entails generating differing opinions critical of what is being learned. Therefore the students, when learning to criticize, need to understand exactly what is going on, and attempt to provide valuable information to their tutor.

On the other hand, predicting implies that the students make deduction about upcoming material from what he or she has already learned (Palincsar & Brown, 1984). The process of asking questions on material that is not yet covered can also be called predicting. A study was conducted by Palincsar & Brown (1984) on four elaborative



strategies, which were, summarizing, questioning, reflecting/criticizing, and predicting. Reflecting/criticizing and predicting were found to significantly improve the learning process using standardized comprehension scores.

### **Knowledge Organization**

In this section, the impact of knowledge organization on learning and recall is discussed. Prior research will be presented that provides evidence that the organization and structure of curriculum content has a profound impact on learning.

Many researchers have agreed that memory is associative, and therefore meaning is represented by a variety of associations in memory (Anderson, 1983, 1993 and 2002) (Anderson and Bower, 1973) (Quillian, 1968, 1969) (Kintsch, 1974, 2002) (Ausubel, 1968, 2002). Ausubel (2002) has defined the classification of meaning in three categories; representational, concept, and propositional meaning.

Representational meaning is defined as words or symbols which correspond to objects, as when one is learning vocabulary for example. Representational meaning is a simple assignment of a name to an object that is referred to as declarative knowledge by (Bower, 1973) (Anderson, 1983, 1993). These names and words form associations that become conceptual meaning in declarative memory.

Conceptual meaning does not have any specific referent as does representational meaning. The meaning of the symbols represent an entire class of instances that share some common attributes. It is these attributes that provide the meaning of a concept by providing distinguishing characteristics. For example, a child may assign the representational meaning of a ball object to the first ball experienced. Once the child

experiences other balls with different sizes and colors, but can be manipulated as the first ball, then the word ball no longer represents an instance but a whole class of specific objects referred to as “ball”.

Propositional meaning is the third type of meaning which expresses relationships between concepts. Propositional meaning is formed by a combination of concepts such that a new idea is formed, that is more than the sum of its component concepts. Most English sentential expressions yield propositional representations in order to establish meaning. Propositions and concepts can be nested within other concepts or propositions forming a hierarchical organization of concepts and relations.

As early as Miller (1956), Knowledge organization has been the topic of considerable research for many years where the concept of chunking proposed the notion of a hierarchical organization of information. Miller (1956) defined chunking when elements of information are grouped and stored as a hierarchy, and as a result facilitate efficient memory storage.

Three years earlier, Bousfield (1953) defined clustering as a consequence of organization in thinking and recall. Therefore the quantification of clustering provides us with information on the nature of organization as it operates in higher mental processes. Bousfield (1953) presented subjects with a list of nouns, and asked them to list serially as many as they could remember. The list consisted of 60 nouns randomly selected from four categories, animals, names, professions, and vegetables as listed in Table 2 such that an equal number of items from each of the categories was included in the 60 nouns.

Table 2  
List of Stimulus Words, (Bousfield, 1953)

LIST OF STIMULUS WORDS							
Animals		Names		Professions		Vegetables	
Word	Freq.	Word	Freq.	Word	Freq.	Word	Freq.
giraffe	1	Amos	1	milkman	1	eggplant	1
baboon	2	Gerald	1	typist	1	parsnip	1
zebra	2	Byron	3	florist	2	garlic	3
panther	5	Oswald	4	plumber	2	rhubarb	3
wildcat	5	Jason	5	diver	4	radish	4
leopard	6	Otto	5	druggist	4	melon	5
reindeer	6	Noah	6	broker	7	mustard	7
chipmunk	7	Wallace	7	printer	7	spinach	8
muskrat	7	Owen	7	dentist	9	parsley	8
woodchuck	7	Bernard	9	baker	10	carrot	9
otter	8	Adam	10	chemist	10	mushroom	10
weasel	9	Sherman	10	dancer	10	turnip	10
badger	11	Simon	11	grocer	11	lettuce	12
donkey	16	Moses	12	waiter	13	pumpkin	13
camel	18	Howard	19	blacksmith	19	cabbage	16
Mean Freq.	7.33		7.33		7.33		7.33

One hundred, 100, subjects were instructed to listen to a list of words read by an assistant. They were then asked to write as many of the words they remembered in a 10-minute recall period. They were instructed to draw a demarcation line under the words every time they were told to do so during the 10-minute recall session. Bousfield (1953) wanted to determine how often an item would be followed by another item in the same category (A, animal; N, name; P, profession; or V, vegetable).

A ratio of repetition of items belonging to a category at these demarcations was computed as the number of repetitions of items in a category divided by the total number of items recalled. The ratio for the subjects as a group was 0.45, meaning that about half of their items in their lists were unknowingly grouped sequentially by category. Bousfield (1953) concluded that during recall, subjects have a tendency to group the items in clusters containing members of the same general category, which implies the operation of an organizing tendency.

To determine the effect of organization on recall, Bower, G.H., Clark, M. C., Lesgold, A. M., and Winzenz, D. (1969) conducted an experiment on four groups that were presented with categorically organized hierarchical trees of common words, representing minerals, animals, transportation and clothing. Four other groups were presented with the same words, but in a randomly organized tree. The results indicated that the groups presented with the categorically organized trees outperformed the groups presented with the randomly organized trees by a vast advantage during recall tests.

Craik and Lochart (1972) prescribed a phenomenon referred to as the Level of Processing Hypothesis that describes the hierarchical processing of information. It is believed that information being assimilated by the human information processing system passes through different levels of processing from general to specific.

To determine the effect of textual information organization on the human processing of information, Frase (1970, 1975) conducted multiple studies that altered the order of the sentences in a text. Frase (1970) conducted a study with two groups of adult subjects, one group was asked to learn text in which the sentences were arranged in logical order, and the other in random order. The data confirmed that the sequence of verbal information can determine the way in which information is stored, and therefore alter the subjects' ability to produce new combinations of that information at a later time. Frase (1970) concluded that text that is organized in a logical order provides for better recall on the part of subjects than randomly organized text. A text is constructed with sentences that are generated from different combinations of names, attributes, and attribute values. For instance, *The ship Encounter (NAME) had a hull (ATTRIBUTE) constructed of wood (ATTRIBUTE VALUE)*, or *The ship Winslow (NAME) was rigged*

(ATTRIBUTE) *as a ketch* (ATTRIBUTE VALUE) are two sentences that can be included in the text. In the logical order text, sentences can be grouped into clusters according to the names in the sentences, or they can be grouped according to the attributes or attribute values of the sentences. For example, the sentence *The ship Encounter had a hull constructed of wood*, can be grouped with *The ship Encounter was as long as thirty feet*, because they share the same NAME in the sentences. On the other hand, on a randomly organized text, the sentence *The ship Encounter had a hull constructed of wood*, can be grouped with the sentence *The ship Winslow had a sail shaped as a square*, because they do not share either names, attributes, nor attribute values. Based on other experiments, Frase (1975) has strengthened his conclusion that the organizational characteristics of text can influence the performance of subjects on recall of information, and clearly emphasized the importance of organization in verbal learning.

Simon (1981), also emphasized the importance of the organization of information. He defined a hierarchy as a system that is composed of interrelated subsystems, which are in turn hierarchic in structure until they reach some lowest level of elementary subsystem. For example, when a subject is asked to draw a human face, the subject will almost always proceed in a hierarchical fashion. The subject will sketch the face first, and then he/she will add major features such as eyes, nose, mouth, ear, and hair. If the subject is asked to elaborate, he/she will continue drawing by adding details such as pupils, eyelids, lashes, and so on, until he/she reaches the limits of his anatomical knowledge. This demonstrates that knowledge about the human face is arranged in memory in a hierarchical fashion. Another example is that the human body is composed of organs, which are in turn composed of cells, which are in turn are composed of cellular

subsystems, and so on. Simon (1981) proposed that one path to the construction of a nontrivial theory of complex systems is by way of a hierarchy. He claimed that, empirically, a large portion of the complex systems we observe in nature exhibit a hierarchic structure.

Shavelson (1972) and Gagne and Briggs (1974) also identified the importance of hierarchy in sequencing and representing knowledge. While Shavelson believes that knowledge is represented from the top downwards, Gagne and Briggs assumes that cognitive structure is organized from the bottom upwards, and that Bottom-Up structure seems the best content organization in terms of learning abstract knowledge as well as other forms of knowledge.

Simon (1981) also argued that, by representing complex systems as hierarchical decompositions, little to no information is lost in the properties of the system. This is referred to as near decomposability as he claims that in hierarchic systems, we can distinguish between the interaction among subsystems on one hand, and the interactions within subsystems on the other hand. The interactions at different levels will differ depending on where the sources are in the hierarchy. For example, in a formal organization, two employees in the same department will interact more than two employees from different departments. Another example is that each cell in a living organism has a metabolic network that consists of a huge number of interactions among substrates, many more than take place between two different cells. Simon (1983) states that near decomposability simplifies the description of a complex system and makes it easier to understand how the information needed for the development or reproduction of the system can be stored in memory in a reasonable manner.

Complex systems were also the focus of Miyake (1986), who conducted a study to determine how people organize and communicate their understanding of how a device works. Multiple pairs of individuals, with different levels of understanding of the device, were observed communicating. Miyake (1986) found that individuals communicated how the device worked using what Miyake calls a function-mechanism hierarchy, which is made up of several levels of abstraction, each describing a different level of functions and mechanisms. Functions describe what happens at each level, while mechanisms describe how it happens. Miyake's (1986) research showed that people go through an iterative process as they explain a device, going from a high level to the lowest level of abstraction, demonstrating the existence of a hierarchical structure.

This hierarchical organization of information was also found by Anderson's (1993) research. He discussed that a feature of chunks is that they can enter into hierarchical organizations, such as chunks within chunks. For example, the string of letters D Y J H Q G W, might be organized as the chunks DY JHQ GW. Bower et al., (1969) were able to show hierarchical organization of elements in up to four levels when describing mineral elements.

Anderson (1993) described the existence of hierarchical goal structures when a person deals with problems solving. A person would solve the sub goals working their way up to the main goal in order to solve the main problem. For example, in order to be able to take his child to preschool, one may need to repair his car first. Therefore, in order to repair his car, one may need to contact an auto repair shop initially. These various goals, would be ordered on a stack, with contacting the repair shop on top of the stack.

This is a Last-In-First-Out (LIFO) stack, where the last sub goal one has put on the stack is the goal one is currently focused on.

These goal structures can be complex depending on the complexity of the problem. For example, designing, constructing, and using a tool would require substantial hierarchical planning and complex coordination of sub goals. Natural language is also a strong and complex hierarchical structure, and was argued by Anderson (1983) that its use was a special case of problem solving.

Anderson, Belleza, and Boyle (1993) undertook a geometry tutoring project that focused on instruction of traditional Euclidean proof skills. The student interacts with the computerized geometry tutor using a series of proof graphs and diagrams, to help them understand and solve sub goals, which leads them to understanding the main problem. This has been defined as reification, because the proof graphs illustrates the concrete abstract features of problem solving in geometry. These features, for which students have a great deal of difficulty, are the logical relationships among the premises and conclusions, and the search process by which one hunts for the correct proof. Students have reported that the graphical features of the proof graphs are more helpful than the traditional textual two-column proof form. Scheines and Sieg (1994) used such representations for proofs in formal logic. They found evidence that such graphical representations help problem solving even without a tutor.

In the theory of problem solving, Novick and Bassok (2005) described that two phenomenon take place during the problem solving process: representation of the problem, and solution generation. They also described that the representation may happen through either of two mechanisms, which are constraint relaxation or chunk



decomposition. Constraint relaxation involves deactivating some knowledge element that has constrained the operators being considered, thereby allowing application of new operators. Constraint relaxation is often used where finding a solution to the original problem is prohibitively expensive or infeasible. For example, during a complex maze problem, constraint relaxation can be used to speed up the solution time. As an example where constraint relaxation is obvious, is when allowing firefighters to break through a door in order to get inside a burning house. The normal constraint would have been to unlock the door with a key to enter, but in order to solve the problem of entering the house as quick as possible, the later constraint has been relaxed to allow for forced entry.

The mechanism (chunk decomposition), involves inheriting the links that bond components of a meaningful unit in the problem. This is a clear indication that problem representation is in hierarchical form, by combining meaningful components (chunks) together with bonds to describe the state of the problem at a given time. For example, in the above burning house example, the firefighter can break the problem of “entering the house as quickly as possible” into multiple components. A house has multiple entry points such as windows, front door, back door, and garage door, while each requires a specific way to open. This decomposition will help the firefighter determine the best course of action to enter the house based on past experiences and the state of the fire at the time.

Halford (2005) stated that children become capable of more complex reasoning tasks with age. He also argued that complex tasks are segmented into components that do not overload capacity to process information in parallel. This processing load can be

reduced by conceptual chunking, a form of decomposition of the task into compressed chunks, a hierarchy.

Williams and Lopez (in press) conducted a study to determine the effect of the organization of technical curriculum for the acquisition of declarative knowledge. During the experiment twenty four subjects were divided into two experimental groups and a control group. One of the experimental conditions was the top-down condition, which reflects the organization of the material presented. The Top-Down Approach is a hierarchical organization approach to the curriculum that presents the highest levels of generality first, at the top with progressively more detailed information as one progress down the hierarchy. The second experimental condition was the bottom-up condition, which simply reversed the order of presentation of the material presented in the top-down condition. The bottom-up approach of organizing a curriculum has been extensively used in textbooks, where the details are first taught, then progressively higher levels of generalization later. Both conditions consisted of the same exact words. The control condition was based on text that was copied verbatim from the sections of the currently used curriculum materials. The experiment consisted of having each subject take a pre-test followed by three trials of approximately 30 to 45 minutes. In each trial, the subjects were presented with the materials appropriate for their group assignment followed by a test. It was found that the top-down acquired more knowledge by a factor of six versus the bottom-up group during the first trials. The top-down group also continued to outperform the bottom-up group across all trials.

Williams, Crumpton-Young , Furterer, and Rabelo (in progress) extended the above research to examine the top-down and bottom-up approaches when it applies to

knowledge of abstract concepts and propositions, as will be referred to as “abstract” knowledge. The curriculum content was organized into three sets, a top-down, a bottom-up, and a random curriculum. Subjects were randomly assigned to one of the three versions of the curriculum. Each subject was given a pretest, and was required to read the text material, and take a test after each reading. Three trials were repeated without any feedback to the subjects on their performance. Williams, Crumpton-Young, Furterer, and Rabelo (in progress) did not find any significant difference between the different groups when the curriculum relates to abstract knowledge. This finding was explained by the fact that abstract concept hierarchies have no obvious real world representation, but have meaning only to the expert with extensive knowledge of the domain in question. Therefore, students, naïve of the terms of an abstract concept hierarchy would find it difficult to identify the explicit structure of the hierarchy. In the words of Anderson, Belleza, and Boyle (1993), this type of information is not readily reified into an abstraction hierarchy as is how-it-works knowledge, which is spatial in nature, and how-to-do-it knowledge, which is temporal in nature. Complex systems (how-it-works knowledge) are physical in nature and can readily be decomposed as indicated by Simon (1981). Problem solving is temporal in nature requiring accomplishment of sequence of how-to-do-it steps or sub goals, as indicated by Anderson (1993). As humans we have become exposed to these kinds of concrete representations which are reified and easy to relate to. Abstractions on the other hand are manufactured by humans who have considerable experience in a domain and are not readily reified.

From the literature review it appears that providing abstract information in a hierarchical form will take advantage of the two mechanisms to support learning of abstract knowledge. The first mechanism is to stimulate greater cognitive activity by having students

generate graphical representations which require students to think about relations between different levels of content regarding an abstract topic. The second mechanism takes advantage of the human's inherent capability to form hierarchical relations, which requires the cognitive system to be more engaged. The result is expected to improve reification of abstract knowledge and thus accelerate the learning experience.

## **CHAPTER 3: METHODOLOGY**

The following is a description of the experiment methodology that will be followed during this dissertation.

### **Participants**

Seventy two, 72, undergraduate students will participate in this experiment conducted in the IEMS lab. Participation in the experiment is open to all students, regardless of age, race, gender, or nation of origin.

### **Apparatus and Materials**

The experiment will take place in the IEMS Simulation Computer Lab, in the 3<sup>rd</sup> floor of the Engineering Building II at the University of Central Florida. The Lab is equipped with 20 general purpose Dell computers with Microsoft Windows XP operating system. Other apparatus to be used in this experiment are a notepad and a pencil for each participant that is required to draw a graph.

During the experiment, participants are required to read material based on abstract content covering concepts in Industrial Engineering (IE). The content used in this experiment, originally developed by Williams et al. (in progress), was taken from a chapter in an introductory course in IE. The organization of the existing chapter contents was linear in nature with topics sequenced as created by the original author. The chapter was reorganized into a top-down framework. The high level concepts addressed in the

chapter were Organizational Performance, Productivity, Efficiency, Managing and Planning for Productivity, Direct and Indirect Costs, the Nominal Group Technique, Team Effectiveness, etc.. The chapter was read and analyzed by Dr. Kent Williams, a cognitive scientist and knowledge engineer, to produce a hierarchical organization of concepts with the highest level propositions presented first followed by successively lower level concepts and detail in the case of the “Top-Down Content”. The process began by identifying the highest level proposition which the expert faculty member wanted the students to understand from the curriculum material. Following this the expert was then asked to identify what lower level concepts the student must understand in order to have an understanding of this highest level proposition. The highest level proposition was identified to be the notion of Organizational Performance. In order to understand Organizational Performance it was specified that the student must understand the role of the IE as a consultant for change, the process for planning and managing for organizational performance. These later two propositions were then further decomposed to identify the concepts which needed to be understood in order to understand these propositions. This continued until all of the concepts were located in a hierarchical structure. The structure was then filled out with definitions of the propositions. Two other sets of content text were generated from this top-down version. The second bottom-up set was generated simply by reversing the order of presentation of the material created for the top-down version. The third version was generated by assigning a number to each topic in the top down version. Numbers were then drawn from a random number table to determine the positioning of a topic in the text with the restriction that no sequence of any two numbers in either an ascending or descending order could occur.

That is, topic number 6, for example, could not be followed by or follows topic number 7 in the sequence of presentation. The resultant order of numbers selected at random then produced the sequencing of topics for this unorganized version of the curriculum. This version then was a simple linear sequencing of topics without any inherent organization. The three different versions of the content “Top-Down Content” ”Bottom-up Content” and “Unorganized Content” are presented respectively in Appendix A, B, and C.

Another item that was added to the experiment material is the graphing instructions. It contains a tutorial with an example of how to create a graph from textual content (see Appendix G). An exercise is also provided to the participant (see Appendix I) to insure he/she understands the Graphing method.

In order to streamline and automate the experiment, the content was uploaded to the University of Central Florida’s Webcourses, an online virtual learning environment. Webcourses is a software tool used by many universities to manage their courses in an e-learning environment. Instructors can add to their Webcourses courses, tools such as discussion boards, mail systems, and live chat, along with content including documents and web pages.

Multiple forms are used during the experiment, these were:

- Personal Data Form
- The informed consent form
- A motivation screening form

The Personal Data Form is required to collect personal data from each participant prior to the beginning of the test. The form requires the participant’s name, age, and

gender, along with questions about their background relative to the content of the experiment.

The Informed Consent Form is required to collect a formal signed consent from the participant to be part of the experiment. It explains the involvement of the participant during the study. The participant must read, and sign to agree to all the terms of the experiment before he/she is allowed to participate. A copy of this form is provided in Appendix D.

A motivation Screening Form is also part of the materials developed for this experiment to determine the level of motivation each participant has prior to starting the experiment. This survey is based on The Locus of Control, a 13 item questionnaire developed by Rotter (1966). It measures internal versus external locus of control. People with an internal locus of control (highly motivated) believe that their own actions determine the rewards that they obtain, while those with an external locus of control (poorly motivated) believe that their own behavior doesn't matter much and that rewards in life are generally outside of their control. Scores range from 0 to 13, and therefore; a low score indicates an internal locus of control (high motivation) while a high score indicates external locus of control (low motivation). Appendix E lists the Locus of Control questionnaire.

Another major item developed was the test that will be administrated during various phases of the experiment. This test contains 18 fill in the blank questions to measure their knowledge about the content of this experiment. When the test is administrated prior to beginning the experiment, it will be called a "Pretest", and when it



is administered after a trial, it is called a “Posttest”. This experiment will have one Pretest and three Posttests. Appendix F lists the content of the test.

A pilot study will be conducted with three participants early in the preparation phase. During the pilot experiment, emphasis will be placed on the usability of the experimental material to insure that all the instructions and procedures are understood by the participants by having a clear understanding of experimental expectations so they can take part in the experiment.

### **Procedure**

There will be six groups of twelve participants to represent six distinct conditions in this experiment. These groups are divided into a control set and an experimental set. The control set contains three groups labeled “Top-Down Control Group”, “Bottom-Up Control Group”, and “Unorganized Control Group”. These groups will respectively be subjected to content in a “Top-Down Content”, “Bottom-up Content” and “Unorganized Content”. The experimental set contains three groups labeled “Top-Down Experimental Group”, “Bottom-Up Experimental Group”, and “Unorganized Experimental Group”. These experimental groups will also be respectively subjected to “Top-Down Content”, “Bottom-up Content” and “Unorganized Content”, but will be required to draw a graphical representation of their understanding of the material prior to taking posttests. The participants are randomly assigned to ensure that each participant had an equal chance of being assigned to any one of the 6 different conditions. Because of the abstract nature of the content, it is believed that some participants may be unmotivated. In order to account for this factor, each participant will have to take a motivation

screening test prior to starting the experiment. Participants that are assigned to the Graphing groups will have to read the Graphing instructions and go through the exercise to create a graph before starting the experiment.

All participants are asked to return to the experiment site after 48 hours without knowing the reason behind it, as they will be presented to take a retention test.

### **Analysis & Design**

There are two experimental designs that will be implemented in this research, the first one is 3 between subject and 1 within subject mixed design, and the second one is 2 between subject and 1 within subject mixed design. They are summarized as follow.

The first design consists of three between groups factors with the last factor used as a blocking factor; Factor A with two levels “Without Graph” (W/G) and “With Graph” (WG); Factor B with three levels “Top-Down” (TD), “Bottom-Up” (BU), and “Unorganized” (UR), and Factor C with two levels “Low Motivation” (LM) and “High Motivation” (HM). The Motivation scores will be used as a blocking factor to identify low from high motivation using values separated by the median score. In each of the six groups, six participants from the set of the lowest motivation scores will be grouped in a “LM” block, while six participants from the set of the highest motivation scores will be grouped in a “HM” block. As a result, there will be 36 participants with “Low Motivation” and 36 participants with “High Motivation” distributed across all six conditions. Consequently, this experimental design will results in 12 conditions labeled W/GTD-LM, W/GBU-LM, W/GUR-LM, WGTD-LM, WGBU-LM, WGUR-LM,

W/GTD-HM, W/GBU-HM, W/GUR-HM, WGTD-HM, WGBU-HM, and WGUR-HM (see Figure 6). An Analysis of Variance (ANOVA) will be conducted on this 3 between-subject and 1 within-subject mixed design. The followings are the degrees of freedom for each design.

Table 3  
ANOVA for a design with 3 between-subjects and 1 within-subject

SV	df
Total	143
Between Group	71
A	1
B	2
C	1
AB	2
BC	2
AC	1
ABC	2
S/ABC	60
Within Group	72
T	1
AT	1
BT	2
CT	1
ABT	2
BCT	2
ACT	1
ABCT	2
ST/ABC	60

The second design consists of 2 between group factors: Factor A and Factor B (already described in the above paragraph). The difference between the two designs is

that Factor C (Motivation) is eliminated from the design in case it is statistically insignificant. Consequently, this design experiment will results in 6 conditions labeled W/GTD, W/GBU, W/GUR, WGTD, WGBU, and WGUR (see Figure 7). An analysis of Variance (ANOVA) will be conducted on this 2 between-subject and 1 within-subject mixed design.

Table 4  
ANOVA for a design with 2 between-subjects and 1 within-subject

SV	df
Total	143
Between Group	71
A	1
B	2
AB	2
S/AB	66
Within Group	72
T	1
AT	1
BT	2
ABT	2
ST/AB	66

During the analysis phase, if a factor with more than 2 treatment levels is significant then comparisons between the means will be conducted. The disadvantage of the ANOVA is that one cannot tell which treatment or treatments were significantly different. Where more than 2 levels of a factor are involved it is appropriate to test for differences between the means. The method to be used for the pairwise comparison is Tukey's HSD (Honestly Significant Difference) Test (Myers and Well, 2003). Both

designs consist of two factors with three levels of a within group factor labeled “Trials” and a between group factor labeled “type of organization”. Pairwise comparison will allow for a determination of what levels are responsible for the omnibus F-ratio significance.

The measures of performances to be assessed during the experiment are:

- Accuracy Score (S0, S1, S2, S3) out of 18 (in all conditions)
  - S0 is the pretest score
  - S1 is the post-test score number 1
  - S2 is the post-test score number 2
  - S3 is the retention test score
- Number of Nodes N0 (for the Graphing groups only)
- Number of Links N1 (for the Graphing groups only)

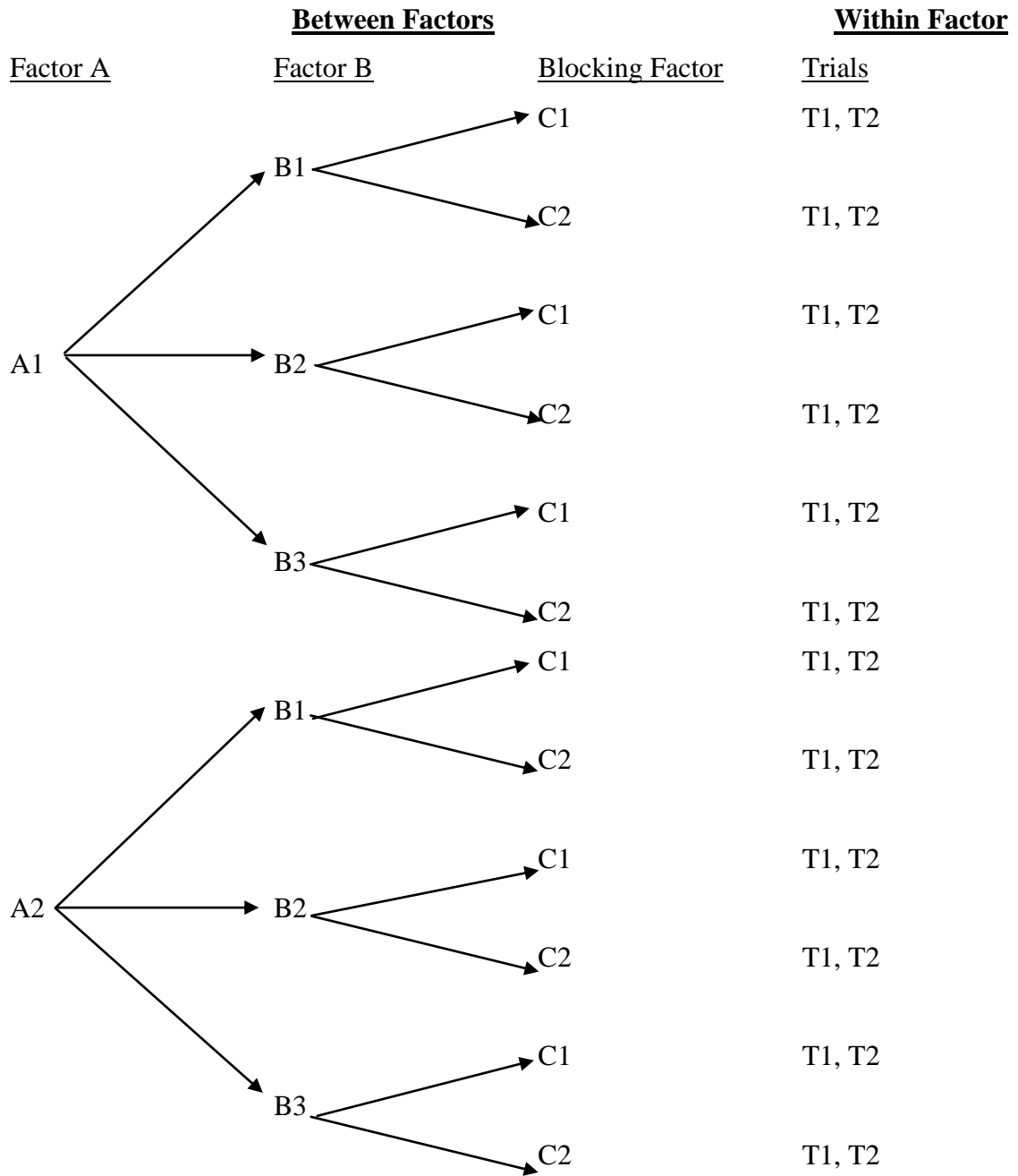


Figure 6 First Design with blocking factor

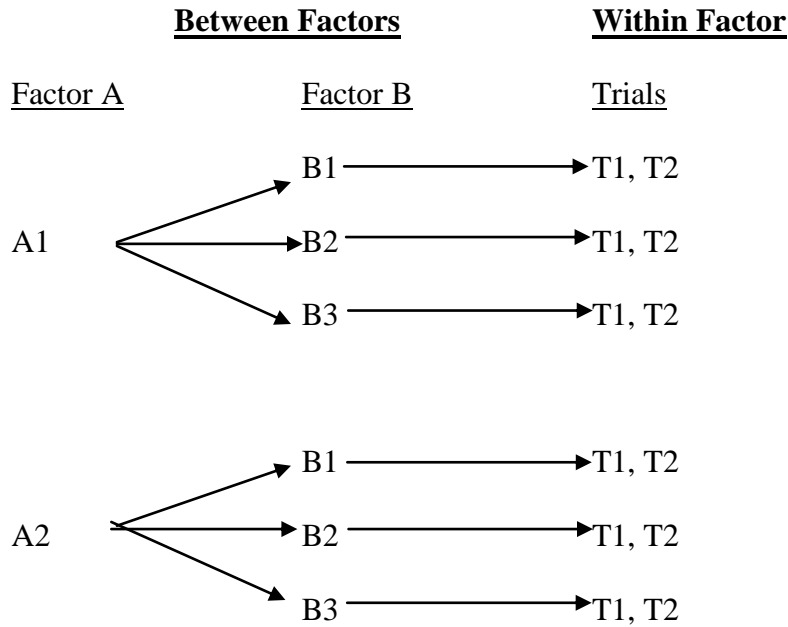


Figure 7 Second Design without blocking factor

The experimental sessions will consist of two phases. The first phase will involve participant screening, orientation, and pretest. The purpose of this phase is to gather information on the participants and provide them with an overview of the experiment. The personal data collected from the individuals is limited to age and gender, along with questions about their background relative to the content of the experiment. Participants with prior knowledge are excluded from the experiment. An informed consent form will be provided the participants with information about the purpose of the experiment, and the time required to complete the experiment. A motivation screening form will be given to all the participants to classify them into achievement categories (High-Low) during the analysis phase. A pretest will also be given to all participants to assess the homogeneity

of participants entering the experiment. A posttest utilizing the same test as a pretest will be given following each trial.

Upon completion of the pretest, participants will be asked to log on to their account in Webcourses for the presentation associated with their condition to start phase two of the experiment. The second phase of the study involves experimental trials, each lasting approximately 30 to 45 minutes. The instructions for the participants will be the same for each trial and each test. When the participants are given the test, they will be told to answer all questions, and if they did not know an answer, they will be told to write “don’t know”. Participants will be allowed to study the presentation at their own pace and have an unlimited amount of time for studying the material on Webcourses. When they finish reading, the computer system instructs them to press “finish” to end the reading session. The participants in the control group will be directed to a posttest in Webcourses, while the participants in the experimental groups will be provided with a paper and pencil to draw a graphical representation of their understanding of the content they have just read. The participants in the experimental group will be provided with direction on the drawing phase, for which they will have unlimited time to complete. An assistant will be present during all phases of the experiment to help the students by answering questions regarding the experimental procedures. After completion of the drawing phase, the participants in the experimental group will be directed to take a posttest in Webcourses. Upon completion of the posttest, trial 1 is terminated, and participants again will be asked to re-open the Webcourses instructional system for the appropriate presentation. Upon completion of the posttest in trial 3, participants will be told they are done with the experiment. During the test, participants will not have access to the training material. The



test is the same test for each trial. Study time and test time are recorded automatically by the computer system for each of the three trials.

## CHAPTER 4: RESULTS

We have already defined in the previous chapter the notation of the effects. The following is a summary to help navigate this chapter.

<b>Factor</b>	<b>Definition</b>
A1	Graph
A2	Without Graph
B1	Bottom Up
B2	Top Down
B3	Unorganized
C1	High Motivation
C2	Low Motivation
T1	Post Test 1
T2	Post Test 2
T3	Retention Test

### Analysis of Pre-Test Scores

The Pre-Test was employed to determine the level of knowledge in the subject matter of the participants, prior to starting the experiment. It was used to determine if a subject had excessive knowledge of the material, which excluded him/her from the experiment. A box plot analysis was conducted on the Pre-Test data to determine the existence of outliers. It was found that 1 participant was an outlier scoring very high on

the pretest. The participant was replaced by another subject scoring within the boundaries of 1.5 times the inter quartile range.

An ANOVA was performed to establish the equality of all the groups' participants. The results indicate that the pre-test for all groups was not significantly different. The majority of subjects did not answer any questions in the pre-test. This was expected due to the unfamiliarity with the curriculum and consequently, the test.

Table 5  
ANOVA Results on Pre-test

Source	SS	df	MS	F	Sig.	$\beta$
Total	33.330	71				
Graphing	.281	1	.281	.568	.454	0.885
Organization	.215	2	.108	.217	.805	0.918
Motivation	.087	1	.087	.175	.677	0.930
Graphing* Organization	.188	2	.094	.189	.828	0.922
Graphing* Motivation	.781	1	.781	1.578	.214	0.765
Organization* Motivation	.049	2	.024	.049	.952	0.943
Graphing *Org.* Motivation	2.021	2	1.010	2.041	.139	0.595
Error	29.708	60	.495			

## Effects of Graphing, Organization, Motivation levels and Trials on Test Scores

To evaluate the effect of Graphing, Organization, Motivation levels and Trials on test score performance, a mixed ANOVA (2\*3\*2\*2) with three between subject factors (Graphing, Organization, Motivation levels) and one within subjects factor (Trials) was conducted. The dependent measure was the Post-Test Score.

Table 6  
ANOVA Results on Test Score for Trial 1 and 2

Source	SS	df	MS	F	Sig.	$\beta$
Total	2982.6	143				
Between Subjects	1945.2	71				
Graphing	.465	1	.465	.020	.887	0.94
<b>Organization</b>	<b>325.2</b>	<b>2</b>	<b>162.6</b>	<b>7.09</b>	<b>.002</b>	<b>0.08</b>
Motivation	18.6	1	18.69	.815	.370	0.85
Graphing * Organization	56.03	2	28.01	1.22	.302	0.74
Graphing * Motivation	.032	1	.032	.001	.970	0.95
Organization * Motivation	140.03	2	70.01	3.05	.055	0.43
Graphing * Org. * Motivation	28.49	2	14.24	.621	.541	0.85
Error	1376.2	60	22.93			
Within Subjects	1037.3	72				
<b>Trials</b>	<b>763.23</b>	<b>1</b>	<b>763.2</b>	<b>187</b>	<b>.000</b>	<b>0.00</b>
Trials * Graphing	3.204	1	3.204	.786	.379	0.85
Trials * Organization	9.040	2	4.520	1.10	.337	0.76
Trials * Motivation	4.995	1	4.995	1.22	.273	0.80
Trials * Graphing * Organization	2.731	2	1.365	.335	.717	0.89
Trials * Graphing * Motivation	.083	1	.083	.020	.887	0.94
Trials * Org.* Motivation	5.559	2	2.780	.682	.510	0.84
Trials*Graphing*Org.*Motivation	3.939	2	1.969	.483	.619	0.87
Error	244.59	60	4.077			

The ANOVA resulted in a main effect for the Organization factor (B),  $F(2,60) = 7.09$ ,  $p=0.002$ ,  $\eta^2=0.082$ . Figure 8 shows a graphical display for the mean scores for the different levels of Organization.

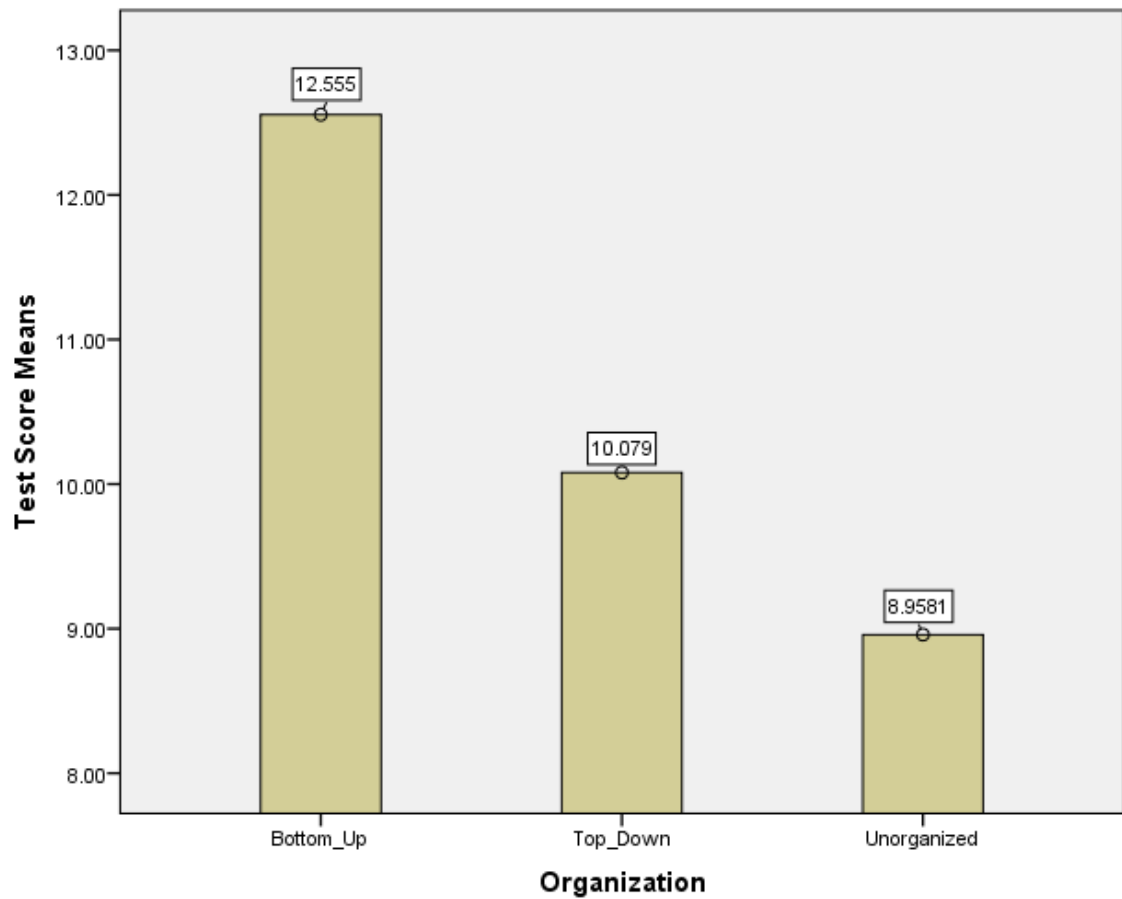


Figure 8 Mean scores for the different levels of Organization

Further post hoc analysis of test scores using the Tukey Honestly Significant Difference test (Tukey HSD) revealed that the Bottom Up organization outperformed the Top Down and the Unorganized groups on mean test scores across the two trials (see Table 7).

Table 7  
 Tukey Pairwise Comparison for the Organization effect

(I) Organization	(J) Organization	Mean Difference (I-J)	Std. Error	Sig.
Bottom_Up	Top_Down	2.4760 <sup>*</sup>	.97761	.037
	Unorganized	3.5973 <sup>*</sup>	.97761	.001
Top_Down	Bottom_Up	-2.4760 <sup>*</sup>	.97761	.037
	Unorganized	1.1213	.97761	.489
Unorganized	Bottom_Up	-3.5973 <sup>*</sup>	.97761	.001
	Top_Down	-1.1213	.97761	.489

As expected, there was a significant main effect for trials,  $F(1, 60) = 187.22$ ,  $p = 0.000$ , (see Figure 9).

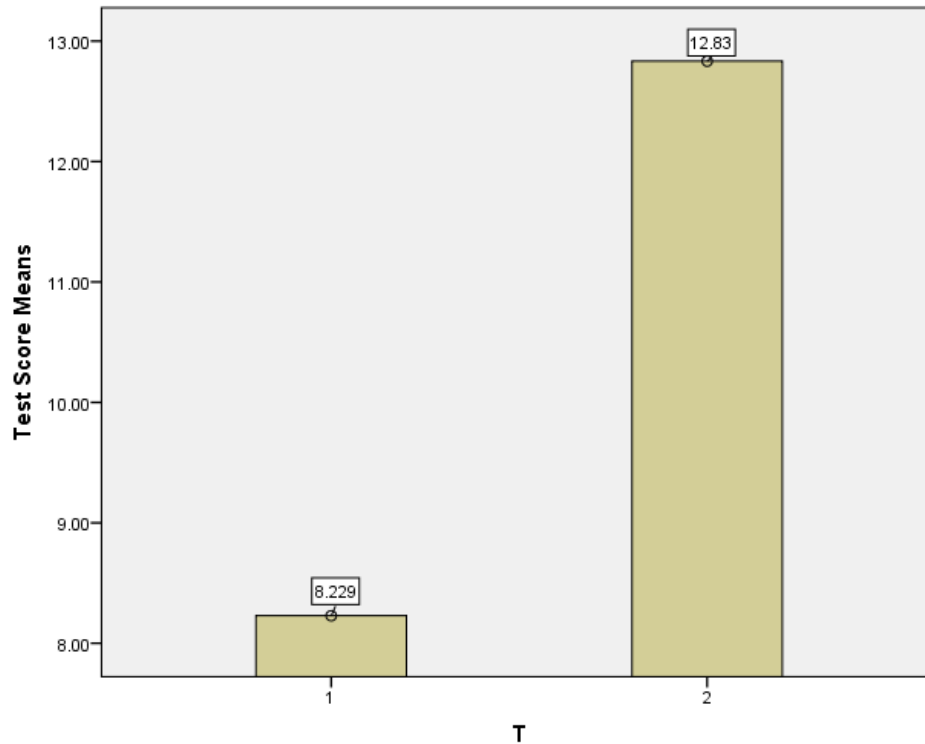


Figure 9 Mean scores on the Trials

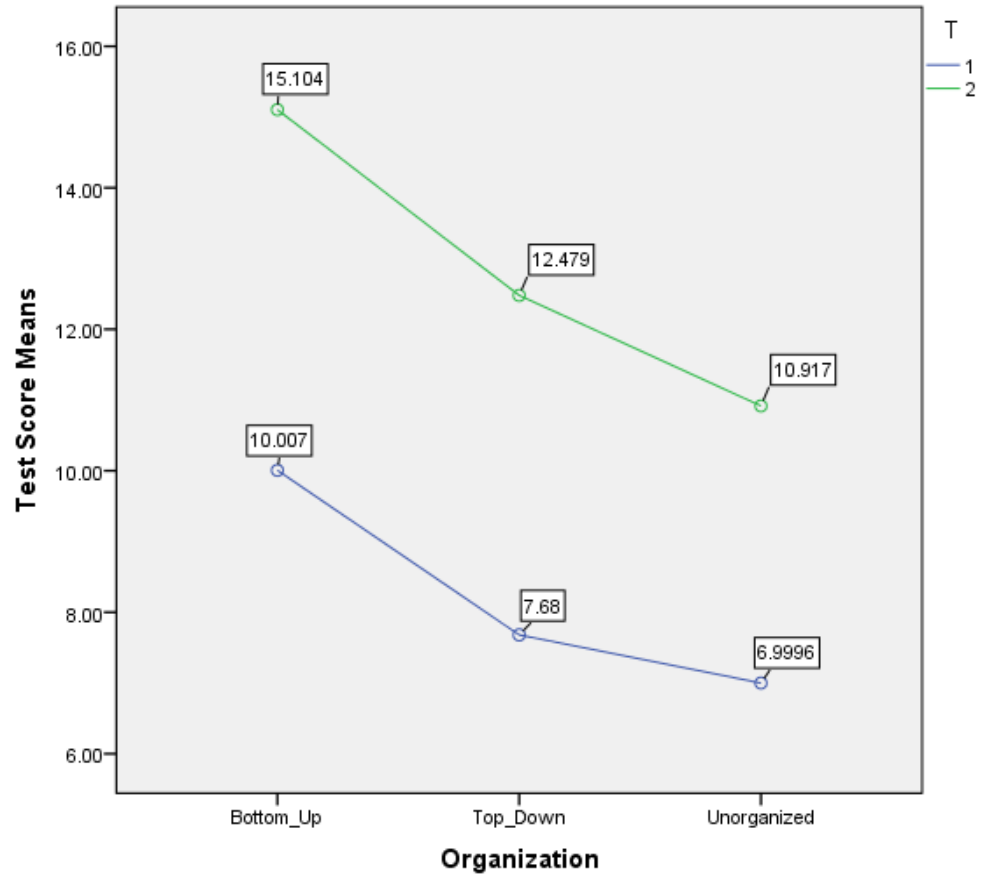


Figure 10 Mean Score on each level of Organization for the two trials

### Effects of Graphing, Organization and Trials on Test Scores

The effect of Motivation was found to be insignificant and therefore it was removed in the following analysis. To evaluate the effect of Graphing, Organization, and Trials on Test Score performance, a mixed effects ANOVA (2\*3\*2) with two between subject factors (Graphing, and Organization) and one within subjects factor (Trials) was conducted on test score data.

Table 8  
ANOVA Results on Test Score for Trial 1 and 2

Source	SS	df	MS	F	Sig.	$\beta$
Total	2982.63	143				
Between Subject	1945.24	71				
Graphing	.465	1	.465	.020	.889	0.94
<b>Organization</b>	<b>325.256</b>	<b>2</b>	<b>162.628</b>	<b>6.865</b>	<b>.002</b>	<b>0.08</b>
Graphing * Org.	56.034	2	28.017	1.183	.313	0.75
Error	1563.49	66	23.689			
Within Subjects	1037.38	72				
<b>Trials</b>	<b>763.233</b>	<b>1</b>	<b>763.233</b>	<b>194.36</b>	<b>.000</b>	<b>0.00</b>
Trials * Graphing	3.204	1	3.204	.816	.370	0.85
Trials * Organization	9.040	2	4.520	1.151	.323	0.75
Trials * Graphing * Org.	2.731	2	1.365	.348	.708	0.89
Error	259.176	66	3.927			



The ANOVA resulted in a main effect for the Organization factor (B),  $F(2,66) = 6.865$ ,  $p=0.002$ ,  $\beta=0.089$ . Figure 11 shows a graphical display for the mean scores for the different levels of Organization.

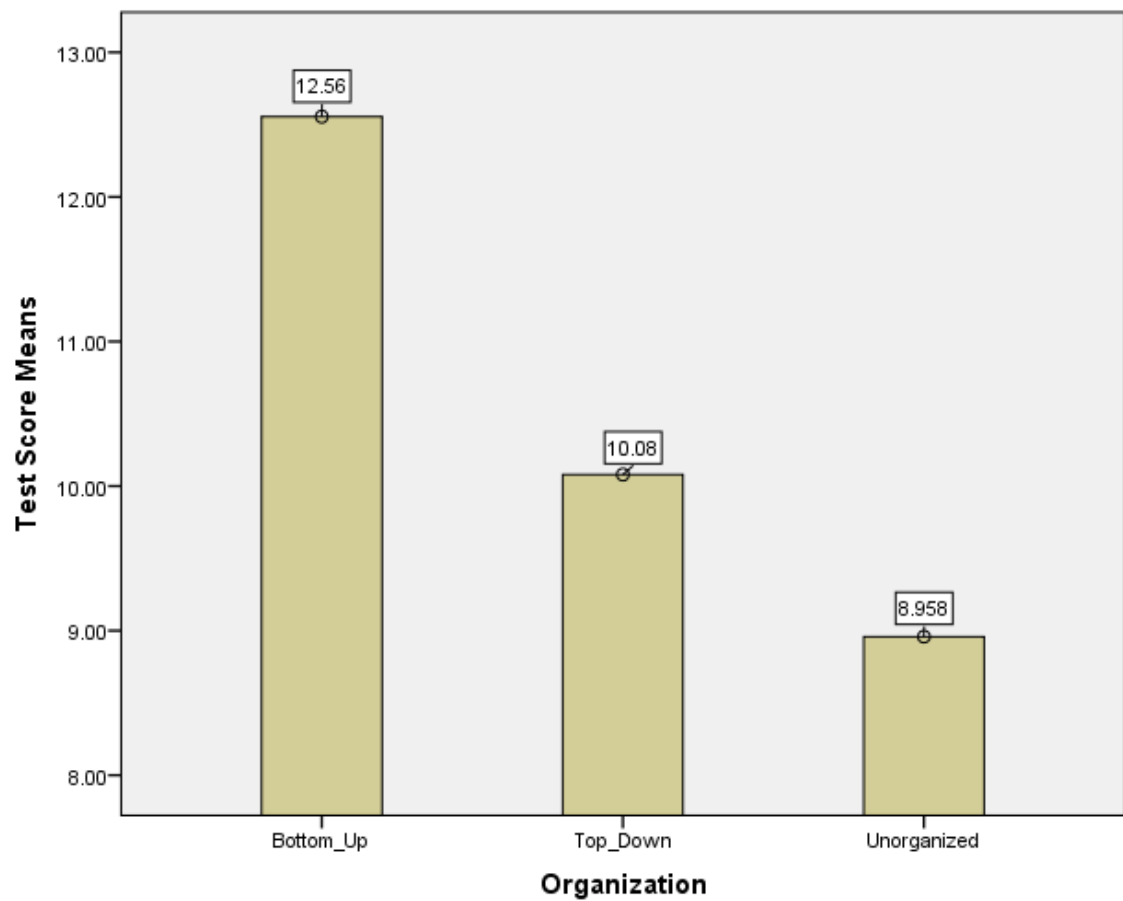


Figure 11 Mean scores for the different levels of Organization

Further post hoc analysis of test scores using the Tukey Honestly Significant Difference test (Tukey HSD) revealed that the Bottom Up organization outperformed the Top Down and Unorganized levels on mean test scores across the two trials (see Table 9).

Table 9  
Tukey Pairwise Comparison for the Organization effect

(I) Organization	(J) Organization	Mean Difference (I-J)	Std. Error	Sig.
Bottom_Up	Top_Down	2.4760 <sup>*</sup>	.99351	.040
	Unorganized	3.5973 <sup>*</sup>	.99351	.002
Top_Down	Bottom_Up	-2.4760 <sup>*</sup>	.99351	.040
	Unorganized	1.1213	.99351	.500
Unorganized	Bottom_Up	-3.5973 <sup>*</sup>	.99351	.002
	Top_Down	-1.1213	.99351	.500

As expected, there was a significant main effect for the trials,  $F(1, 66) = 194.36$ ,  $p = 0.000$ , (see Figure 12).

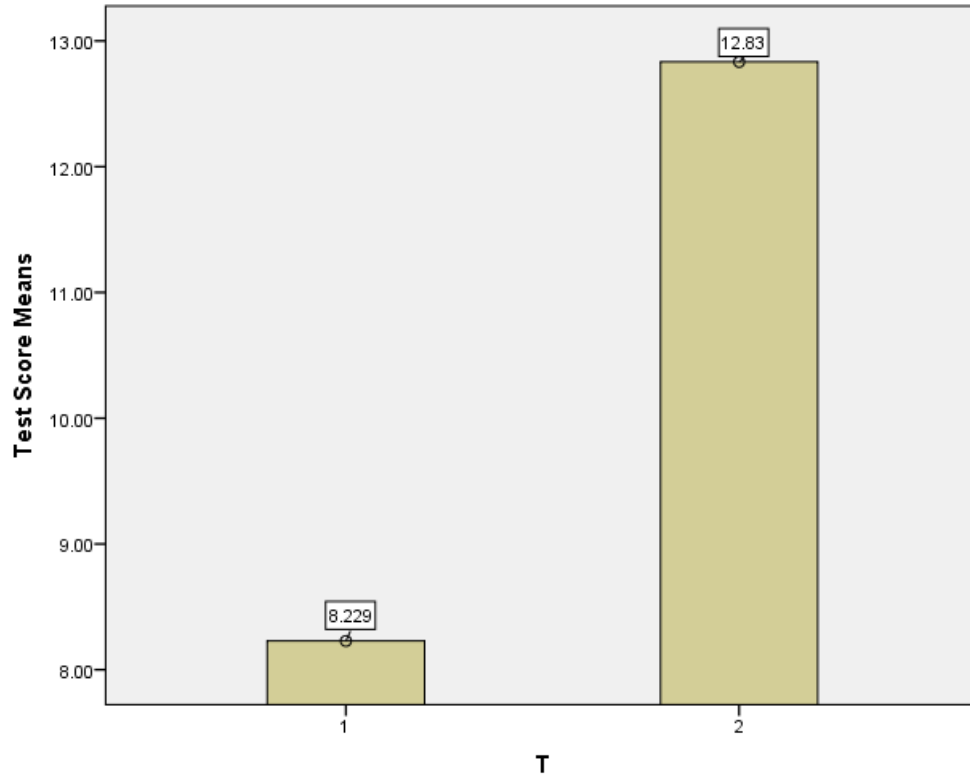


Figure 12 Mean scores on the Trials

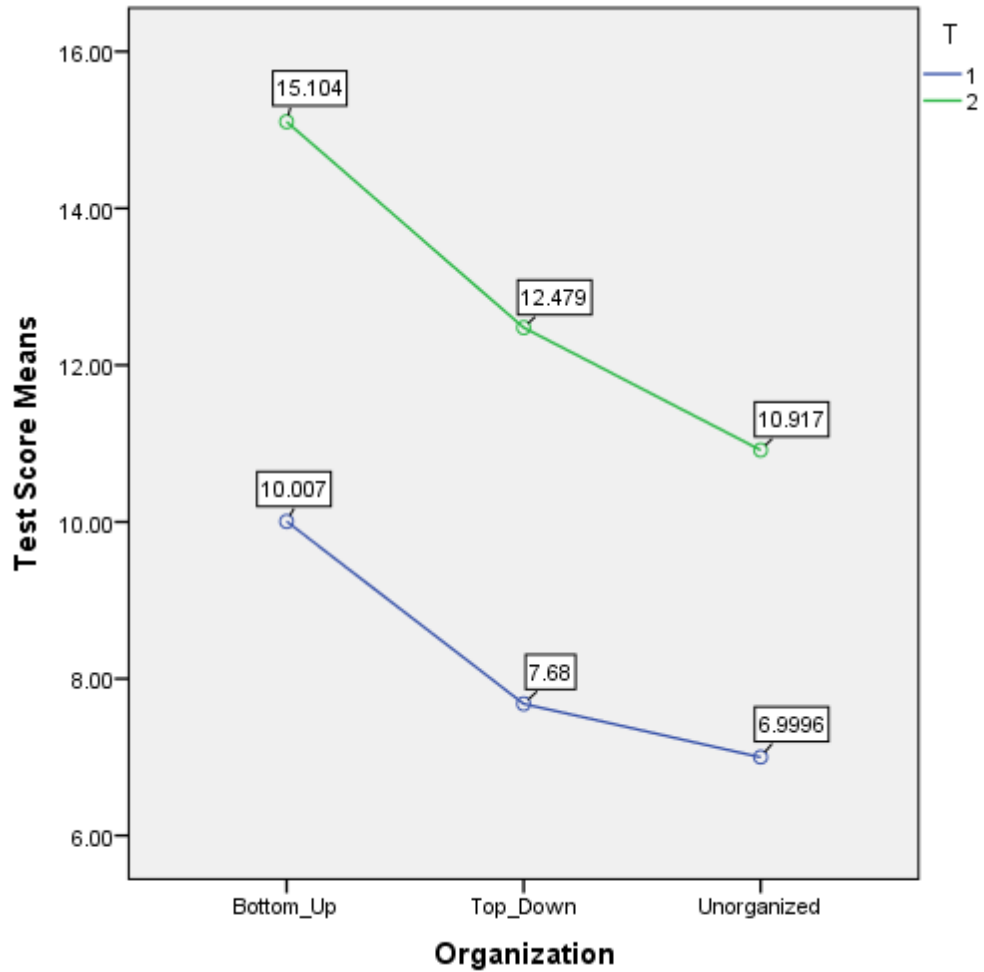


Figure 13 Mean Score on each level of Organization for the two trials

The outcome of the ANOVA with motivation removed yielded similar result for the factors Graphing, Organization, and Trials, as was the case, for the ANOVA incorporating the motivation factor.

### **Effects of Graphing and Organization on Gain**

To evaluate the effects of Graphing and Organization on gain scores, an ANOVA (2\*3) with two between subject factors (Graphing and Organization) was conducted. The dependent measure was the Training Gain, which is the difference between Post Test 2 and Post Test 1.

Table 10  
ANOVA Results on Gain between Trial 1 and 2

Source	SS	df	MS	F	Sig.	$\beta$
Total	548.302	71				
Graphing	6.408	1	6.408	0.816	.370	0.85
Organization	18.080	2	9.040	1.151	.323	0.75
Graphing* Organization	5.462	2	2.731	0.348	.708	0.89
Error	518.352	66	7.854			

The ANOVA resulted in no factors being significant in the score gain.

### **Effects of Graphing and Organization on Retention**

To evaluate the effects of Graphing and Organization on performance at Retention, a two-way between subjects ANOVA (2\*3) (Graphing, Organization) was conducted. The dependent measure was Retention measured as the difference between Test 2 Scores and Test 3 Scores.

Table 11  
ANOVA Results on Retention

Source	SS	df	MS	F	Sig.	$\beta$
Total	326.0	71				
Graphing	4.02	1	4.023	.838	.363	0.85
Organization	4.90	2	2.454	.511	.602	0.86
Graphing* Organization	.057	2	.028	.006	.994	0.94
Error	317.01	66	4.803			

There were no main and interaction effects as a result of the ANOVA analysis.

**Effects of Organization on Number of Nodes and Number of Links**

To evaluate the effect of Organization on Number of Nodes and Number of Links for the Graph group, a mixed effect ANOVA (3\*2) with one between subject factors (Organization) and one within subjects factor (Trials) was conducted on Number of Nodes and Links data.

Table 12  
ANOVA Results on Number of Nodes

Source	SS	df	MS	F	Sig.	$\beta$
Total	50801.50	71				
Between Subjects	49860.50	35				
Organization	4644.00	2	2322.00	1.695	.199	0.669
Error	45216.50	33	1370.19			
Within Subjects	941.00	36				
<b>Trials</b>	<b>624.22</b>	<b>1</b>	<b>624.22</b>	<b>77.831</b>	<b>.000</b>	<b>0.00</b>
Trials * Org.	52.11	2	26.05	3.249	.052	0.42
Error	264.66	33	8.02			

There were no main and interaction effects as a result of the ANOVA analysis on the Number of Nodes.

Table 13  
ANOVA Results on Number of Links

Source	SS	df	MS	F	Sig.	$\beta$
Total	56221.50	71				
Between Subjects	55221.50	35				
Organization	7775.08	2	3887.542	2.704	.082	0.50
Error	47446.41	33	1437.770			
Within Subjects	1000.00	36				
<b>Trials</b>	<b>672.22</b>	<b>1</b>	<b>672.222</b>	<b>72.396</b>	<b>.000</b>	<b>0.00</b>
Trials * Org.	21.36	2	10.681	1.150	.329	0.76
Error	306.41	33	9.285			

There were no main and interaction effects as a result of the ANOVA analysis on the Number of Links.

## CHAPTER 5: DISCUSSION

This section compiles the above findings into a discussion that relates to the results obtained. The experimental results show in general that the Organization factor had the greatest impact on learning abstract knowledge as presented in this experiment, with the Bottom Up approach having the most positive effect relative to Top Down and Unorganized conditions.

### **Effect of Motivation**

Motivation is typically an uncontrolled factor in computer based instruction experiments. In this experiment, however, it was introduced to control for any discriminable differences detected between subjects. The first analysis was conducted with Motivation as a factor, and it was determined that it was not a significant factor. Because motivation was insignificant, it was removed from the analysis, and only Graphing, Organization, and Trials were employed to determine any significance in terms of main and interaction effects. It also increased the degrees of freedom for error terms to increase the power of the F test conducted.

### **Effect of Organization**

As previously stated, Organization was found to be an important factor in learning abstract knowledge. This factor had three levels: Bottom-Up, Top-Down, and Unorganized. It was found that the Bottom-Up group outperformed every other group in



all measures involving test score performance. This provided a strong indication that the Bottom-Up organization is most suitable for abstract knowledge. On the other hand, neither the Top-Down nor the Unorganized levels were significant in the learning of abstract knowledge. There was no difference between these two organization levels on their contribution to learning abstract knowledge relative to the Bottom-Up level. It is surprising that even with some kind of organization in the Top-Down level, students still did not outperform the Unorganized group.

Consistent with Gagne and Briggs (1974), the Bottom-Up level seems the best content organization in terms of learning abstract knowledge as well as other forms of knowledge. However, Williams, Crumpton-Young , Furterer, and Rabelo (in progress) have found the Top-Down model promotes better learning when the content relates to task knowledge (how-to-do-it) and physical system knowledge (how-it-works) contrary to the Gagne and Briggs (1974) position. Similarly, Simon (1981) and Miyake (1986) also identified that a Top-Down organization of knowledge is evident when individuals report their understanding of physical information. The findings herein, on the other hand, do support the Gagne and Briggs (1974) position when acquiring abstract knowledge. Finally, no differences were found between the different Organization Levels on retention as measured by the difference between the last post-test scores.

### **Effect of Graphing**

As a result of this experimentation it was found that Graphing of abstract knowledge was not an important factor in the learning process. This comes as a surprise because in the Graphing group, students created graphs that lay out their understanding of

the subject matter requiring greater cognitive activity which in turn should support greater elaboration in depth, consistent with well learned information (Scheines and Sieg, in press). No differences were found between any of the organization conditions when graphing was involved. However, there was an increase in number of nodes (i.e. elaboration) and number of links (i.e. depth) between trials consistent with previous finding reported by Chi & Koeske (1983). This finding is explained by the fact that novices would find it difficult to identify relationships between the elements of the organization of abstract knowledge because it is not easy to relate to. Experts in the domain in question, on-the other hand, may easily identify the organization of knowledge and take advantage of the Graphing method when learning new knowledge related to the same domain. Anderson, Belleza, and Boyle (1993) have identified that novices have difficulty understanding the logical relationships among units of knowledge, which is the core of constructing a meaningful graph. By having difficulty understanding relationships, novice students may have difficulties creating graphs, and therefore do not benefit from the intended use of the Graphing method. Halford (2005) argued that novices unnecessarily increase the cognitive processing load, when trying to segment a complex task. In contrast, experts use conceptual chunking, which is a form of hierarchical decomposition of knowledge into compressed chunks that reduces the processing load. The graphing method requires the students to segment the content, which, based on Halford (2005), unnecessarily increases their cognitive workload. This explains why Graphing did not improve abstract knowledge learning in these novice students. Furthermore, Stokes, Kemper and Kite (1997) identified that more connections are formed and stronger ties are created in the knowledge base when a novice moves

through the learning process, when acquiring experience to become an expert. This identified a difference in creating relationships in the organization of knowledge between novices and experts, and therefore Graphing abstract knowledge may be difficult for the novice, and as a result may not fully benefit from it. On the other hand, the literature suggests that experts may be good candidates for the Graphing method, when adding new knowledge in their domain of expertise.

This research presents strong evidence that when novice students are presented with an abstract curriculum, they learn better in terms of test performance when the curriculum progresses from the more detailed to the more general. In conclusion, the results suggest that abstract knowledge be presented in a Bottom-Up hierarchical organization to facilitate the learning process.

As for future research, it is suggested that a group of novices over learn the content in a Bottom-Up fashion. Following this, the student would be required to report their understanding of the content to determine if it becomes organized in a Top-Down fashion after having well learned the content. If so, this would be consistent with how experts report their understanding of a domain as suggested by Shavelson (1972) and Miyake (1986). As another suggestion, it is proposed to add another condition which would consist of providing the novices with a prepared graph to assist them in forming relationships as opposed to requiring them to create their own graph. This would take the processing load off of the novices to determine if a graph would assist students in the learning process. We would also extend the delay time between last test trial and retention test to be 7 days instead of 48 hours and see if that will reveal any effect on retention test scores.



## **APPENDIX A: TOP DOWN CURRICULUM**

# **The New Role of the Industrial Engineer and Productivity**

The basic concept of client collaboration is a necessary condition for the new role of the IE as a designer of change processes. For one to be effective as an industrial engineer (in assisting a client to identify, evaluate, accept and then embrace productivity improvement), interpersonal skills are important. As described by Block there are three primary skill groups that a successful industrial engineer (IE) must master: (1) technical, (2) interpersonal, and (3) consulting.

## **Stages of development of the IE**

One way to view the professional development of the industrial engineer is to see it as a sequence of three stages.

### **Stage one: The Analytic Stage**

The IE is seen as technical expert, however not that familiar with line operations. He was not looked upon as expert in line operations, but looked upon as interference in line operations. The IE in stage one development focuses upon learning tools, techniques, methods, mathematical skills, experimental skills, and basic engineering concepts. Stage one is referred to as the analytic stage.

The traditional practice of industrial engineering has been based on a technical expert approach to solving problems. In years past, management was authoritarian in nature; and an authoritarian “technical expert” role for industrial engineering seemed consistent and compatible. However, the line organization did not always view the industrial engineer as an “expert” on “their” operations; operations people often would simply prefer to be left alone by management when trying to meet immediate goals, and industrial engineers were typically seen as an extension of management.

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## Stage two: The Problem Solving Stage

The focus here is problem solving. As a problem solver, the IE typically tells managers there is better way of doing things. This was not seen as very tactful. During stage two of development the IE is learning synthetic skills, learning to design systems, learning creative skills, learning how analysis fits into design-the problem solving stage.

Any effort today to improve operations in the future will typically interfere to some degree with present operations. For that reason, experienced industrial engineers are cognizant of operations personnel's focus on short-term goals (i.e., today's production) and the inconvenience that today's industrial engineering efforts impose on present operations. However, good operations personnel also know that today's operations are not good enough for the long run, and even if somewhat begrudgingly, they typically offer their assistance.

Another difficulty is that managers are not ready to embrace analysis and evaluation of their operations – Self Evaluation is inhibited. Therein lies a difficult problem for industrial engineers; what they do typically has a lot to do with running the business. The industrial engineer is often indirectly telling a manager that there is a better way of running the business, and such an inference, no matter how tactfully stated, is often received as inconsistent with the manager's self-image.

Equally unfortunate is the considerable national underutilization of industrial engineering as a productivity improvement resource simply because the managers who can approve improvement projects sometimes perceive an industrial engineering study as a potential threat to their self-image. It is therefore naïve to assume that all managers are psychologically ready and willing to embrace analysis and evaluation of their operations. A part of being open to change is being open to evaluation of present performance. This openness, unfortunately, is most frequently found among highly successful clients who are least in need of self-evaluation and self-change.

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## **Stage three: The Client Centered Stage**

During this stage the IE is learning how to deal with clients, how to design change processes which will involve clients actively in the creation of new methods and systems, learning that involvement and collaboration are the essential features of successful change.

Bringing out data which can be interpreted as “showing people up” or implying criticism may, of course, harden attitudes, increase defensiveness, and simply build further the resistance that must eventually be dealt with if change is to occur. Protection of participants, maintenance of psychological safety, and appropriate assurances of confidentiality are of major concern in this phase. Evaluation, especially self-evaluation, comes later. Ideally, the IE hopes to cultivate the attitude among client personnel that the facts are almost always friendly, that change is exciting rather than threatening, and that ultimately there is no need to be apprehensive about an open appreciation of the way things are going.

An added complication, therefore, is the realization that managers are not perfect and exhibit normal human faults. An additional malady afflicting managers, often born of their possession of power, results from a vicious cycle of “success breeds confidence” and “confidence breeds success” that sometimes concludes with ad hominem decision making. Ad hominem decision making relates to decisions which are biased by the manager’s personal feelings or prejudices rather than intellect.

## **The Role of the IE as Consultant for Change**

A lot of people know that there are industrial engineering consultants, but are all industrial engineers consultants? The answer is yes! You cannot be an industrial engineer and not be a consultant. Some industrial engineers are paid directly by the company as employees (internal consultants), whereas other industrial engineers are paid as independent contractors (external consultants), but they are all consultants. All industrial engineers try through the results of their efforts to persuade their clients (I.e., typically management) to adopt their recommendations. The assumption is that the client will be better off for having done so, and therein lies the justification for remunerating the efforts of industrial engineers. An industrial engineer not caring about how to consult is somewhat analogous to a fish not caring about how to swim.

The consultant who assumes a collaboration role enters the relationship with the notion that management issues can be dealt with effectively only by joining his or her specialized knowledge with the manager’s knowledge of the organization. Problem solving becomes a joint undertaking, with equal attention to both the technical issues and the human interactions involved in dealing with the technical issues. The key is client collaboration, involvement, ownership, and commitment, through group processes that unite the group toward a common goal.



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## Promoting Client Change

To be honest and fair to management, it needs to be stated that practicing industrial engineers ought to identify improvement opportunities and bring them to management's attention in such a way that the opportunity can be clearly understood by management. Not all practicing industrial engineers have been "stars" at meeting this need, nor has the profession stressed the need for industrial engineering education that prepares them to do so. This is the "bedside manner" part of successful practice that medical doctors are universally criticized for not having been adequately trained; the same criticism can and does apply to industrial engineers as well.

## The client change process

Morris has identified four strategies which have been used to promote client change and favors the fourth of these implementation strategies.

### Demonstration

- actually showing the client that one's recommendations will work as promised.

### Power, Politics

- getting top management support for change and relying on the power of top management to order that it occur.

### "Selling," Persuasion

- telling the client what advantages are to be found in the proposed changed or in the new system.

### Involvement, Participation, Collaboration

- acceptance is enhanced by making those whose behavior will be influenced by changes participates in the planning and design of those changes.

The second implementation strategy above is the traditional industrial engineering approach. Getting top management support, both in words and in actions, is not always easy; even when support is given it does not guarantee project success.

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# **The Role of the IE as Consultant and Manager of Performance Improvement**

In the practice of industrial engineering, a fundamental underlying goal is productivity improvement. Productivity improvement implies successful implementation, not merely a desire.

## **Performance Improvement Planning Process**

An important step in the performance management process is planning and implementation. Organizational productivity requires planning for improvements in performance at all levels of the organization and is typically not a traditional engineering problem. Technical industrial engineering is the easy part. Planning and implementation is really more a psychological problem than an engineering problem; therefore, if industrial engineering is to be successfully practiced in the future, industrial engineers will need to be better educated in the “psychology of implementation”.

A focal technique recommended to implement this Performance Improvement Planning Process is the Nominal Group Technique. The nominal group technique is applied to the development of action teams.

## **Nominal Group Technique – team efforts**

As does Sink and Tuttle, Morris proposes the use of the Nominal Group Technique in developing improvements in organizations. The Nominal Group Technique takes its name from the fact that it is a carefully designed, structured, group process which involves some participants in some activities as independent individuals rather than in the usual interactive mode of conventional groups. In its general form, it is a well-developed and tested method. Group processes such as the Nominal Group Technique will be more commonly employed in the future as industrial engineering becomes increasingly practiced in work team and management consensus environments. Industrial engineers will need to be trained to both lead and function within team efforts of the future to effect productivity throughout the organization.

## **Productivity**

### **Worker Productivity. /Efficiency**

Worker productivity and/or efficiency involve doing things well in the shortest possible time. It requires equipment, tools, training, materials, and worker motivation. Note that most behaviorist philosophy espouses the importance of motivation but often ignores equipment, tools, and methods under the assumption that the properly motivated direct labor employee, the “expert” for that operation, will identify all the necessary physical needs. It is management’s job to ensure that direct labor has the equipment, tools, methods, and motivation to be as productive as possible-something they will often choose to be if given a productive environment in which to work.

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## **Process Productivity/Effectiveness**

Process productivity and/or effectiveness means doing it right which in turn involves the right methods. Direct labor employees often “reach an accommodation” with their tasks. It may involve standing in ice water up to their ankles, but if they are used to it and it is non-threatening (i.e., they have learned to perform it successfully), they will typically resist any change. It is called RC factor-resistance to change. Any new method involves making an adjustment, risking failure or humiliation in the eyes of their peers. They may not want to admit that the method they were using was not the best.

## **Direct Cost**

Direct cost has traditionally been the concern of IE. It is hands on labor involved in production of product. Today direct cost only amounts to 3 to 8 percent of the total cost. Direct costs include materials for product and cost of labor to produce the product. These are variable costs. As work force size change and wages change material costs also change in the short term.

## **Non-Direct Labor/ Indirect Cost**

Non-direct and overhead labor consists of the costs associated with those individuals not directly involved in making a specific product. Traditionally, the field of industrial engineering began in manufacturing, and in that environment, Frederick W. Taylor invented the concept of manufacturing staff. This staff is an example of non-direct labor. Initially there were few staff members-a stock clerk or two, a maintenance man, a paymaster, an accountant, a salesman. Costs were low.

Today non-direct costs make up the lions share – typically fixed cost – costs which don’t change over a long period of time – costs for machinery, equipment, rent, tools, etc. as fixed costs increase so do indirect costs. Today, in the United States, it is not uncommon for the cost of nondirect and overhead labor to be eight times the direct labor cost of an operation. Typically, as fixed costs increase, so do indirect costs (e.g., maintenance).

## **APPENDIX B: BOTTOM UP CURRICULUM**

# Productivity

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## **APPENDIX C: UNORGANIZED CURRICULUM**

## The client change process

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## Stage three: The Client Centered Stage

During this stage the IE is learning how to deal with clients, how to design change processes which will involve clients actively in the creation of new methods and systems, learning that involvement and collaboration are the essential features of successful change.

Bringing out data which can be interpreted as “showing people up” or implying criticism may, of course, harden attitudes, increase defensiveness, and simply build further the resistance that must eventually be dealt with if change is to occur. Protection of participants, maintenance of psychological safety, and appropriate assurances of confidentiality are of major concern in this phase. Evaluation, especially self-evaluation, comes later. Ideally, the IE hopes to cultivate the attitude among client personnel that the facts are almost always friendly, that change is exciting rather than threatening, and that ultimately there is no need to be apprehensive about an open appreciation of the way things are going.

An added complication, therefore, is the realization that managers are not perfect and exhibit normal human faults. An additional malady afflicting managers, often born of their possession of power, results from a vicious cycle of “success breeds confidence” and “confidence breeds success” that sometimes concludes with *ad hominem* decision

making. Ad hominem decision making relates to decisions which are biased by the manager's personal feelings or prejudices rather than intellect.

===== Page 1 =====

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## **Worker Productivity. /Efficiency**

Worker productivity and/or efficiency involve doing things well in the shortest possible time. It requires equipment, tools, training, materials, and worker motivation. Note that most behaviorist philosophy espouses the importance of motivation but often ignores equipment, tools, and methods under the assumption that the properly motivated direct labor employee, the “expert” for that operation, will identify all the necessary physical needs. It is management’s job to ensure that direct labor has the equipment, tools, methods, and motivation to be as productive as possible-something they will often choose to be if given a productive environment in which to work.

## **Non-Direct Labor/ Indirect Cost**

Non-direct and overhead labor consists of the costs associated with those individuals not directly involved in making a specific product. Traditionally, the field of industrial engineering began in manufacturing, and in that environment, Frederick W. Taylor invented the concept of manufacturing staff. This staff is an example of non-direct labor. Initially there were few staff members-a stock clerk or two, a maintenance man, a paymaster, an accountant, a salesman. Costs were low.

Today non-direct costs make up the lions share – typically fixed cost – costs which don’t change over a long period of time – costs for machinery, equipment, rent, tools, etc. as fixed costs increase so do indirect costs. Today, in the United States, it is not uncommon for the cost of nondirect and overhead labor to be eight times the direct labor cost of an operation. Typically, as fixed costs increase, so do indirect costs (e.g., maintenance).

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## **Stages of development of the IE**

One way to view the professional development of the industrial engineer is to see it as a sequence of three stages.

### **Stage one: The Analytic Stage**

The IE is seen as technical expert, however not that familiar with line operations. He was not looked upon as expert in line operations, but looked upon as interference in line operations. The IE in stage one development focuses upon learning tools, techniques, methods, mathematical skills, experimental skills, and basic engineering concepts. Stage one is referred to as the analytic stage.

The traditional practice of industrial engineering has been based on a technical expert approach to solving problems. In years past, management was authoritarian in nature; and an authoritarian “technical expert” role for industrial engineering seemed consistent and compatible. However, the line organization did not always view the industrial engineer as an “expert” on “their” operations; operations people often would simply prefer to be left alone by management when trying to meet immediate goals, and industrial engineers were typically seen as an extension of management.

### **Nominal Group Technique – team efforts**

As does Sink and Tuttle, Morris proposes the use of the Nominal Group Technique in developing improvements in organizations. The Nominal Group Technique takes its name from the fact that it is a carefully designed, structured, group process which involves some participants in some activities as independent individuals rather than in the usual interactive mode of conventional groups. In its general form, it is a well-developed and tested method. Group processes such as the Nominal Group Technique will be more commonly employed in the future as industrial engineering becomes increasingly practiced in work team and management consensus environments. Industrial engineers will need to be trained to both lead and function within team efforts of the future to effect productivity throughout the organization.

---

## **The Role of the IE as Consultant and Manager of Performance Improvement**

In the practice of industrial engineering, a fundamental underlying goal is productivity improvement. Productivity improvement implies successful implementation, not merely a desire.

### **Stage two: The Problem Solving Stage**

The focus here is problem solving. As a problem solver, the IE typically tells managers there is better way of doing things. This was not seen as very tactful. During stage two of development the IE is learning synthetic skills, learning to design systems, learning creative skills, learning how analysis fits into design-the problem solving stage.

Any effort today to improve operations in the future will typically interfere to some degree with present operations. For that reason, experienced industrial engineers are cognizant of operations personnel's focus on short-term goals (i.e., today's production) and the inconvenience that today's industrial engineering efforts impose on present operations. However, good operations personnel also know that today's operations are not good enough for the long run, and even if somewhat begrudgingly, they typically offer their assistance.

Another difficulty is that managers are not ready to embrace analysis and evaluation of their operations – Self Evaluation is inhibited. Therein lies a difficult problem for industrial engineers; what they do typically has a lot to do with running the business. The industrial engineer is often indirectly telling a manager that there is a better way of running the business, and such an inference, no matter how tactfully stated, is often received as inconsistent with the manager's self-image.

Equally unfortunate is the considerable national underutilization of industrial engineering as a productivity improvement resource simply because the managers who can approve improvement projects sometimes perceive an industrial engineering study as a potential threat to their self-image. It is therefore naïve to assume that all managers are psychologically ready and willing to embrace analysis and evaluation of their operations. A part of being open to change is being open to evaluation of present performance. This openness, unfortunately, is most frequently found among highly successful clients who are least in need of self-evaluation and self-change.



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## **Performance Improvement Planning Process**

An important step in the performance management process is planning and implementation. Organizational productivity requires planning for improvements in performance at all levels of the organization and is typically not a traditional engineering problem. Technical industrial engineering is the easy part. Planning and implementation is really more a psychological problem than an engineering problem; therefore, if industrial engineering is to be successfully practiced in the future, industrial engineers will need to be better educated in the “psychology of implementation”.

A focal technique recommended to implement this Performance Improvement Planning Process is the Nominal Group Technique. The nominal group technique is applied to the development of action teams.

## **The New Role of the Industrial Engineer and Productivity**

The basic concept of client collaboration is a necessary condition for the new role of the IE as a designer of change processes. For one to be effective as an industrial engineer (in assisting a client to identify, evaluate, accept and then embrace productivity improvement), interpersonal skills are important. As described by Block there are three primary skill groups that a successful industrial engineer (IE) must master: (1) technical, (2) interpersonal, and (3) consulting.

## **The Role of the IE as Consultant for Change**

A lot of people know that there are industrial engineering consultants, but are *all* industrial engineers consultants? The answer is yes! You cannot be an industrial engineer and not be a consultant. Some industrial engineers are paid directly by the company as employees (internal consultants), whereas other industrial engineers are paid as independent contractors (external consultants), but they are all consultants. All industrial engineers try through the results of their efforts to persuade their clients (I.e., typically management) to adopt their recommendations. The assumption is that the client will be better off for having done so, and therein lies the justification for remunerating the efforts of industrial engineers. An industrial engineer not caring about how to consult is somewhat analogous to a fish not caring about how to swim.

The consultant who assumes a collaboration role enters the relationship with the notion that management issues can be dealt with effectively only by joining his or her specialized knowledge with the manager’s knowledge of the organization. Problem solving becomes a joint undertaking, with equal attention to both the technical issues and the human interactions involved in dealing with the technical issues. The key is client collaboration, involvement, ownership, and commitment, through group processes that unite the group toward a common goal.

---

## **Process Productivity/Effectiveness**

Process productivity and/or effectiveness means doing it right which in turn involves the right methods. Direct labor employees often “reach an accommodation” with their tasks. It may involve standing in ice water up to their ankles, but if they are used to it and it is non-threatening (i.e., they have learned to perform it successfully), they will typically resist any change. It is called RC factor-resistance to change. Any new method involves making an adjustment, risking failure or humiliation in the eyes of their peers. They may not want to admit that the method they were using was not the best.

## **Promoting Client Change**

To be honest and fair to management, it needs to be stated that practicing industrial engineers ought to identify improvement opportunities and bring them to management’s attention in such a way that the opportunity can be clearly understood by management. Not all practicing industrial engineers have been “stars” at meeting this need, nor has the profession stressed the need for industrial engineering education that prepares them to do so. This is the “bedside manner” part of successful practice that medical doctors are universally criticized for not having been adequately trained; the same criticism can and does apply to industrial engineers as well.

## **Direct Cost**

Direct cost has traditionally been the concern of IE. It is hands on labor involved in production of product. Today direct cost only amounts to 3 to 8 percent of the total cost. Direct costs include materials for product and cost of labor to produce the product. These are variable costs. As work force size change and wages change material costs also change in the short term.

## **APPENDIX D: INFORMED CONSENT FORM**

**Case Study – Human Information Processing System  
Saleh Al-Foraih**

**(Human Information Processing System) HIPS- based Abstract Knowledge  
Organizational Hierarchies**

**Informed Consent**

<b>Principal Investigator(s):</b>	Saleh Al-Foraih
<b>Faculty Supervisor:</b>	Kent Williams, PhD
<b>Investigation Site:</b>	University of Central Florida, IEMS.

**Introduction:** Researchers at the University of Central Florida (UCF) study many topics. To do this we need the help of people who agree to take part in a research study. You are being invited to take part in a research study which will include about 72 people at UCF. You have been asked to take part in this research study because you are an undergraduate student in the college of engineering. You must be 18 years of age or older to be included in the research study.

The person doing this research is Saleh Al-Foraih of UCF IEMS Department. Because the researcher is a graduate student, he is being guided by Dr. Kent Williams, a UCF faculty supervisor in IEMS Department.

**What you should know about a research study:**

- Someone will explain this research study to you.
- A research study is something you volunteer for.
- Whether or not you take part is up to you.
- You should take part in this study only because you want to.
- You can choose not to take part in the research study.
- You can agree to take part now and later change your mind.
- Whatever you decide it will not be held against you.
- Feel free to ask all the questions you want before you decide.

**Purpose of the research study:**

A Human Information Processing System (HIPS) is the internal component that is responsible of acquiring and assembling the knowledge in the human brain. Each person has a different Human Information Processing System, and therefore learns Abstract knowledge differently. The purpose of this study is to design an instructional method that facilitates teaching of abstract knowledge based on (HIPS), and to demonstrate its effectiveness through empirical research.

**What you will be asked to do in the study:** You will be randomly assigned in either a control group, or an experimental group. You will receive a group assignment before starting the experiment.

You will be asked to fill a motivation screening form. You will be asked to take a pretest afterward. You will be asked to answer the questions, you will be asked to complete all of the questions, and, if you do not know an answer, to please write “don’t know”.

Upon completion of the pretest, you will be asked to log on to your account in Webcourses for the content associated with your condition to start the experiment. This phase of the study involves 3 experimental trials, each lasting approximately 30 to 45 minutes. The instructions for the participants are the same for each trial and each test. You are allowed to study the content at your own pace and have an unlimited amount of time for studying the material on Webcourses. When you finish reading, the computer system will instruct you to press “finish” to end the reading session. If you are a participant in the control group, you will be directed to a posttest in Webcourses, while if you are a participant in the experimental groups, you will be provided with a paper and pencil to draw a graphical representation of your understanding of the content you have just read. The participants in the experimental group will be provided with direction on the drawing phase, for which they will have unlimited time to complete. I, the principal investigator, will be present during all phases of the experiment to help you by answering questions about the experiment procedures. After completion of the drawing phase, you will be directed to take a posttest in Webcourses. Upon completion of the posttest, trial 1 is terminated, and regardless of your group assignment, you again will be asked to re-open Webcourses instructional system for the appropriate content. Upon completion of the posttest in trial 3, you will have completed the experiment. During the test, participants do not have access to the reading content. The test is the same test for each trial. Study time, drawing time, and test time are recorded automatically by the computer system for each of the three trials.

**Location:** Simulation Lab, Room 326, Engineering II Building.

**Time required:** We expect that you will be in this research study for 2 hours and 25 minutes outside of class time.

**Risks:**

There are no reasonably foreseeable risks or discomforts involved in taking part in this study.

**Benefits:**

There are no expected benefits to you for taking part in this study.

**Compensation or payment:**

There is no payment to you for taking part in this study. Extra credit may be provided at the discretion of the course instructor.

Please note that when an instructor offers extra credit to students for participating in research, the instructor **MUST** provide an alternate assignment of comparable time and effort for students who wish to earn extra credit, but who do not want to take part in the research.

**Confidentiality:** We will limit your personal data collected in this study to people who have a need to review this information. We cannot promise complete secrecy. Organizations that may inspect and copy your information include the IRB and other representatives of UCF.

**Study contact for questions about the study or to report a problem:** If you have questions, concerns, or complaints, or think the research has hurt you, talk to Saleh Al-Foraih, Graduate Student, IEMS Department, College of Engineering and Computer Science, (407) 823-1094 or Dr. Kent Williams, Faculty Supervisor, IEMS Department at (407) 823-1094 or by email at [kent.williams@ucf.edu](mailto:kent.williams@ucf.edu).

**IRB contact about your rights in the study or to report a complaint:** Research at the University of Central Florida involving human participants is carried out under the oversight of the Institutional Review Board (UCF IRB). This research has been reviewed and approved by the IRB. For information about the rights of people who take part in research, please contact: Institutional Review Board, University of Central Florida, Office of Research & Commercialization, 12201 Research Parkway, Suite 501, Orlando, FL 32826-3246 or by telephone at (407) 823-2901. You may also talk to them for any of the following:

- Your questions, concerns, or complaints are not being answered by the research team.
- You cannot reach the research team.
- You want to talk to someone besides the research team.
- You want to get information or provide input about this research.

## **APPENDIX E: LOCUS OF CONTROL TEST**

## The Locus of Control

Questions: 13

### Instructions

Click on the button next to the one statement that best describes how you feel. You can always go back to a question and change your answer.

---

1. (Points: 1)

- a. Many of the unhappy things in people's lives are partly due to bad luck
- b. People's misfortunes result from the mistakes they make.

[Save Answer](#)

---

2. (Points: 1)

- a. One of the major reasons why we have wars is because people don't take enough interest in politics.
- b. There will always be wars, no matter how hard people try to prevent them.

[Save Answer](#)

---

3. (Points: 1)

- a. In the long run, people get the respect they deserve in this world.
- b. Unfortunately, an individual's worth often passes unrecognized no matter how hard he tries.

[Save Answer](#)

---



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**4.** (Points: 1)

- a. The idea that teachers are unfair to students is nonsense.
- b. Most students don't realize the extent to which their grades are influenced by accidental happenings.

[Save Answer](#)

---

**5.** (Points: 1)

- a. Without the right breaks, one cannot be an effective leader.
- b. Capable people who fail to become leaders have not taken advantage of their opportunities.

[Save Answer](#)

---

**6.** (Points: 1)

- a. No matter how hard you try, some people just don't like you.
- b. People who can't get others to like them don't understand how to get along with others.

[Save Answer](#)

---

**7.** (Points: 1)

- a. I have often found that what is going to happen will happen.
- b. Trusting to fate has never turned out as well for me as making a decision to take a definite course of action.

[Save Answer](#)

---

**8.** (Points: 1)

- a. In the case of the well prepared student, there is rarely, if ever, such a thing as an unfair test.
- b. Many times exam questions tend to be so unrelated to course work that studying is really useless.

[Save Answer](#)

---

**9.** (Points: 1)

- a. Becoming a success is a matter of hard work; luck has little or nothing to do with it.
- b. Getting a good job depends mainly on being in the right place at the right time.

[Save Answer](#)

---

**10.** (Points: 1)

- a. The average citizen can have an influence in government decisions.
- b. This world is run by the few people in power, and there is not much the little guy can do about it.

[Save Answer](#)

---

**11.** (Points: 1)

- a. When I make plans, I am almost certain that I can make them work.
- b. It is not always wise to plan too far ahead because many things turn out to be a matter of luck anyway.

[Save Answer](#)

---

**12.** (Points: 1)

- a. In my case, getting what I want has little or nothing to do with luck.
- b. Many times we might just as well decide what to do by flipping a coin.

[Save Answer](#)

---

**13.** (Points: 1)

- a. What happens to me is my own doing.
- b. Sometimes I feel that I don't have enough control over the direction my life is taking.

[Save Answer](#)

---

## Test Scores

Question	Answer Scores
1	a. 1
	b. 0
2	a. 0
	b. 1
3	a. 0
	b. 1
4	a. 0
	b. 1
5	a. 1
	b. 0
6	a. 1
	b. 0
7	a. 1
	b. 0
8	a. 0
	b. 1
9	a. 0
	b. 1
10	a. 0
	b. 1
11	a. 0
	b. 1
12	a. 0
	b. 1
13	a. 0
	b. 1

## **APPENDIX F: TEST AND ANSWERS**

## Test

Questions: 18

---

1. (Points: 1)

There are three primary skill groups that a successful industrial engineer (IE) must master: technical, interpersonal, and .

[Save Answer](#)

---

2. (Points: 1)

decision making relates to decisions which are biased by the manager's personal feelings or prejudices rather than intellect.

[Save Answer](#)

---

3. (Points: 1)

The line organization did not always view the industrial engineer as  on "their" operations.

[Save Answer](#)

---

4. (Points: 1)

- (For questions 4,5,and 6) One way to view the professional development of the industrial engineer is to see it as a sequence of three stages:

The first stage is  stage.

[Save Answer](#)

---

5. (Points: 1)

The second stage is the  stage.

[Save Answer](#)

---

6. (Points: 1)

The third stage is the  stage.

[Save Answer](#)

---

7.(Points: 1)

During the  stage the IE is learning how to deal with clients, how to design change processes which will involve clients actively in the creation of new methods and systems.

[Save Answer](#)

---

8. (Points: 1)

Actually showing the client that one's recommendations will work as promised is the definition of .

[Save Answer](#)

---

9. (Points: 1)

In the  stage, the IE focuses upon learning tools, techniques, methods, mathematical skills, experimental skills, and basic engineering concepts.

[Save Answer](#)

---

10. (Points: 1)

Worker productivity and/or efficiency involves doing things well in the shortest possible time. It requires equipment, tools, training, and .

[Save Answer](#)

---

11. (Points: 1)

Labor Employees may not want to admit that the method they were using was not the best, because they will typically resist any change.

[Save Answer](#)

---

12. (Points: 1)

Overhead labor consists of the costs associated with those individuals  involved in making a specific product.

[Save Answer](#)

---

**13.** (Points: 1)

One of the roles of the IE to assist clients is to identify, evaluate, accept and then embrace  improvement.

Save Answer

---

**14.** (Points: 1)

One of the roles of the IE is to be familiar with line operations prior to the  stage.

Save Answer

---

**15.** (Points: 1)

- (For questions 15,16,17,and 18) Morris has identified four strategies which have been used to promote client change:

is actually showing the client that one's recommendations will work as promised.

Save Answer

---

**16.** (Points: 1)

,  is getting top management support for change and relying on the power of top management to order that it occur.

Save Answer

---

**17.** (Points: 1)

and  is telling the client what advantages are to be found in the proposed changed or in the new system.

Save Answer

---

**18.** (Points: 1)

, , and  promote acceptance which is enhanced by making those whose behavior will be influenced by changes to participate in the planning and design of those changes.

Save Answer

---



Answer Key

Question	Answer	Scoring Matrix
1	Consulting	1
2	Ad hominem	1
3	Expert	1
4	Analytical	1
5	Problem Solving	1
6	Client Centered	1
7	Client Centered	1
8	Demonstration	1
9	Analytical	1
10	Worker Motivation	1
11	Direct	1
12	Indirectly	1
13	Productivity	1
14	Problem Solving	1
15	Demonstration	1
16	Power, Politics	1= 0.5, 2= 0.5
17	Selling, Persuasion	1= 0.5, 2= 0.5
18	Involvement, Participation, Collaboration	1= 0.33, 2= 0.33, 3= 0.33

## **APPENDIX G: GRPHING INSTRUCTIONS**

## Graphing Instructions

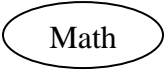
This section will provide you with the instructions on how to create a graphical representation of your understanding of a text you will be reading in the next section.

### Definitions

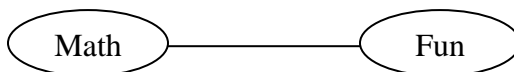
**Concepts** are defined as objects, events, situations, or properties that possess common descriptions. An example of a concept would be “Ball” as a set of objects that share the same characteristics such as “round” and “bouncy”.

**Propositions** are defined as relationships between concepts.

An example of a proposition would be the sentence “Math is Fun” which expresses the relationship between the concept “Math” and the concept “Fun”.

**Nodes** are graphical representations of concepts. A node is represented by an ellipsoid with the name of the concept. 

**Links** are connections between the nodes that represent relationships between those nodes. A link is represented by an arch to indicate an association between the two nodes.



## **Graphing Instructions**

The following are the steps required to create a graphical representation of the understanding of the text material.

### **Step 1:**

For each section of the material, read the text and select the key concept(s) for understanding the meaning of the text. List these concepts.

### **Step 2:**

For each listed concept in the previous step, draw a node with the concept name inside the node. Do not draw duplicate nodes.

### **Step 3:**

For each section in the text, use a link between nodes to indicate if there is a relationship between the concepts as described in that section.

### **Step 4:**

Try to link concepts between the different sections of the text based on your understanding of the text material as a whole.

## **Graphing Example**

Text material

Sharks are a group of fish characterized by a cartilaginous skeleton, five to seven gill slits on the sides of the head, and pectoral fins that are not fused to the head. Most sharks are carnivorous, and some species, eat almost anything.

Sea lions are pinnipeds characterized by long foreflippers, short, thick hair and the ability to walk on all fours. Some species of sea lion are readily trainable and are often a popular attraction at zoos and aquariums. Some species are prey to predator fish like sharks, in open waters.

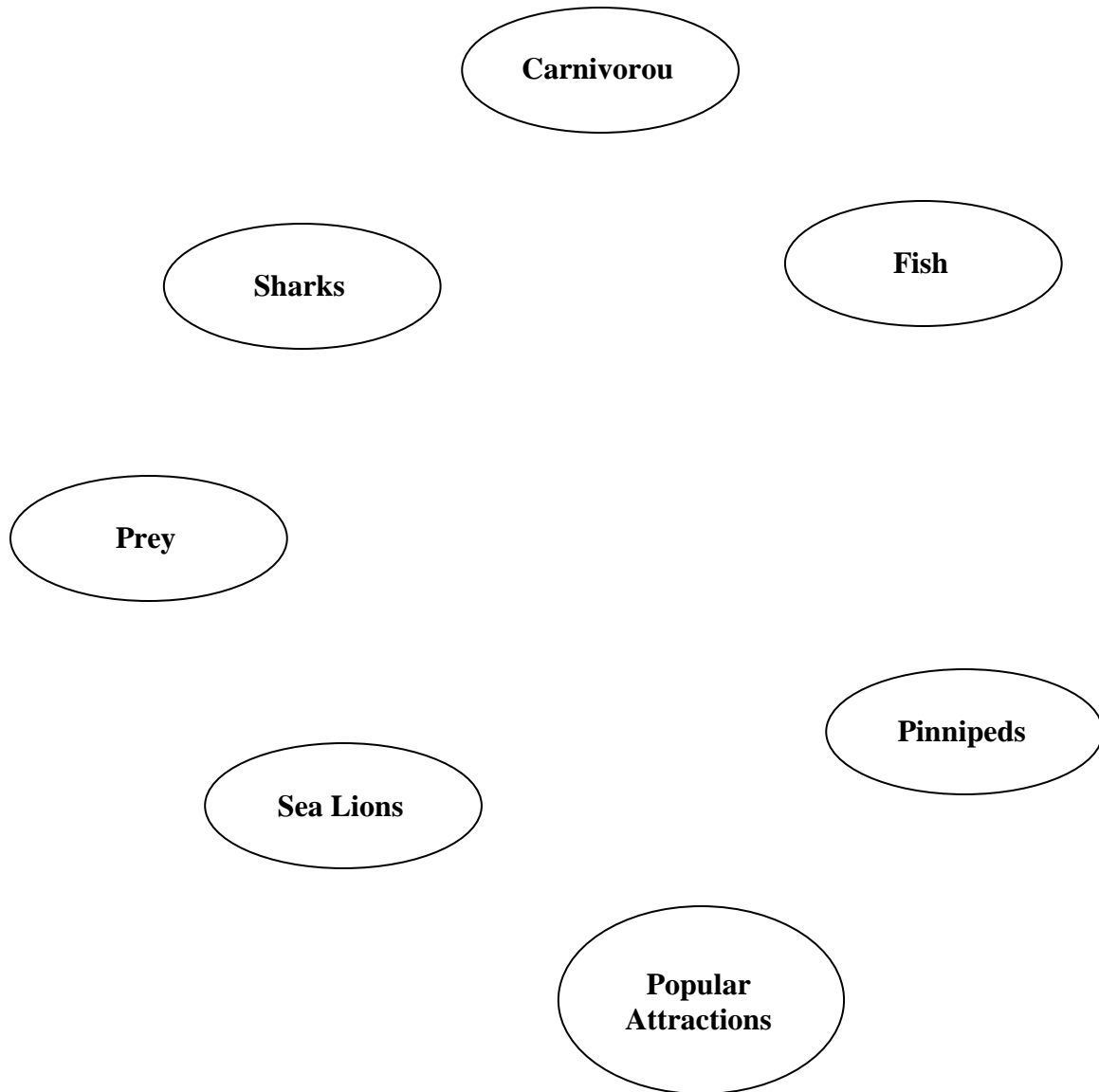
Step 1:

Section 1 key concepts: Sharks, Fish, carnivorous

Section 2 key concepts: Sea Lions, Pinnipeds, Popular Attractions, Prey

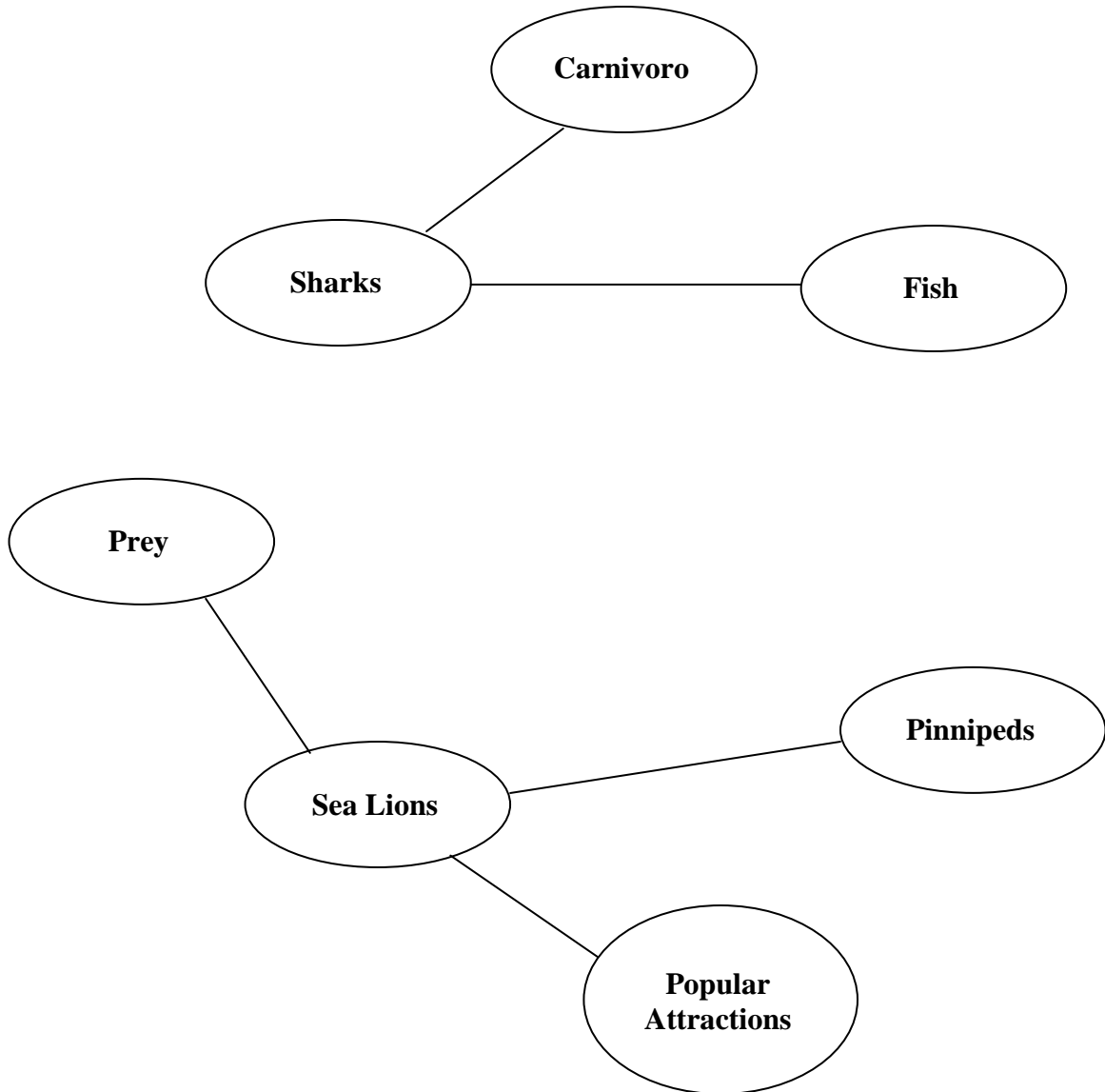
Step 2:

The following nodes represent key concepts:



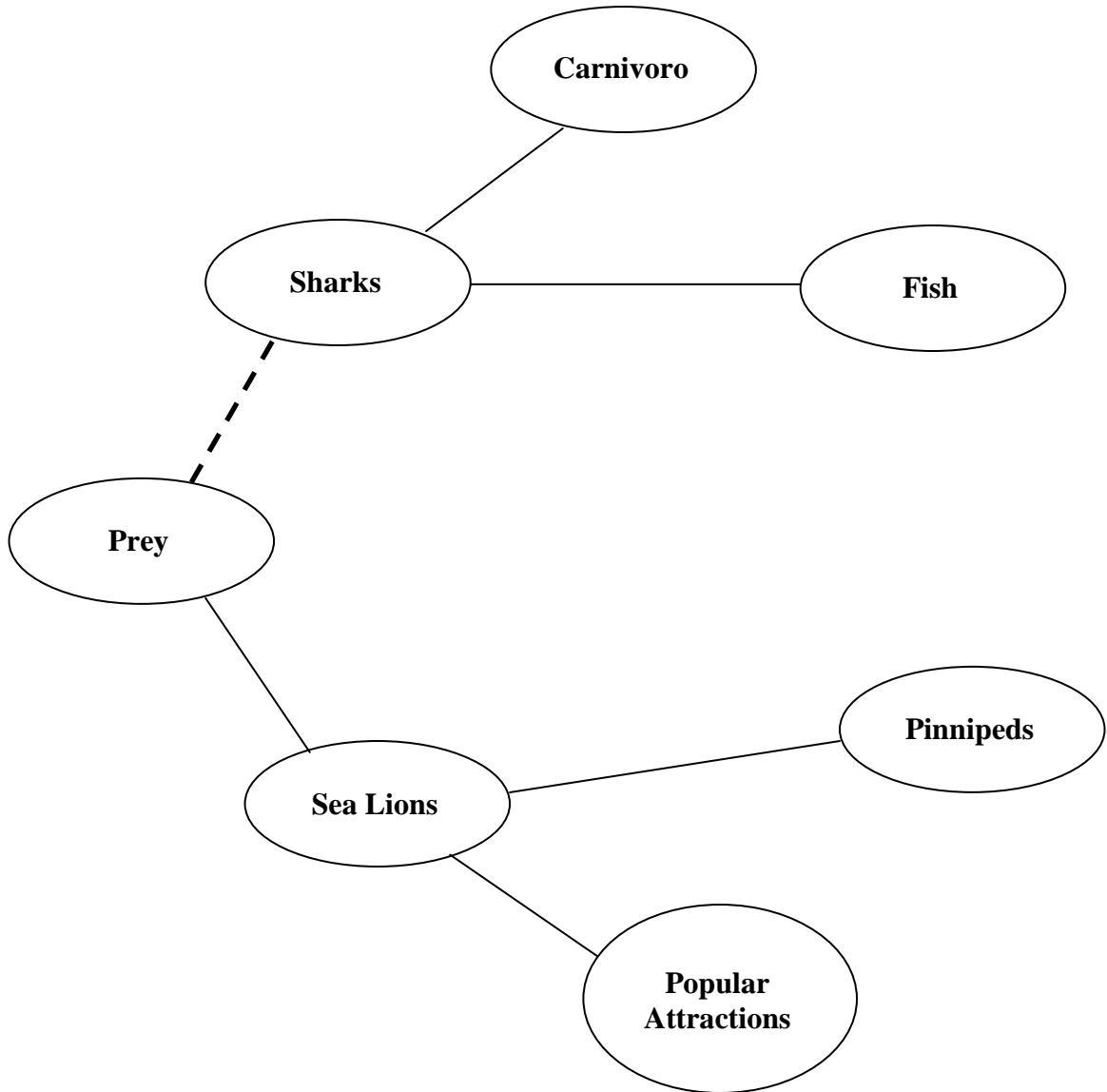
Step 3:

Using links between nodes to show important relationships between the concepts



Step 4:

Note that a new link between “Sharks” and “Prey” has been created based on understanding of both sections.





## **APPENDIX H: GRPHING EXERCISE**

A computer is a general purpose device which can be programmed to carry out arithmetic or logical operations. Since a sequence of operations can be readily changed, the computer can solve more than one kind of problem.

The processing unit is a component that carries out arithmetic and logic operations. It executes a series of instructions that make it read, manipulate and then store data. A computer consists of at least one processing unit.

## **APPENDIX I: IRB APPROVAL OF HUMAN RESEARCH**



University of Central Florida Institutional Review Board  
 Office of Research & Commercialization  
 12201 Research Parkway, Suite 501  
 Orlando, Florida 32826-3246  
 Telephone: 407-823-2901 or 407-882-2276  
[www.research.ucf.edu/compliance/irb.html](http://www.research.ucf.edu/compliance/irb.html)

### Approval of Human Research

From: **UCF Institutional Review Board #1  
 FWA00000351, IRB00001138**

To: **Saleh M. Al-Foraih**

Date: **June 05, 2012**

Dear Researcher:

On 6/5/2012 the IRB approved the following human participant research until 6/4/2013 inclusive:

Type of Review: Submission Correction for UCF Initial Review Submission Form  
 Expedited Review Category # 7  
*This approval includes a Waiver of Written Documentation of Consent*

Project Title: HIPS-based Abstract Knowledge Organizational Hierarchies  
 Investigator: Saleh M. Al-Foraih  
 IRB Number: SBE-12-08364  
 Funding Agency:  
 Grant Title:  
 Research ID: N/A

The Continuing Review Application must be submitted 30days prior to the expiration date for studies that were previously expedited, and 60 days prior to the expiration date for research that was previously reviewed at a convened meeting. Do not make changes to the study (i.e., protocol, methodology, consent form, personnel, site, etc.) before obtaining IRB approval. A Modification Form **cannot** be used to extend the approval period of a study. All forms may be completed and submitted online at <https://iris.research.ucf.edu>.

If continuing review approval is not granted before the expiration date of 6/4/2013, approval of this research expires on that date. When you have completed your research, please submit a Study Closure request in iRIS so that IRB records will be accurate.

Use of the approved, stamped consent document(s) is required. The new form supersedes all previous versions, which are now invalid for further use. Only approved investigators (or other approved key study personnel) may solicit consent for research participation. Participants or their representatives must receive a copy of the consent form(s).

In the conduct of this research, you are responsible to follow the requirements of the Investigator Manual.

On behalf of Sophia Dziegielewski, Ph.D., L.C.S.W., UCF IRB Chair, this letter is signed by:

Signature applied by Patria Davis on 06/05/2012 10:56:06 AM EDT

IRB Coordinator

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