THE EFFECTS OF 3D INTERACTIVE ANIMATED GRAPHICS ON STUDENT LEARNING AND ATTITUDES IN COMPUTER-BASED INSTRUCTION

By

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Dedication

This dissertation is dedicated to Daniel.

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Abstract

Visuals are most extensively used as instructional tools in education to present spatially-based information. Recent computer technology allows the generation of 3D animated visuals to extend the presentation in computer-based instruction. Animated visuals in 3D representation not only possess motivational value that promotes positive attitudes toward instruction but also facilitate learning when the subject matter requires dynamic motion and 3D visual cue. In this study, three questions are explored: (1) how 3D graphics affects student learning and attitude, in comparison with 2D graphics ; (2) how animated graphics affects student learning and attitude, in comparison with static graphics ; and (3) whether the use of 3D graphics, when they are supported by interactive animation, is the most effective visual cues to improve learning and to develop positive attitudes.

A total of 145 eighth-grade students participated in a 2x2 factorial design study. The subjects were randomly assigned to one of four computer-based instructions: 2D static; 2D animated; 3D static; and 3D animated. The results indicated that: (1) Students in the 3D graphic condition exhibited more positive attitudes toward instruction than those in the 2D graphic condition. No group differences were found between the posttest score of 3D graphic condition and that of 2D graphic condition. However, students in the 3D graphic condition took less time for information retrieval on posttest than those in the 2D graphic condition. (2) Students in the animated graphic condition exhibited slightly

more positive attitudes toward instruction than those in the static graphic condition. No group differences were found between the posttest score of animated graphic condition and that of static graphic condition. However, students in the animated graphic condition took less time for information retrieval on posttest than those in the static graphic condition. (3) Students in the 3D animated graphic condition exhibited more positive attitudes toward instruction than those in other treatment conditions (2D static, 2D animated, and 3D static conditions). No group differences were found in the posttest scores among four treatment conditions. However, students in the 3D animated condition took less time for information retrieval on posttest than those in other treatment conditions.

Chapter 1

The Problem

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1.1 Introduction

This chapter describes a statement of the problem situation, the purpose, and the significance of the present study. Research questions are also presented, followed by a brief outline of the methodology and the limitations/delimitations. Next, some selected terms are defined to clarify the meaning.

As a result of the dynamic development of computer technology and steady decline of computer prices, computer usage and application have become commonplace in our society. One rapidly growing field of computer-related activity is the computer-based instruction in the school system. The majority of these computer-based instructions in use today utilize computer graphics to lessen the tension traditionally associated with computer usage. One of the most distinctive graphics features to gain popularity in the recent years is the three-dimensional animated visual. This study investigates the effect of the use of three-dimensional animated graphics on student learning and attitudes toward instruction in computer-based instruction.

1.2 The Problem Situation

Educators all over the country are witnessing the trend toward the use of computers to facilitate teaching and learning processes. Computer-based instruction (CBI) is hailed as a major development in instruction at the individual level. Studies have found that computer-based instruction enhances learning and fosters positive attitudes toward instruction (Askar, Yavuz, & Koksal, 1992; Geban, Askar, Oakan, 1992; Kulik, 1994; Kulik & Kulik, 1991;). The incorporation of innovative capabilities such as computer graphics, previously unavailable on text-based instruction, yields new challenges to traditional educational practices.

The significance of computer-generated graphics cannot be dismissed because it offers a key element of conceptual understanding, visualization, which had formerly been limited by computer technology. Visualization is a powerful instructional medium which can be used to facilitate learning as a cognitive strategy (West, farmer, & Wolff, 1991). Several theories and researches support the use of instructional visuals (Clark & Paivio, 1991; Craik & Lockhart, 1972; Kulhavy, Stock, & Caterino, 1994; Kulhavy, Stock, Peterson, Pridemore, & Klein, 1992; Mayer, 1997; Mayer, Steinhoff, Bower, & Mars, 1995; Paivio, 1990, 1991; Plass, Chun, Mayer, & Leutner, 1998; Rittschof, Stock, Kulhavy, Verdi, & Doran, 1994; Schnotz, Picard, & Hron, 1993; Schnotz, Picard, & Henninger, 1994; Verdi, Johnson, Stock, Kulhavy, & Whitman-Ahern, 1997). Studies have proven that the use of static visuals such as maps, diagrams, or illustrations is helpful to enhance learning (Kulhavy et al., 1992, 1994; Verdi, Johnson, Stock, Kulhavy, & Whitman-Ahern, 1997; Mayer & Gallini, 1990; Purnell & Solman 1991; Winn, Li, & Schill, 1991). Dwyer (1994) generalized from his experiments that student achievement improves when instructional visual cues are integrated into computer-based instruction.

It is worth considering the application of animated visuals as well as traditional static visuals if technological tools such as computers can make it feasible in designing instruction. Computer animation is the process of artificially creating visual movement through the use of a computer (Park & Gittleman, 1992). Animated graphics is generated by presenting a series of slightly different still pictures and gives the viewer the illusion of movement. One graphic feature which has been popular in computer-based instruction is animation. Designers of computer-based instruction need to take advantage of the computer's unique features like animation when developing educational software.

Animated visual, which is a subset of instructional visuals, has powerful instructional potential. If the learning task requires the dynamic movement of objects, animated visuals rather than static visuals, should be provided as learning aids (Rieber, 1990a; Park & Hopkins, 1993). Numerous studies have consistently indicated positive effects in learning aided by computer-generated animation, when the learning material demands dynamic motion (Baek & Layne, 1988; Chanlin & Chan, 1996; Mayer, 1994, 1997; Mayer & Anderson, 1991, 1992; Mayer & Sims, 1994; Mayton, 1990; Park & Gittleman, 1992; Pookay & Szabo, 1995; Rieber, 1990a, 1990b, 1991a, 1996; Rieber, Boyce, & Assad, 1990; Rieber & Kini, 1991; Thompson & Riding, 1990; White, 1993). Most of these researches have focused on the learning outcomes rather than attitudinal gains and have employed only two-dimensional graphics.

The use of animated graphics in computer-based instruction deserves attention of instructional designers due to its attitudinal and motivational value, important factors in learning. Students who have high motivation and positive attitudes toward instruction tend to engage in learning activity, to exert more efforts, and then to learn more. Instructional designers should utilize instructional tools to stimulate motivation and to develop positive attitudes. The affective response usually occurs more frequently to visual stimuli than to verbal stimuli (Paivio, 1991). Affective outcomes as well as cognitive outcomes are attained from the animated graphics in computer-based instruction. Some researchers showed the motivational values of animated graphics in computer-based instruction (Chanlin & Chan, 1996; Rieber, 1991b). However, there is little research that has systematically investigated the affective function of graphics in computer-based instruction.

Affective function of computer application is regarded as important in science teaching. Computers can encourage the development of positive attitudes toward science instruction as well as enhance student performance in learning science (Geban, Askar, Oakan, 1992; Hounshell & Hill, 1989). Computer-based instruction which gives control to the learners (learner controlled instruction) improves learning and fosters more positive attitudes as opposed to the computer-based instruction in which learners just follow sequences predetermined by the program (program control instruction) (Hannafin & Sullivan, 1995). Geban et al. (1992) showed that computer-simulation approaches was more effective in producing positive attitudes toward chemistry learning than traditional instruction. In this sense, science teachers and school officials need to consider the integration of modern computer technology into the classroom.

To date, most research indicating positive effects of animation in computer-based instruction were interested in teaching abstract science concepts (Baek & Layne, 1988; Chanlin & Chan, 1996; Mayer, 1994, 1997; Mayer & Anderson, 1991, 1992; Mayer & Sims, 1994; Mayton, 1990; Park & Gittleman, 1992; Pookay & Szabo, 1995; Rieber, 1990a, 1990b, 1991a, 1996; Rieber, Boyce, & Assad, 1990; Rieber & Kini, 1991; Thompson & Riding, 1990; White, 1993). However, inadvertent and indiscriminate use of animation in computer-based instruction does not guarantee positive effects (Park & Hopkins, 1993; Park & Gittleman, 1992; Rieber, 1990a). The prerequisite of applying animation in instruction is that the learning task should require dynamic motion corresponding to the attributes of animation (Rieber, 1990a). Instructional designers need to be careful in applying the animation technique selectively and strategically where the learning task merits it. One designing strategy has been suggested by Rieber (1990a), called visual grouping. This strategy helps the learners attend to relevant animated visual cues. It divides one instructional screen frame into several visual groups and then presents them one at a time, which keeps the learners from being distracted. The present study conducted an experiment using the computer-based instruction designed to embrace those design considerations.

Not only animation but also three-dimensional realistic images as visual analogy cues can positively influence learning. Some researchers have utilized three-dimensional visuals to improve student learning (Hakerem, Dobrynina, & Shore, 1993; Seddon, Eniaiyehu, & Jusoh, 1984; Susten, Kastella, & Conley, 1991; Tretheway, 1991; Williamson, 1992). The learning material they used was human anatomy or molecular structures, which requires 3D visualization for full understanding.

Interactiveness is regarded as one of the most important contributions to computer-based instruction (Rieber, 1990a). Animated graphics that continuously changes in response to the learner's input is provided to the learner in highly interactive computer-based instruction. This interactive function is well utilized in real-time simulations and virtual reality applications. Virtual reality is a new computer-generated environment which enables us to experience a multisensory, real-time interactive, three-dimensional reality (Franchi, 1995; McLellan, 1993; Ferrington & Loge, 1992). This innovative technology generates a three-dimensional realistic representation of our physical world, which provides the user with perceived realism and immerses them into the virtual world.

Although virtual reality deals with a multisensory system, its emphasis is on visualization with three-dimensional graphics. More research needs to be conducted to validate the efficacy of virtual reality in education, while some empirical research in this area (Ainge, 1996; Merickel, 1990, 1992; Regian, Shebilske, & Monk, 1992) have indicated positive effects of three-dimensional visual representation on learning and training. None of the researchers have compared the differences between three-dimensional representation of virtual reality technology and the conventional two-dimensional representation, under two distinct conditions, animated condition or static condition. Accordingly, it is worth investigating the differential effects of two representations under two distinct conditions.

1.3 Purpose and Significance of the Study

This research investigated the value of computer graphics in computer-based science instruction to improve learning and to develop positive attitudes. The purpose of this study is to examine the effects of animated graphics and three-dimensional graphics on student learning and attitudes. It compared the student's scores on achievement tests, attitudinal responses, and speed of information retrieval on the achievement test, each collected under four distinct conditions : two-dimensional static graphics; two-dimensional animated graphics; three-dimensional static graphics; and three-dimensional animated graphics.

Three questions are to be explored in this study : (1) how three-dimensional graphics affects student learning, attitude toward instruction, and information retrieval time, in comparison with two-dimensional graphics; (2) how animated graphics affects student learning, attitude toward instruction, and information retrieval time, in comparison with static graphics; and (3) whether three-dimensional graphics, when they are supported by animation (virtual reality technology), is the most effective visual cues to improve learning, to develop positive attitudes, and to have the students retrieve the information fast. The present study will be an extension of the empirical research and theories previously developed for supporting instructional visuals.

Even though research findings have steadily pointed out the potential of computer-generated animation in learning (Baek & Layne, 1988; Chanlin & Chan, 1996; Mayer, 1994, 1997; Mayer & Anderson, 1991, 1992; Mayer & Sims, 1994; Mayton, 1990; Park & Gittleman, 1992; Pookay & Szabo, 1995; Rieber, 1990a, 1990b, 1991, 1996; Rieber & Kini, 1991; Thompson & Riding, 1990; White, 1993), those findings were limited to cognitive outcomes of animated graphics ignoring affective outcomes. The present study considered not only cognitive gains but also students' attitudes toward computer-based instruction including computer-generated animation. It investigated the differential effects of four kinds of computer graphics stated above on the students' attitudes toward instruction. It also analyzed underlying factors which consist of students' attitudes toward computer-based science instruction. Therefore, the results of this study can contribute to recognition of instructional visuals to promote positive attitudes and to identification of components of attitudes in computer-based science instruction.

Most research on the instructional value of animation are limited to animation in two-dimension. The present study has an educational importance of designing instructional software, since it highlights 3D realistic representation, whether it is animated or static, using a cutting edge technology of computer graphics. The three-dimensional visuals, with more realistic characteristics than the two-dimensional visuals, have not yet been systematically investigated in the research of animation. For this reason, the present study may contribute to understanding the efficacy of three-dimensional visuals over two-dimensional visuals, under two different conditions, which are the static and the animated graphics. The comparisons among the four experimental groups employing different computer graphics will clarify how the instructional designers should utilize computer graphic features in designing instruction.

The primary level of virtual reality technology was applied in this study, which enables the learners to navigate through computer screen by clicking the mouse. Since there is little research for the effects of virtual reality on learning, the findings of the proposed study will contribute to encouraging the designers of computer-based instruction to make best use of the recent technology, such as virtual reality technology or 3D animation.

1.4 Research Questions

The following research questions were answered in the present study.

(1) Are animated graphics, which provides visual stimuli analogous to reality, more effective than static graphics in helping students gain positive attitudes toward instruction ?

(2) Are animated graphics, which provides visual stimuli analogous to reality, more effective than static graphics in facilitating learning ?

(3) Are three-dimensional graphics, which provides visual stimuli analogous to reality, more effective than two-dimensional graphics in helping students gain positive attitudes toward instruction ?

(4) Are three-dimensional graphics, which provides visual stimuli analogous to reality, more effective than two-dimensional graphics in facilitating learning ?

(5) Are three-dimensional animated graphics, which provides visual stimuli analogous to reality, more effective than two-dimensional graphics or static graphics in helping students develop positive attitudes toward instruction and in facilitating learning.

1.5 Methodology Outline

1.5.1 Subjects

The subjects of the present study consisted of 145 eighth-grade students from a public junior high school of the inner-city area in Los Angeles. This group was composed of 72 boys and 73 girls, ranging in age from 13 to 14.5 years.

1.5.2 Design and Data Analysis

The experimental design used in this study is a 2x2 factorial design with three dependent variables. The dependent variables are : post-test scores, attitudes toward instruction, and response time in answering the post-test questions. There are two independent variables. Dimension, the first independent variable, includes two types : 3D and 2D. The two levels of motion, the second independent variable, were : animated graphics and static graphics.

1.5.3 CBI Learning Material

The learning material in the computer-based instruction unit was the " Motion of the Earth and the Moon" in the space. This learning material merits the use of animation and 3D representation as visual aids because it deals not only with the revolution and self-rotation of the Earth and the Moon but also with the moon phases according to the movement of the Moon. The changing shape of the Moon depends on the position of the Moon and the reflected sunlight as it travels around the Earth in our three-dimensional space.

1.5.4 Computer-Based Instructional Program

There were four versions of the Computer-Based Instructional Program, combining two modes of visual display (static visuals vs. animated visuals) with two levels of visual dimension (2D vs. 3D). For the 2D version, all the pictures of the planets were displayed on a computer screen in a two-dimensional format. The 2D images of the planets looked like those from God's Eye View. Shadows and color textures as visual cues were applied to the pictures of the 3D version to provide the depth within the three-dimensional image.

For the static visuals, the motion of the planets was presented by circled arrows. In the animated version, the motion of the Earth and the Moon was animated along their orbits or axes. The moon phases were dynamically enlarged into a full moon or shrunken into the new moon according to the revolution of the Moon around the Earth. In the 3D animated version, the students were also able to navigate through the screen by clicking navigation buttons. The realistic dynamic images of those planets rapidly change according to their viewpoint, so that they interact with 3D representation of objects on the computer screen.

1.5.5 Measures

Eleven survey questions developed by the author were used to measure the students' attitudes toward computer-based instruction. These survey questions consisted of Y (Yes) or N (No) scales, with Y being positive, N being negative. A total of 30 post-test items were given to students to assess the learning outcomes. This measure was made up of twenty four multiple-choice questions and six true/false questions. Response time to the posttest was measured to see how fast the students could retrieve information from their memory.

1.5.6 Procedures

The experiment was conducted in a well-equipped computer lab at the junior high school. Twenty six Power Macs with CPU speed of 180 to 230 megahertz and 16 megabytes of RAM were used in the experiment. The computer-based instruction, attitude survey, and post-test questions were administered by computers. As the subjects arrived in the lab, they were randomly assigned to one computer station. Each station had one of the four treatment programs preinstalled, in which they completed individually. Those same procedures were repeated six times to work with 145 students.

1.6 Delimitations

(1) The sample of the present study was limited to 8th grade students from the inner-city area of Los Angeles.

1.7 Limitations

(1) The subjects selected for this study are not representative of all 8th grade students in US.

(2) The learning outcomes can be effected by the level of participation in computer-based instruction, not by the differential treatments. Indifference to learning task can lead to low learning outcomes, while active involvement in learning task can produce greater learning outcomes.

(3) Internal and external consistency of the instrument is limited to the subjects' self-reports.

1.8 Definition of Terms

(1) Computer-Based Instruction (CBI)

CBI is the most popular term describing the use of computers for instructional tasks (Bitter, Camuse, & Durbin, 1993). A student is instructed by a computer, and the computer acts as a tutor by performing a teaching role (Merril, Hammons, Tolman, Christensen, Vincent, & Reynolds, 1992). This term is also referred to by various names such as CAI (Computer-Assisted Instruction), CAL (Computer-Aided Learning), educational software, or courseware.

(2) Computer Animation

Computer animation refers to the process of creating visual movement through the use of computers (Fox & Waites, 1984). An illusion of motion is produced by rapidly presenting a series of individually generated graphic frames (Latham, 1995).

(3) Virtual Reality

Virtual Reality refers to a recent computer graphic technology, which offers a real-time interactive and three-dimensional graphic environment, creating a realistic world.

1.9 Organization of the Remainder of the Dissertation

Chapter 2 provides a selected review of the literature related to the present study. Chapter 3 describes the methodology and the procedure of the experiment. Chapter 4 presents the findings of statistical analysis as the results of the experiment. Chapter 5 summarizes the findings of the present study and discusses the findings with respect to research hypotheses, followed by implications based on the results of the present study.

Chapter 2

Literature Review

2.1 Introduction

This chapter focuses on the selected review of literature pertinent to the effects of 3D animated graphics on student learning and attitudes in Computer-Based Instruction. The review provides the background research for the following topics: (1) Theoretical Justification for the Use of Instructional Visuals; (2) Effectiveness of Animated Visuals in Learning; (3) Three-dimensional Graphics and Virtual Reality Technology; and (4) Attitudes toward Instruction. The first section of this chapter reviews several theories supporting the use of visual aids in learning. In the second section, previous research for the effectiveness of animated visuals is discussed. Third section covers the issues of three-dimensional graphics and virtual reality technology in learning. In the fourth section, review of student attitudes toward instruction is discussed.

2.2 Theoretical Justification for the Use of Instructional Visuals

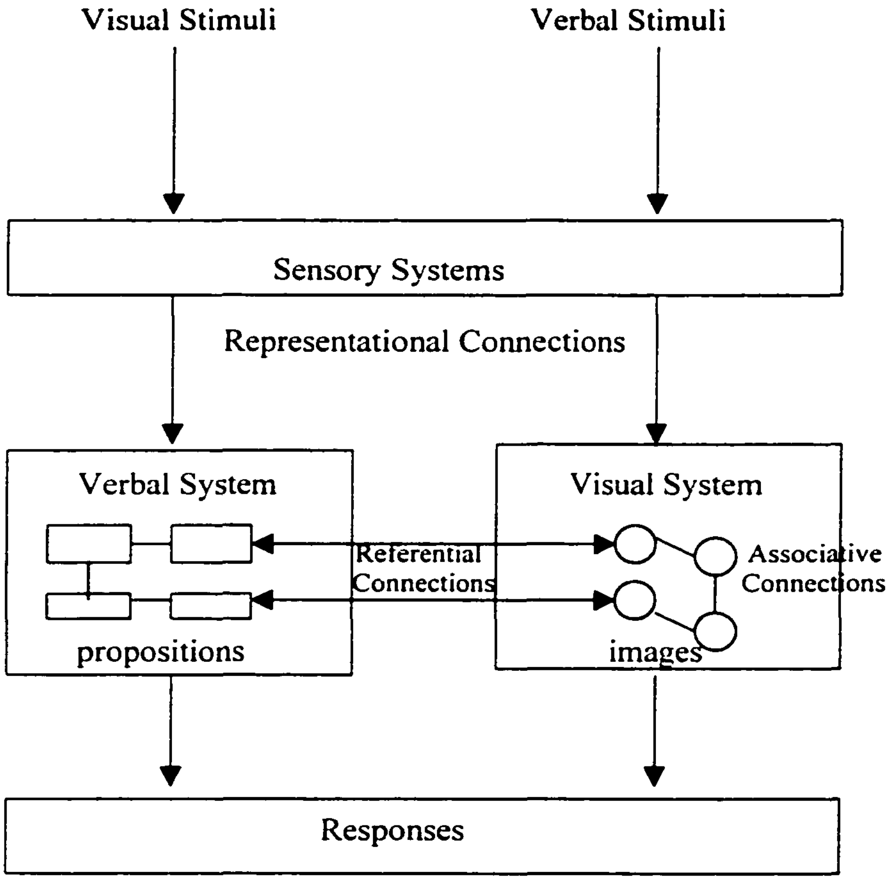
Image is an efficient way of representing spatial or visual information, because large amounts of spatial or visual information are encoded as an organized entity in human working memory, and its mental representation is simultaneously available (Paivio, 1991). Visual imagery can deliver large amounts of abstract information more concretely and precisely than words or sentences (Purnell & Solman, 1991). The term visualization is used synonymously with imagery (Rieber, 1995). Visualization is defined as representations of spatial, nonarbitrary, and continuous information, whereas verbal information is defined as those of arbitrary and discrete information (Paivio, 1990). Visualization is used in various ways to facilitate learning as a cognitive strategy (West, Farmer, & Wolff, 1991). It is most extensively used as an instructional tool in education to present spatially-based information. Numerous studies among educational researchers have been continued to explore the effects of visuals on learning, indicating positive outcomes (Chanlin & Chan, 1996; Kulhavy, Stock, & Caterino, 1994; Kulhavy, Stock, Peterson, Pridemore, & Klein, 1992; Mayer, 1994, 1997; Mayer & Sims, 1994; Purnell & Solman, 1991; Rieber, 1990b, 1996; Verdi, Johnson, Stock, Kulhavy, & Whitman-Ahern, 1997). Theoretical foundations for the use of instructional visuals will be reviewed in next five subsections.

2.2.1 Dual-Coding Theory

Paivio's dual-coding theory (1990; Clark & Paivio, 1991) presented in Figure 1 is the most authoritative theory that strongly supports the important role of visual aids. It explains how people process visual and verbal information in their memory. According to this theory, human cognition consists of two major functionally distinct systems for information processing, one the visual system and the other the verbal system. The verbal system concerns the processing of language information such as words and sentences, whereas the visual system manages pictorial information. Words and pictures presented in learning material activate these two encoding systems. The two independent encoding mechanisms make it possible to construct two mental representations in long-term memory, i.e. one the visual representation and the other the verbal representation.

The redundant dual-encoding mechanism increases the probability of later recall, because if one memory representation is missed, the other is still available. Based on this dual-coding theory, learning material provided by both text and illustrations would be remembered better than the material provided by text only or illustrations only.

Figure 1. A Dual-Coding Model



Important assumptions for the picture superiority effects can be found in Paivio's dual-coding theory. From his perspective, pictures are more likely to be dually coded in both visual and verbal form, while words are less likely to be coded in visual form. In other words, verbal representation for pictures is more available than visual representation for words. Due to the superior mnemonic value of visual codes over verbal codes, visual information is easier to remember than verbal information. This assumption means that pictures are better recalled than words covering the same learning content. If content features accompany highly visual and spatial concepts, a learner can encode and represent the information of the learning content into memory using both visual and verbal codes.

Dual-coding theory offers three different levels of cognitive processing to integrate visual and verbal information in memory: representational processing, associative processing, and referential processing. Representational processing refers to the cognitive process of encoding from incoming stimuli to internal mental representation of verbal or visual information. Associative processing involves activation of intra-system codes within either visual system or verbal system, while referential processing describes the connections between visual system and verbal system.

Referential processing of dual-coding theory integrates visual and verbal systems, encouraging the creation of a feasible mental model (Mayer, 1993a). Learning can be improved by a well-developed mental model (Winn & Schill, 1991). Understanding something involves having the right internal representation of it; in other words, having a mental model that a person can manipulate and visualize (Greeno, 1991). External stimuli such as dynamic images can be a powerful medium for building internal mental representation (Sharp, Bransford, Goldman, Risko, Kinzer, & Vye, 1995). Well-chosen external images such as visual analogies reduce the cognitive load for encoding in working memory (Perkins & Unger, 1994) and facilitate representational processing of dual-coding theory. The visual analogies can be developed by innovative computer technology.

Visualization embraces internal representation like mental imagery as well as external representation like pictures, graphs, and video (Rieber, 1995). The learners can create the internal representation of some phenomena with the aid of the external representation. Mental imagery helps learners remember what they read (Pressley, 1976), and the use of supplemental pictures as external visual aids to learning expository text is also helpful in facilitating learning (Dwyer, 1994). Therefore, according to dual-coding theory, animation, a subset of instructional visuals can aid recall.

The value of visualization has been long recognized in human cognition (Rieber, 1995). Cognitive theory of visual learning is required to know about the cognitive processes in human memory during understanding of visual information (Mayer, 1993b). Identifying how people learn from graphics and text is an important issue to adequately employ the full potential of graphics and to design instructional material combining graphics and text. This cognitive approach focuses on mental processes and representation (Mayer, 1993b). In this sense, Paivio's dual-coding theory successfully accounts for the cognitive processes in human memory to understand visual and verbal information.

Many research has been conducted to empirically validate dual-coding theory (Chanlin & Chan, 1996; Kulhavy, Stock, & Caterino, 1994; Kulhavy, Stock, Peterson, Pridemore, & Klein, 1992; Mayer, 1994, 1997; Mayer & Sims, 1994; Purnell & Solman, 1991; Rieber, 1990b, 1996; Verdi, Johnson, Stock, Kulhavy, & Whitman-Ahern, 1997). Kulhavy et al. (1992, 1994; Verdi, Johnson, Stock, Kulhavy, & Whitman-Ahern, 1997) proposed conjoint-retention model and Mayer (1997) developed generative theory of multimedia learning based on dual-coding theory. These theories will be discussed in next section.

2.2.2 Conjoint Processing Model

Conjoint retention model was developed by Kulhavy et al. (1992, 1994; Verdi, Johnson, Stock, Kulhavy, & Whitman-Ahern, 1997), which draws on dual-coding theory. This theory demonstrates why learning a map facilitates memory for the related text passage. There are two assumptions in conjoint retention (Kulhavy. Stock, Peterson, Pridemore, & Klein, 1992). First, verbal and spatial information is stored in functionally different memory codes and are reciprocally accessible. Second, map representation has computational advantage in working memory, which can be efficiently searched and simultaneously available in memory as intact image. These two assumptions allow the learners to retrieve associated text information using the mental representation of the map.

The proponents of conjoint retention model (Kulhavy, Stock, & Caterino, 1994; Kulhavy, Stock, Peterson, Pridemore, & Klein, 1992; Verdi, Johnson, Stock, Kulhavy, & Whitman-Ahern, 1997; Rittschof, Stock, Kulhavy, Verdi, & Doran, 1994) found that when students are required to study a geographic reference map in conjunction with either reading or hearing a related text, there is an increase in recall of related text content. This productive relation between maps and text has been explained by conjoint retention model, which refers to the fact that both map and text elements are represented "conjointly" in memory.

In their experiments, students who were provided with maps before the corresponding text passage could recall significantly more facts from learning material than students who were provided with the text passage before the map. The effects of presentation order of map and text explain superiority of visual display over verbal information. When maps are presented before text, they are encoded as intact images which retain spatial properties of visual displays. Since the learners are able to scan and maintain the entire intact images which take up less space in working memory, they can process and learn the text passage with the images at the same time. Simultaneous availability of both images and text in working memory demonstrates the computational advantage of reciprocal cueing, which leads to more efficient encoding and retrieval of the information.

However, when text passage is presented before the map, students do not have the computational advantage. As the students read the text passage, each verbal proposition is formed and stored sequentially in the long-term memory. Then, when the students view the map, the related propositions are retrieved from the memory to aid in learning the map. Large amount of cognitive space is required for retaining the propositions in working memory. Thus, the students used up their cognitive efforts in retaining verbal propositions and thus cannot afford to process map images efficiently.

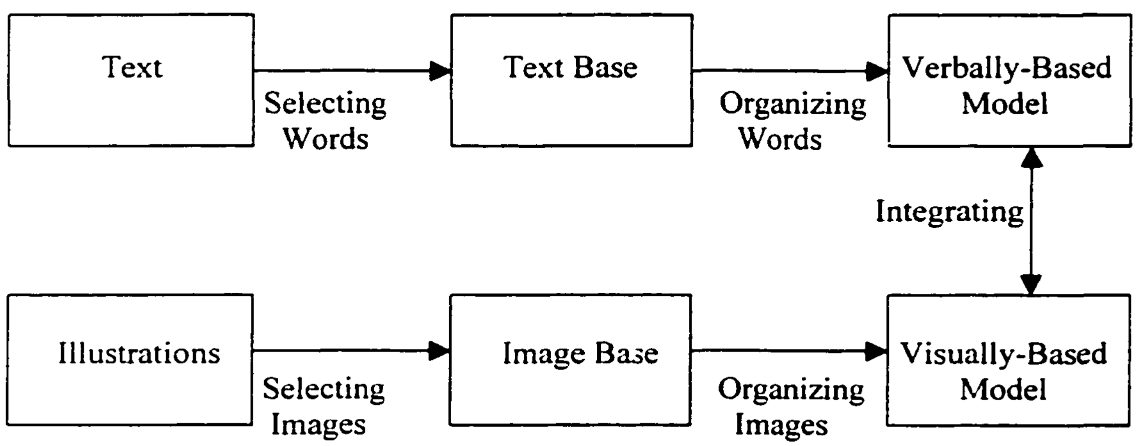
The computational advantage of a map image in working memory accounts for the "picture superiority" as in dual-coding theory. The advocates of conjoint retention model validated the "picture superiority effects" through the presentation order of map and text (Kulhavy, Stock, Caterino, 1994; Kulhavy, Stock, Peterson, Pridemore, & Klein, 1992; Verdi, Johnson, Stock, Kulhavy, & Whitman-Ahern, 1997; Rittschof, Stock, Kulhavy, Verdi, & Doran, 1994). One different approach to explain "picture superiority" and computational advantage of the map to retrieve text was conducted by some researchers (Stock, Kulhavy, Peterson, Hancock, & Verdi, 1995). They showed that fact recall and map drawings were more accurate for the students who studied map than for those who studied comparable verbal description. The results indicated the mental representation derived from maps is superior to that derived from verbal description with respect to the retrieval of facts from an associated text.

2.2.3 Mayer's Generative Theory of Multimedia Learning

Mayer (1997; Mayer, Steinhoff, Bower, & Mars, 1995; Plass, Chun, Mayer, & Leutner, 1998) proposed the generative theory of multimedia learning as shown in Figure 2, which is based on Wittrock's (1989) generative theory, Mayer's (1994) dual-coding model of multimedia learning, and Paivio's (1990, 1991; Clark & Paivio, 1991) dual-coding theory. The generative theory of multimedia learning concerns how people process verbal and visual information and integrate them during multimedia learning. From Figure 2, there are three cognitive conditions for meaningful learning: *selecting*, *organizing*, and *integrating*.

In a multimedia learning environment, *selecting*, as a first cognitive process, involves selecting relevant words and selecting relevant images from incoming stimuli. This process is related to the "representational process" of dual-coding theory. Verbal stimuli activate to construct mental representation of verbal information (verbal encoding), whereas visual stimuli activate to construct mental representation of visual information (visual encoding). For example, a proposition can be constructed from a text and a mental image constructed from an illustration. The second cognitive process in multimedia learning is *organizing*, which involves connecting selected pieces of information in working memory into a coherent mental model. From Paivio's (1990, 1991; Clark & Paivio, 1991) perspective, organizing process is regarded as "associative processing" which occurs within the verbal cognitive system or visual cognitive system. Combining a series of images within visual system or combining several propositions within verbal system allows the learners to construct a coherent mental model which is a mental representation consisting of information pieces and cause-and-effect relations among them (Mayer, 1994, 1997). *Integrating* is a final process in generative theory of multimedia learning. Learners build connections between verbally-based model and visually-based model. This process corresponds to "referential processing" of dual-coding theory.

Figure 2. Generative Model of Multimedia Learning



The generative theory of multimedia has been consistently supported by extensive research (Mayer & Anderson, 1991, 1992; Mayer & Gallini, 1990; Mayer & Sims, 1994; Mayer, Steinoff, Bower, Mars, 1995; Plass, Chun, Mayer, & Leutner, 1998). Multimedia instruction was found to be effective in learning of causal relations of scientific systems (Mayer & Anderson, 1991; Mayer & Gallini, 1990; Plass, Chun, Mayer, & Leutner, 1998). Students who received both narration as verbal stimuli and animation as visual stimuli outperformed those who received narration only (Mayer & Anderson, 1991, 1992). Consistently, students showed higher scores on problem-solving test when text passage was given in combination with illustration than when only the text was provided (Mayer & Gallini, 1990). In a second-language multimedia learning environment, students who were presented with both translation in English as verbal stimuli and video clip as visual stimuli remembered word translation better than those who were presented with only one stimulus (Plass, Chun, Mayer, & Leutner, 1998).

In a series of experiments, the researchers generalized "contiguity effect", which is an important condition of effective multimedia instruction (Mayer & Anderson, 1991, 1992; Mayer & Gallini, 1990; Mayer & Sims, 1994; Mayer, Steinoff, Bower, Mars, 1995; Plass, Chun, Mayer, & Leutner, 1998). Contiguity effects occur when pictures and words are presented simultaneously in terms of time and space. Accordingly, students perform better on problem-solving test when narration and animation are provided contiguously in terms of time than when they are provided separately (Mayer & Anderson, 1991, 1992; Mayer & Sims, 1994). In the same way, students who are presented with text and illustration on a same page contiguously in terms of space generated higher scores on problem-solving test than those who were given separate presentation of text and illustration on a different page (Mayer, Steinoff, Bower, & Mars, 1995).

From the viewpoint of generative model of multimedia learning, learning is facilitated by *selecting* and *organizing* of words and images, and *integrating* the mental representations of words and images. Those three cognitive processes mostly and effectively occur when words and images are presented contiguously.

2.2.4 Concept of Complementarity

Schnotz et al. (Schnotz, Picard, & Hron, 1993; Schnotz, Picard, & Henninger, 1994) contended that words and pictures provide complementary information sources, since the words represent an object in a symbolic way and the pictures describe the object in an analog fashion. According to their theory, the learners process visual information more intensively than verbal information, if the required information to construct mental model is not available in verbal stimuli. They focus on verbal information more frequently than visual information when the necessary information to construct mental model can not be found in visual stimuli. In other words, some objects to be integrated into mental model which are rarely supported by graphics, are intensively aided by text, whereas some objects that are little supported by the text, are much aided by the graphics.

In a study of how text and graphics are utilized as complementary sources of information, Schnotz, Picard, and Henninger (1994) indicated differences in integration of text and graphics information between successful learners and unsuccessful learners. Successful learners were more prudent in referencing to the text information for processing the objects little supported by graphics than unsuccessful learners, while unsuccessful learners indiscriminately accessed the text information twice as much as successful learners. From the perspective of complementary information sources, the construction of a mental model relies on text information, when the need arises, i.e. the graphic information does not sufficiently support the objects to be integrated into mental model. Furthermore, the successful learners utilized graphic information more intensively than unsuccessful learners. The two results from the experiments, selective use of text information and frequent use of graphic information by successful learners explain the advantage of visual information over verbal information.

2.2.5 Level of Processing

One theory that supports the use of pictures in learning is "level of processing theory" (Craik & Lockhart, 1972). According to this view, the more deeply processed the information is, the better remembered it is. Specific mnemonic strategy or cueing materials can be used for deeper processing of the given information (Chanlin, 1994). Visual aids encourage the learners to process the information more deeply, which is likely to be retained longer. Chanlin (1994) suggested two ways for deep processing of learning material. First, use of imagery instruction induces the information to be deeply processed by the learners. Generating mental images as the learners read text passage improves their memory (Pressley, 1976). Second, presentation of external stimuli such as pictures helps the learners visualize the learning material. Illustrations presented with text facilitate learner's retention and recall of text material (Purnell & Salmon, 1991).

In this sense, animation, which is a subset of instructional visuals, can aid deep processing of information. Providing animated graphics while the children are listening to stories enhances their understanding and remembering of the story (Sharp, Bransford, Goldman, Risko, Kinzer, & Vye, 1995). Learning science concepts can be also supported by animated graphics (Baek & Layne, 1988; Park & Gittleman, 1992; Pookay & Szabo, 1995; Rieber, 1990a, 1990b, 1991a 1996; ; Rieber, Boyce, & Assad, 1990; Rieber & Kini, 1991; Thompson & Riding, 1990; White, 1993).

Information can be deeply processed within the same mode. In other words, metaphor is considered as a deeper processing of verbal information, whereas animation can contribute to a deeper processing of visual information. As the information is deeply processed, the level of abstraction entailed in the information is changed. The abstract concept is shifted to concrete concept which is easy to understand. Therefore, the learner's cognitive load to process the information in working memory can be reduced, if stimuli such as animated graphics or metaphors are externally provided for deep processing.

2.2.6 Summary

Many researchers have proposed theories supporting the use of instructional visuals. Dual-Coding Theory (Paivio, 1990, 1991; Clark & Paivio, 1991) is the most validated and solid theory, on the basis of which other theories have developed. It explains well the cognitive paradigm of visual and verbal processing in human memory, assuming the advantage of pictures over words. Kulhavy et al. (1992, 1994; Verdi, Johnson, Stock, Kulhavy, & Whitman-Ahern, 1997)'s Conjoint Processing Model draws on the Dual-Coding Theory, which demonstrates the value of instructional visuals through a series of research using a geographic map. Generative Theory of Multimedia

Learning (Mayer, 1997; Mayer, Steinhoff, Bower, & Mars, 1995; Plass, Chun, Mayer, & Leutner, 1998) was an extended version of Dual-Coding Theory in multimedia learning environment. In accordance with the theories mentioned above, Schnotz et al. (1991, 1994) contended that visual stimuli and verbal stimuli provide complementary information sources. Level of Processing Theory (Craik & Lockhart, 1972) suggested the use of instructional visuals for the deep processing of information, manifesting that the more deeply processed the information is, the better retained it is in human memory. Numerous studies have been conducted to empirically validate those theories using various kinds of instructional visuals, and animation research is one of such studies.

2.3 Animation in Computer-Based Instruction

The trend toward the use of microcomputers as an educational tool has been increasing in the schools. According to Kulik and Kulik's (1994) meta-analytic study of computer-based instruction, there were significant achievement gains with computer-based instruction. Students exhibited positive attitudes toward computer-based instruction and tended to learn more (Askar, Yavuz, & Koksal, 1992).

Certain features of computers provide powerful instructional potential, although there is controversy (Clark, 1983, 1985, 1994) as to the unique effectiveness of the computer as an instructional aid. Animation is one of the distinctive computer graphics feature, which has recently gained popularity. Computer animation is the process of creating visual movement through the use of computer (Fox & Waite, 1984). The motion pictures in computer animation do not really move. The animation is accomplished by swiftly displaying a series of still pictures of objects, with slight changes from one picture to the next (Park & Gittleman, 1992). By connecting the slightly different pieces of information into a smooth, continuous event, the user's visual system perceives motion even though there is no real movement. Animation in computer-based instruction can be used to support or improve instruction especially for visually-oriented or spatially-oriented information entailing motion.

2.3.1 Why is animation used in Computer-Based Instruction ?

Animation in computer-based instruction holds powerful instructional potential. Instructional animation is used in computer-based instruction to accomplish one of three functions : attention-gaining, presentation, and practice (Rieber, 1990a). According to Park and Hopkins (1993), animation in visual displays fulfills five instructional roles : as an attention guide; as an aid for illustrating functional or procedural behavior; as a representation of domain knowledge entailing movement; as a device model for forming a mental image of system functions which are not directly observable; and as a visual analogy or reasoning anchor for understanding abstract concept. Computer graphic technology including innovative capabilities previously unavailable through printed text or still pictures is strategically applied in instruction with rationales. It is presenting new challenges to traditional educational practice. Three major rationales to employ animation in computer-based instruction will be discussed in next subsections.

2.3.1.1 Representation of Movement

Animation, like other instructional visuals, should facilitate recall and retention when it illustrates visually-based or spatially-based facts or concepts which are related with movements. Animated graphics are probably much better than static graphics at representing ideas which involve changes over time because of its ability to implement motion, therefore concretizing abstract temporal ideas (Rieber & Kini, 1991). If a learning task only requires learners to visualize fixed objects, then the use of static visuals would be sufficient. However, if the learning task requires the dynamic process, a situation in which an element is changing or evolving over time, it is better illustrated through animated visuals.

Most research supporting animated visuals in computer-based instruction were interested in the effects of animation on the learning of dynamic concepts instead of static concepts (Chanlin & Chan, 1996; Hakerem, Dobrynina, & Shore,1993; Mayer, 1994, 1997; Mayer & Anderson, 1991, 1994; Mayer & Sims, 1994; Park & Gittleman, 1992; Rieber, 1990, 1991a, 1991b, 1996; Rieber, Boyce, Assad, 1990; Thompson & Riding, 1990). Rieber (1990b, 1991a, 1991b; Rieber, Boyce, & Assad, 1990) indicated positive effects of animated graphics on the learning of Newton's Law of Motion, while Mayer (1994, 1997; Mayer & Anderson, 1991, 1994; Mayer & Sims, 1994) utilized animation to depict causal relationship of the scientific system such as how a bicycle tire pump works, how a braking system works, or how a human respiratory system works. Accordingly, animated graphics is well applied to learn dynamic abstract concepts that are difficult to visualize.

2.3.1.2 Interaction Between Students and Computers

Some traditional visual aids, such as film and videotapes are able to show the motion and dynamic processes. But in many of these film and videotapes, the illustrations we would like to show are separated by some period of time while students are watching them. Those students are not likely to absorb and process the learning material while sitting in a darkened room, and it does not help the learning process (Epstein, 1990). How nice would it be if we had at our disposal the visual illustration ? How nice if the students could control the pace and sequence of learning, and interact with computers ? Computers have the unprecedented capability of allowing students to interact with visual illustrations.

Interactive learning takes place in a learning situation where a learner and computer are actively and mutually responding to input/output and adapting to responses (Jonassen, 1985). There are three levels of interactivity according to the way in which users interact with computers (Lucas, 1992). The "reactive" model which is the lowest level of interactivity, draws on behavioristic approach and simply refers to physically pressing the space bar to advance to the next step of program. The "proactive" model which is based on a cognitive approach, is the highest level of interactivity in which the learner is actively engaged in knowledge construction. Recent computer technology enables the instructional designers to develop computer-based instruction with proactive model of interactivity. The model between reactive and proactive models is an "interactive" model, in which the users can branch through the instruction depending on their inputs. They control the sequence of learning program. The animated graphics, which is recently applied in computer-based instruction, involves the proactive model of interactivity, such as those in simulation or interactive three-dimensional graphics in virtual reality technology.

Rieber (1990a) argued that the interactive graphic application is one of the most important contributions to computer-based instruction. Highly interactive computer-based instruction provides the learners with continuously changing (animated) graphics according to the learners' input. Accordingly, interaction occurs in the form of immediate animated graphic feedback between the learners and the learning task, which is called "interactive dynamics" (Brown, 1983). The mechanism of interactive dynamics is used in real-time simulations and virtual reality technology. This mechanism creates an environment where students are given control over an interactive dynamic, strongly being engaged in learning, and thereby learning by discovery (Rieber, 1990a). The capability of an interactive dynamics distinguishes the computer from other instructional media and demonstrates the uniqueness of animation in computer-based instruction.

Some studies showed the effectiveness of interactive dynamics with respect to practice and feedback in computer-based lesson (Park & Gittleman, 1992; Rieber, 1990b, 1996; Rieber, Boyce, & Assad, 1990). Rieber (1990b) found that cognitive practice in computer-based instruction with a simulation activity was generally superior to other practice conditions- whether it was behavioral or no practice at all. Fourth and fifth grade children in cognitive practice were given increasing levels of control over an interactive dynamic that simulated a free-floating object(starship) in a frictionless, gravity-free environment in a lesson of Newton's Law of motion. They manipulated the degree of speed and forces acting on the starship. In his subsequent study (Rieber, Boyce, & Assad, 1990) with adult subjects, students in cognitive practice treatment with interactive dynamics took less time to answer post-test questions than other treatment groups, i.e. the traditional behavioral practice group and no practice group. This result suggests that the cognitive treatment with interactive dynamics supported encoding and retrieval task better than the traditional questioning practice.

Consistently, Rieber's (1996) recent research replicated the previous findings. He investigated how users interact and learn from three simulation conditions : graphical feedback, textual feedback, and graphical plus textual feedback. Real-time graphic feedback was presented to the learners in graphical feedback conditions. Graphical feedback was found to be more effective than textual feedback in understanding of science principles.

The selective use of animation and immediate feedback helps students understand and acquire electronic troubleshooting procedures (Park & Gittleman, 1992). The troubleshooting input of students can be instantly reflected in a computer-based learning system. The student inputs information and the computer immediately offers visual feedback letting the student know if his response is correct or incorrect. This interactive dynamics between students and the computer-assisted learning system aids the acquisition of troubleshooting skills.

The "microworlds" typically implemented on computers in which the learners can manipulate and interact, is an innovative representation to foster understanding, while traditional representations such as formal notation and diagrams frequently lead to misunderstanding (Perkins & Unger, 1994). "Thinkertools" developed by White (1993) enables students to have a more precise and insightful picture of Newtonian motion. Children systematically explore computer-generated microworlds through continuous interaction. From the immediate feedback of the simulation, they can actively check their thoughts about the influence of forces on objects. The external representational systems like the "Thinkertools" reduce cognitive load by minimizing the learner's working memory encoding (Perkins & Unger, 1994). The encoding of complex cognitive structures is facilitated by well-chosen external representational system. "Thinkertools" which is characterized by continuous interaction between the learners and computers, is a visual aid to promote performance.

2.3.1.3 Attention-guide

According to Rieber (1991a), "Attention involves cognitive decisions regarding which information to attend to, given the fact that the environment contains far more information than any one person can handle at any given time." (p6). Interesting pictures gain and maintain learner's attention in instructional text (Keller & Burkman, 1994). Good pictures motivate learners and encourage curiosity. Pictures including novelty and drama maintain learner's attention (Keller & Burkman, 1994). In this sense, learners can be attracted to animated visuals that include dramatic and unique effects.

One of the important roles of animation as an instructional tool is gaining the students' attention (Park & Hokins, 1993; Rieber, 1990a). Attentiveness is a prerequisite to learning (Hannafin, 1985). Gagne, Briggs, and Wager (1992) described attention as the first event of instruction. Attention correlates with students' achievement more highly than the time-to-learn and poor learners have poor attention (Wittrock, 1986). The presentation of highly visual quality material is an effective teaching technique for arousing and sustaining student's attention (Hativa & Reingold, 1987).

Attention-gaining is an obvious, practical and rational use of animation. Rapidly changing visuals can be displayed on a computer screen to grab the student's attention, such as carton figures, screen washes, and moving objects reinforcing the learning content. However, indiscriminate use of animation in computer-based instruction may hinder its positive effects on learning. Students' selective attention to animation is affected by instructional design method (Rieber, 1991a). Only well-designed animation directing a selective attention can be an efficient aid to learning compared to static graphics.

2.3.2 Learning Outcomes of Instructional Animation

Animated visuals can produce not only cognitive but also affective outcomes. In this section, the research findings of cognitive learning outcomes through the use of animated graphics in computer-based instruction will be reviewed first. Then the effectiveness of animated visuals in terms of affective appeal will be discussed.

2.3.2.1 Cognitive Outcomes

There are three classes of educational objectives : cognitive, affective, and psychomotor. The cognitive domain is concerned with the intellectual responses of the learners, such as performing mathematical solutions or solving various kinds of "mental" problems (Knirk & Gustafson, 1986). Bloom (1956) developed a taxanomy of learning objectives in cognitive domain. He classified cognitive objectives as knowledge, comprehension, application, analysis, synthesis, and evaluation. Materials can be revised or programmed until specific objectives are attained. Cognitive objectives are used to design instructional programs with observable outcomes. Extensive studies have indicated cognitive outcomes in learning aided by computer-generated animation.

2.3.2.1.1 Animation in Math and Science Learning

The advantage of computer animation as an instructional medium is that it provides learners with visual information regarding dynamic movement. Presenting dynamic movement as visual aids can produce cognitive outcomes in learning math and science concept (Baek & Layne, 1988; Chanlin & Chan, 1996; Mayton, 1990; Pookay & Szabo, 1995; Thompson & Riding, 1990). The question of how color, graphics, and animation influence the learning outcomes of teaching average speed concept was answered in Baek and Layne's research (1988). The purpose of this study was to determine the instructional effectiveness of three computer-assisted learning (CAL) modes : (a) CAL without any graphics (text group), (b) CAL with still graphics (still graphics group), and (c) CAL with animated graphics group (animation group). The three CAL modes were compared in colors and as well as in black and white. The result showed that the animation group scored higher than the still graphics group, and that the still graphics group scored higher than the text group. Thus, animation in computer-assisted learning proved to be more effective in generating students' cognitive outcomes than still graphics or text material in learning scientific concepts. The effectiveness of color was not detected because color was not used as an important factor in this study.

Consistently, Mayton (1990) conducted a study to investigate the effects of animated visuals on the learning of anatomical dynamic processes. Subjects completed one of three treatment forms of a computer-based tutorial presenting the structure and function of the human heart. The three levels of instructional presentation method were static visuals only, static visuals with an embedded imagery cueing strategy, and animated visuals with imagery cues. When tested immediately after treatment, the animated visuals treatment group outperformed the static visuals with imagery cue group or static visuals only group on the free-recall test. With respect to the following one-week delayed test, the animated-visuals group maintained superiority over the static visuals only group for the cued-recall and verbal form of the free-recall tests. The results of this study were supportive of the contribution made by the animated visuals in CBI to the recall of information about dynamic processes.

Understanding construction and transformation of mathematical diagrams can be improved by animation. Thompson and Riding (1990) examined the effects of animated diagram on the understanding of Pythagoras's Theorem in eleven to fourteen year-old students. The experimental group that saw a computer-animated display scored higher on a post-test than the static graphic group. The static graphic group was presented with a series of still pictures consisting of ten discrete stages of diagram transformation. However, the instruction was provided as a whole-class format with only one computer rather than assigning computers to each student. Presenting computer animation was also found to be effective on the acquisition of the mathematics skill using a compass to create triangles in Pookay and Szabo's study (1995). Each student in this research was assigned to one computer station which preinstalled one of three instructional methods : animation, still graphics, and text only. The process of constructing a triangle using a compass was lively animated in animation treatment group. A series of static graphics was substituted for animation in still graphics group. Animated group scored significantly higher on post-test than the other two groups while still graphics group scored significantly higher than text only group.

Animated graphics as visual elaboration strategy facilitate learning in conjunction with verbal elaboration strategy such as metaphor. Coordination of metaphor as verbal encoding stimuli and animation as visual encoding stimuli build dual-coding (Paivio, 1990, 1991), which makes the learning material more comprehensible and memorable. Chanlin & Chan (1996) revealed the additive learning outcomes of integrating animated graphics and metaphorical strategy for learning biotechnology concepts. Six experimental groups participated in this study to learn Basic Recombinant DNA Technology : control group; group of static graphics without metaphor; group of animated graphics without metaphor; group of non-graphics with metaphor; group of static graphics with metaphor; and group of animated graphics with metaphor. Animated graphics plus metaphorical treatment enhanced learning the most. From the results, it is conjectured that visual stimuli encourage the learners to build semantic links between the abstract and concrete concepts, whereas verbal stimuli form analogical connection between familiar and unfamiliar.

It should be noted that interactive animation as well as simple animated presentation of learning material yields positive learning outcomes. In Park and Gittleman's study (1992), students in animated condition of computer-based instruction who interactively practiced electronic troubleshooting skills needed fewer trials at both practice session and performance test than those in static condition. Thereupon, animated visual displays in computer-based instruction were found to be more effective for teaching electronic troubleshooting skills than static visual displays.

2.3.2.1.2 Animation in Language Learning

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Language comprehension as well as science learning can also be facilitated by animated visual aids. According to Sharp et al.'s research (1995), dynamic visual support in story telling is an effective strategy for constructing mental models of stories. They employed animated images as a framework for understanding a story, instead of as a medium of simple presentation for entire story. The subjects were young at-risk kindergartners. The children in the animated visual group were presented with story sentences with animated video clip including maximal information about characters, actions, and spatial relationship. Static visual condition offered only static illustration with minimal information, while each story in control group was read without any accompanying video clips. The children in animated visual group were better able to remember the imagination sentences which they had to visualize in their own imagination than those in static visual condition or control condition. Imagination sentences, which were always at the end of the story, were not provided with any visual support in story telling. Similarly, the children in animated visual group outperformed those in static visual group or control group on the test of story framework retrieval.

Three interpretations can be inferred from those results : animated presentation plays an important role in conveying story events in more natural and familiar way which later will be solidly maintained in memory; animated video clips have after-effects promoting better recall of story-ending that was not supported with any visuals, in other words, they encourage the children to better remember the subsequent story without visual aids; and multimedia technology incorporating motion pictures can facilitate literacy development for young at-risk children. Not only young children but also adults benefit from multimedia language-learning environment. In a study of multimedia effects on second-language learning, Plass et al. found (1998) that presenting both verbal and visual annotations improves student learning more than only one annotation or no annotation. Verbal annotation consisted of a translation of German key words in the story into English, whereas visual annotation consisted of animated video clip or picture representing the word.

2.3.2.1.3 Mayer's Finding

Mayer et al. (Mayer & Anderson, 1991, 1992; Mayer & Sims, 1994) conducted a series of research focusing on the role of explanative animation in the learning of scientific system. There are two important media available in multimedia instruction : words and pictures (Mayer, 1993a, 1994, 1997). Some of the conditions for the effective use of animation in computer-based instruction were suggested by the researchers in the study of how to design multimedia instruction using words and pictures (Mayer, 1993a, 1994, 1997; Mayer & Anderson, 1991, 1992; Mayer & Sims, 1994). Consistent evidences were indicated for multimedia effects revealing that presenting computer-generated animations in conjunction with computer-generated narration in a computer-based instruction was more effective for cognitive outcomes than presenting animation only or narration only. They also consistently explored a contiguity effect, which states that learning is facilitated when animation and narration are provided contiguously at the same time.

In their experiments, students studied the animated operation of a bicycle tire pump, an automobile braking system, or a human respiratory system. Students who received presentation of dual media, i.e. both computer animation and narration outperformed those who received presentation of one medium, i.e. animation or narration (Mayer & Anderson, 1991, 1992). A concurrent group who received oral narration and computer animation contiguously in terms of time scored higher on a problem-solving test than the groups who were given successive presentation of animation and narration (Mayer & Anderson, 1991, 1992; Mayer & Sims, 1994).

2.3.2.1.4 Rieber's Finding

Many of Rieber's findings (1990b, 1991a, 1991b, 1996; Rieber, Boyce, & Assad, 1990) showed positive effects of animated visuals over static visuals in computer-based science instruction, whereas his previous study (1989) and research with other colleague (Rieber & Hannafin, 1988) did not demonstrate any powerful influences of computer animation on learning. However, the lack of differential effects in those research (Rieber, 1989; Rieber & Hannafin, 1988) were attributed to poor instructional design and task difficulty. These defects in design were supplemented and improved in his subsequent studies (1990b, 1991a, 1991b), which indicated positive effects of animation in computer-based lesson. Some of his research (Rieber, 1990b; 1991b; Rieber, Boyce, & Assad, 1990) employed interactive animation like structured simulation activity as practice activity, pointing out the superiority of animated graphics over static graphics.

Rieber (1991a, 1991b) also revealed that students were able to successfully extract incidental information from computer-animated presentation of science concepts without any harm to intentional information. According to Good and Brophy (1990), incidental learning occurs when any deliberate intention is not assumed. Similarly, Rieber (1996) contended that learning through animated visual displays remain implicit or tacit because the attribute of animation allows the information to be represented like natural phenomena. In this sense, incidental learning can be drawn out from natural and implicit representation of knowledge.

In his recent research (Rieber, 1996) exploring the role of computer animation as real-time graphic feedback, he employed post-test as explicit measure to assess students' formal learning of science principles and game-score as implicit tacit measure. The learning task for all the students was to understand the relationship between acceleration and velocity by way of interactive computer simulation. The computer-based instruction embodied simulation in a game-like context. Game-score was measured as the time in seconds to complete the cognitive game successfully. The lower the game-score was, the higher the student performance was in the game. The results revealed that the students who participated in real-time animated feedback outperformed those who did in textual feedback with respect to game-score which was tacit measure, whereas there were no significant differences with respect to post-test scores which was explicit measure.

2.3.2.2 Affective Outcomes

The affective domain is concerned with the learner's attitudes, emotions, and values (Knirk & Gustafson, 1986). The affective taxanomy was developed by Krathwohl (1964). Behaviors such as attending to instruction, having favorable attitudes toward instruction, volunteering answers in class, being task-oriented, and interacting with teachers and other students are correlated with success in learning. Emotions have influence on the process of attending, storing, and retrieving information (Langhinrichsen & Tucker, 1990).

Learner's attitudes and motivation play important roles in learning, since the first construction stage of learning is paying attention to and selecting information from the given text or pictures (Mayer, 1997). Motivation refers to "process whereby people set goals and engage in cognitive activities and behaviors to attain their goals" (Schunk, 1991). Motivation affects when, what, and how we learn (Schunk, 1991). Students who are motivated to learn tend to participate in activities that they believe will facilitate their learning and tend to make learning efforts, while those who are not motivated to learn are not likely to attend to the teacher's instruction. There is reciprocal relationship between performance and academic motivation (Schunk, 1991). Meece, Blumenfeld, and Hoyle (1988) revealed that students who were highly motivated to learn, emphasized on setting task-mastery learning goal (understanding learning material). Student motivation and task-mastery goal setting were also found to be positively related with perceived competence, and students who had task-mastery learning goals were more actively involved in cognitive self-regulatory activities such as reviewing learning materials not understood.

Thus, the motivation to learn and the attitudes toward instruction can be considered important factors in learning. Students with high motivation and positive attitudes toward instruction are likely to engage in learning, to put forth more efforts, and in turn, to learn more. In this sense, it is an instructional designer's responsibility to utilize the proper instructional tool to stimulate the motivation and to foster positive attitudes.

Rogers (1983) argued that affective reaction enhances retention. Positive attitudes toward instruction motivate the learners to actively manage and organize the representation of text or pictures into their knowledge construction. Affective response usually occurs more to pictures than to text (Paivio, 1991). Graphics such as illustrations, diagrams, or graphs are used to motivate the learners and make the information easier to interpret (Keller & Burkman, 1994). Motion pictures encourage the students to more enjoy the learning and better remember the information to be learned (Weinstock, 1986).

In a study designed to investigate the effects of animated presentation and practice, Rieber (1990b) found that students generally had strong favorable attitudes about computers, science, and instruction, regardless of which treatment condition they received. Three treatment of visual elaboration (static graphics, animated graphics, and no graphics) were crossed with three levels of practice (behavioral, cognitive, and no practice). No significant differences in attitudes were found between treatment conditions and overall students seemed to enjoy the instruction incorporating computers.

Later, Rieber (1991b) examined motivational characteristics of the structured simulation activities, which were found to improve learning of science concepts in his previous study (1990b). This research was the first attempt to investigate whether a computer-based practice activity including simulation can intrinsically motivate children. Children can be intrinsically motivated without external incentives or reinforcement. Continuing motivation is defined as an individual's willingness to choose an instructional activity again, even after external pressure to do the activity has ceased (Maher, 1976). In his study, continuing motivation was used to measure the intrinsically motivating characteristic of a structured simulation activity.

He hypothesized that students would be likely to return to practice activities involving animated interactive dynamics more often than traditional questioning practice activities or even highly-interesting activities such as puzzles. Supporting his hypothesis, the results showed that sixty percent of the students chose to return to the starship practice with animated interactive dynamics, whereas about thirty six percent of the students returned to entertaining activities such as word-finding puzzles. Thereby, this research finding supported the motivational value of animated simulation activity.

Rieber's recent research (1996) examined the learner's attitudes by way of assessing frustration-score. College students participated in computer-based simulation activity which modeled the relationship between velocity and acceleration. The simulation was implemented as animated feedback in graphical condition or as text feedback in textual condition. Students reported their level of frustration scaling from one to nine at the end of the simulation trials. The number of clicking up or down buttons on computer screen was also used to measure how efficiently the students solved the problem. The subjects in textual condition reported greater level of frustration and higher number of clicking than those in graphical condition did. It is conjectured that students who were provided with animated graphical feedback more enjoyably and efficiently completed the learning task in a short time than those who were provided with textual feedback.

Some studies indicated the positive effects of animated graphics on both affective outcomes and cognitive outcomes. In a study of instructional effectiveness and motivational appeal of animation, Frederick and Lehman (1992) found that animation facilitates college students' retention and increases continuing motivation. Chanlin and Chan (1996) argued that animated graphics can produce most effective cognitive and affective outcomes when it is provided with verbal elaboration such as metaphor.

Students who participated in the treatment of animated graphics plus metaphor, scored higher on post-test and on attitude survey than those who participated in the treatment of static graphics plus metaphor.

2.3.2.3 Summary of Cognitive and Affective Outcomes

In summary, it is general consensus that animated visuals in computer-based instruction can enhance student learning and produce positive cognitive outcomes if the instruction is well designed considering the learning objectives. The effectiveness of strategic application of animated visuals in learning has appeared in a variety of subject matters such as math, science, and language learning. Affective outcomes as well as cognitive outcomes can be generated from the use of animation in learning. Researchers have agreed on the motivational and attitudinal value of animated graphics, while more research should be systematically conducted on these values. Further research is suggested to clarify the solid ground of the effectiveness of animated visuals to produce positive affective outcomes. Following sections will consider some design considerations which can improve student's learning through the use of animation in computer-based instruction.

2.3.3 Design Considerations

Animated graphics can produce cognitive outcomes as well as affective outcomes as reviewed in previous section. However, instructional designers should selectively and carefully apply the animation technique not to hinder the learning outcomes but to generate positive outcomes. Two design considerations will be discussed in next subsections.

2.3.3.1 Congruency Between Learning Task and Animation Attributes

Instructional visuals can facilitate learning only when their attributes are consistent with the learning task requirement (Baek & Layne, 1988; Levin & Lesgold, 1978; Rieber, 1990a; Park & Gittleman, 1992; Rieber & Kini, 1991). Winn and Schill (1991) contended that the effectiveness of diagrams as adjuncts to text can be attained only in situation where the purpose of the learning content is to convey spatial inter-relationships.

Indiscriminate and aimless use of animated visuals does not guarantee greater efficiency of animation over static visuals. Park and Hopkins (1993) suggested six instructional conditions for using dynamic visual displays : (1) demonstrating procedural actions; (2) simulating system behaviors; (3) explicitly representing invisible movements or phenomena; (4) illustrating structural, functional, and procedural relationships among objects and events; and (5) focusing the learner's attention on important concepts.

Animated graphics, when selectively used in congruence with the characteristics of subject matter, would result in better learning outcomes than static graphics displaying the same information (Rieber, 1991a; Park & Gittleman, 1992). Highly dynamic concepts in need of visualizing an object's motion such as Newton's Law of Motion, can be effectively implemented by graphical animation (Rieber, 1990b). Perceptually, animated visuals have two distinctive attributes compared to static visuals : motion and trajectory (Rieber & Kini, 1991; Rieber, 1990a, 1990b, 1991a).

Motion changes over time. For example, the motion of a car travelling from San Francisco to Los Angeles displayed on the computer screen in conjunction with the travelling distance and travelling time helps to concretize the mathematical rule for average speed. Static visuals, at most, use some arrows and lines to represent the motion of a car. In Baek and Layne's (1988) research to find the effectiveness of color and animated graphics in computer-based lesson, each subject participated in a lesson teaching the mathematical rule for average speed. The speed was simulated on the computer screen with travelling time, helping the students learn that speed is defined as distance divided by time. Animated graphics pioneers new frontiers in the teaching of certain math concepts which otherwise could not be demonstrated, such as speed.

Trajectory is defined as the direction of the travelling path of an object (Rieber & Kini, 1991). Instruction often involves concepts and rules which not only change over time but also move in a certain direction. For example, velocity refers to the speed of a moving object denoting its direction. Therefore, learning from instructional tasks which require students to visualize the motion of objects along certain paths can be improved with appropriate and selective application of animation.

Research findings have consistently indicated that computer-animated presentation enhances student learning when the learning task is in congruence with the attributes of animation. Rieber (1990b) reported positive results when animated visuals were utilized to present physics concepts to young children. Newton's Law of Motion was used as lesson content in his research. A ball symbol to represent an object was animated to demonstrate the consequences of the forces acting on the object. This animation was added to the lesson text in places considered to be most difficult and in need of visual support.

This study was replicated on adults with content modifications (Rieber, Boyce, & Assad, 1990). In the research, no differences in learning performance were found between text, static, and animated graphic presentation. The lack of differences can be accounted for by maturation effects (Pressley, 1977). The role of cueing imagery as a learning aid is decreased, as an individual is matured. The adult subjects in text treatment could form their own mental images without any visual aids as well as those in static graphics and animated graphics groups. However, an analysis of response latency data on the post-test showed that students who were provided with animated visuals took significantly less time to answer. Those results explain that animated presentations of Newtonian mechanics assisted learning, since the learning task requirements of Newton's Law were congruent with the characteristics of animation. Consistently, Rieber's recent research (1996) which revealed high efficacy of animated graphics as feedback strategy, employed "Acceleration and Velocity" as subject matter. The students had control over the acceleration of an animated ball and could observe the consequent effects upon the ball's velocity. The nature of subject matter was matched with the two attributes of animation – motion and trajectory.

Park and Gittleman (1992) found that animated visual displays in computer-based instruction were more effective than static visual displays for teaching electronic circuit troubleshooting skills. Natural feedback involving the circuit's automatic reactions to student input was found to help understanding of the learning material as much as explanatory feedback did. In this research, animation was selectively applied in order to simulate the invisible functional behaviors of electronic circuits and to demonstrate the procedural actions of troubleshooting. The subject matter, electronic troubleshooting skill, was consistent with the attributes of animation and also was in accordance with the instructional conditions (Park & Hopkins, 1993) in which animated visuals can be used effectively.

In summary, animation effects are possible when its conditions and attributes are congruent to the nature of the learning task. Because external representation of the object's movement on the screen is critical to the understanding of the concepts, instructional animation has been effectively utilized to teach abstract and dynamic concepts like Newton's Law, speed, acceleration, or electronic troubleshooting. Direct observation of these concepts in the movements of an actual object is particularly impossible in the real world. We can facilitate student learning in certain areas through the use of animation when those subject areas lend themselves to animation attributes.

2.3.3.2 Visual Grouping

On the computer screen, animated figures change continuously and the instructional designers need to be careful with the design of the lesson content. Even though the learning task is congruent with the attributes of animation, sometimes positive effects of animation may be lost due to such factors as poor design of computer-based instruction, which could lead to distraction and inhibit attention to the animated presentation of the learning material. Rieber (1990a) suggested "visual grouping" as a design recommendation. If the designer breaks down one instructional screen frame into several visual groups and presents them one at a time, it will help students pay attention to the animated presentation.

In Rieber's study (1989), there was no support for the use of animation even though the lesson content taught Newton's Laws of Motion, which is related to the attributes of animation. The learning time data showed that they spent less time viewing the animated visuals, and instead used more time reading the text. They failed to attend to relevant cues provided by animated visual displays. They were distracted by the simultaneous presentation of both animated and textual information on one instructional screen frame.

In his later research, Rieber (1990b) modified the design in two aspects. The lesson content was made easier than that of the previous version (Rieber, 1989), and the visual grouping strategy was applied to the instructional frame design, i.e. each screen frame was divided into several textual or graphic "chunks" or "groups". Students viewed and studied each chunk (group) one at a time, pressing the space bar when they finished viewing and were ready to go to the next chunk. Thus, each screen frame was presented in a series of visual groups depending on student pace (pressing space bar). This change (visual grouping) in design, which prevented the students from being distracted by other textual material, helped them pay attention to the pertinent information included in the animated presentation. Therefore, the result showed that the animated graphic group performed better than both the static and no graphic group. Those results were confirmed in Rieber's subsequent study (1991a) designed to investigate the effects of visual grouping strategies on selective attention in computer-based science instruction. Students given animated presentation of a lesson content outperformed students in a static graphic group, but only when the animated lesson frames were presented in groups, or chunks of textual and visual sequences.

In conclusion, when instructional designers incorporate special effects, like animation into computer-based instruction, they should employ strategies to reduce student's distraction and to maximize efficacy of animation. Visual grouping is one such strategy to enhance learning. The positive outcomes of the application of animation in instruction is very sensitive and susceptible to the computer-based instructional developer's design decisions.

2.4 Virtual Reality and 3D Visuals

Recent advances in computer technology allow us to create a virtual reality environment, providing three-dimensional virtual representation of our physical world. Virtual reality refers to an innovative computer-generated graphic world with a multisensory, real-time interactive, three-dimensional environment resembling the real world (Ferrington & Loge, 1992; Franchi, 1995; McLellan, 1994). Both three-dimensional images and motion are integrated into virtual reality technology. Individuals can create their own experiences in virtual space, which they cannot do in real world. This evolution of human-computer interface technology leads to concerns about the effects of virtual reality technology on student learning. It is helpful for educational researchers to understand the concepts and characteristics of virtual reality technology so that they can better apply them in the teaching process.

2.4.1 What is Virtual Reality ?

Development of high-speed computer processor and computer graphic technology enables us to create a virtual representation of our physical world and to construct our own learning in that environment. For instance, scientists can work in the virtual world of a realistic three-dimensional molecular structure and pilots are trained in a simulated flight-training world. When learning is not just to memorize simple facts but to encourage learning-by-doing or learning-by-discovery, then virtual reality becomes a valuable tool for instruction.

Virtual reality (VR) is defined as a new computer technology which consists of a multisensory, real-time interactive, three-dimensional graphic environment, creating a realistic world (Ferrington & Loge, 1992; Franchi, 1995; McLellan, 1993). In addition to providing three-dimensional pictures, current-generation virtual reality offers the users the illusion of being physically present in a virtual visual-spatial world (Held & Durlach, 1991). It is a world of integrated computer technology using both hardware and software, whereby the users are immersed in as a participant rather than an observer. McLellan (1994) pointed out that, "The purpose of virtual reality is to create an experience that occurs in physical reality or perhaps only in the imagination, representing ideas so we can move through them and manipulate them in ways we cannot in physical reality"(p2).

From a technology-oriented viewpoint, Helsel (1992) defined virtual reality as human-computer communication interface, enabling the users to deal with information interactively and vividly in the computer-simulated virtual world. Visual display of virtual reality technology at the lowest level is provided with a non-head mounted system without fixed goggle, whereby the users position their eyes on the computer screen as needed. They navigate through the screen changing their viewpoint with a mouse and keyboard. At the higher level, a head-mounted (goggle-like) device with wide-angled optics positioned in front of eyes is used to display three-dimensional virtual world. Both display systems allow people to perceive the computer-generated graphic world as a three-dimensional world, which is "real-like".

In virtual reality, the user's motion is controlled either by a mouse and keyboard at the lowest level, or by a dataglove and head-mounted device at the higher level. At the lowest level of virtual reality, the users navigate through the virtual world represented on the computer screen, by clicking a mouse or handling a joystick. At the higher levels, the user who wears a head-mounted device and dataglove can travel and move throughout the virtual space as if it were real (Ferrington & Loge, 1992; Franchi, 1995; Mclellan, 1993; Merickel, 1992; Craver, 1994). A dataglove is an electric sensor which tracks the user's position. The head-mounted device has a motion detector which senses the change of the user's position. The data of new location is delivered to the computer and the computer produces the new shifted images to create an illusion of movement, altering the user's point of view.

There are two features in graphic-based virtual reality (Ainge, 1996). First, apparent 3D nature of the worlds is presented to the learner. By navigating in three-dimensional coordinates with input device such as mouse or joystick, the learner can change their perspective and explore the spatial relationships between objects. Second, the graphic-based virtual reality encourages the learner to become actively involved in learning, modifying the virtual world. It is different from film or video where the learner is a passive viewer. Those features of virtual reality technology are enough to grasp the learner's interest.

2.4.2 Importance of Realism

Due to the rapid advances in computer technology, sophisticated images with high resolution graphics and real-time interactiveness can be readily attained in a computer.

Learning can be enhanced by images with appropriate color, spatial, and motion cues. Three-dimensional realistic image is a part of the most recent technology and the increased realism provides learners with a more accurate depiction of the learning content. Thus, the transfer of learning or training from virtual reality to the real world can be maximized.

2.4.2.1 Realism Theories

Proponents of realism theories (Dale, 1946; Carpenter, 1953) suggest that the more realistic the instructional cues are, the more likely they are to facilitate learning. In the "cone of experience" theory by Dale (1946), the continuum from the most abstract experience to the most concrete experience was referred to as the "cone of experience". His basic assumption was that an increase of realistic detail in visual illustration leads to an increase in learning. Carpenter's (1946) "sign-similarity hypothesis" proposed that learning is more likely to occur as the degree of similarity increases between symbols and real situations. Unfortunately, these theories were questioned by Dwyer (1994)'s generalization of his previous research about instructional visuals. From his experiments with other colleagues (Berry & Dwyer, 1982; Dwyer & Parkhurst, 1984; Joseph & Dwyer, 1984), he generalized that the increase in the amount of realism in visual cues does not guarantee a corresponding increase in learning outcomes. However, if the human heart function, which he used as learning material, were illustrated by current computer graphic technology in a three-dimensional representation including computer animation, the illustration would be more sophisticated and refined, and the results might be different from his previous research.

2.4.2.2 Three-dimensional Realistic Images and Learning

Preble and Preble (1989) noted that "to perceive is to become aware through the senses, particularly through sight or hearing, and to achieve understanding by means of such awareness" (p5). Therefore, perceived realism using effective visuals is important to facilitate learning and to increase retention. Three-dimensional pictures as well as moving pictures contribute to conveying the realism to the learner. Milheim (1994) described the instructional potential of three-dimensional graphics as three levels : three-dimensional graphics without motion; three-dimensional graphics with motion (not interactive); and three-dimensional graphics with learner control (interactive). The three-dimensional graphics with interactive learner control is utilized in the virtual reality technology. He also contended that depth should be embodied in the three-dimensional images. The depth can be portrayed by using shade and perspective in three-dimensional form.

The realistic image is ranked by how accurately and naturally the objects are modeled and represented visually. Three-dimensional images with rendering play important roles in signifying realistic visuals, and this function can be implemented easily by current computer technology. Rendering refers to the processing of representing the physical world realistically and naturally on a two-dimensional space, such as a computer screen (Duff, 1994). Current computer graphics present effective rendering with photorealistic software and hardware. More effective rendering images can be produced as a result of more powerful computers, more sophisticated modeling and rendering software, and higher quality hardware device. Photorealistic rendering describes objects and their environment realistically, just like pictures. The rendering features are valuable when it is impossible to observe the physical situation or objects. Computer rendering is performed by three-dimensional computer geometry. The material, the environment, the movement, and the light source are the input values of the geometry function. The computer calculates the values of the picture element and then displays them on the screen. Thus, rendering allows for a three-dimensional realistic image to be displayed on the computer screen. Computer-based instruction utilizing this feature can increase the student's perception of spatial relationships. Rendering greatly enhances the potential of the computer as a visual learning tool.

The way in which something is viewed influences the learner's perception. For example, in the medical area where the learning intent is to teach complex body structures, perceptual cues with sophisticated imagery are needed to help the students better comprehend and encode the complex information. The teaching of surgical skills requires the visualization of sophisticated images in order to understand real body structures. In this situation, two-dimensional and still pictures do not provide sufficient perceptual cues for learning. However, three-dimensional images could greatly facilitate learning. Surgical simulation, like flight simulation in pilot training, provides student surgeons with a non-threatening environment in which to rehearse a surgical operation on a virtual patient. The learning is greatly improved by the realistic perceptual cues. Susten, Kastella, and Conley (1991) in medical education field developed 3D animated computer images of the human brain and its components, and then recorded them on a videodisc. The researchers reconstructed 3D images of anatomical objects from a series of 2D images of cross-sections, so called Digital Anatomist. They argued the effectiveness of computer-generated models in providing a powerful visualization tool for learning 3D anatomical relationship.

Chemistry provides another example of a topic that is very difficult to conceptualize. Molecules are intangible entities with three-dimensional structures. Many students have difficulty in visualizing the operation of molecules (Seddon, Tariq, & Veiga, 1982). Seddon, Eniaiyehu, and Jusoh (1984) developed two strategies to remedy the difficulty in the learning of visualizing molecules rotation in diagrams of three-dimensional structure. First, using the shadow is one of the important cues to visualize the molecules rotation showing three-dimensional spatial relationship in diagram. Second method is to simulate the motion of molecules rotation. These two methods have been shown to improve a student's performance on molecules rotation task in their study.

Consistently, 3D interactive computer simulation was found to be effective for teaching molecular structure of the water in Hakerem et al. (1993)'s study. The researchers employed 3D dynamic simulations to change students' misconceptions about the formation of individual water molecules, and the molecular structure of ice and vapor. External visualization of the water molecules on the computer screen in three-dimensional format helped the students understand the particle nature of water, which is impossible to view in real world.

There is more evidence to support the use of three-dimensional visuals in science learning. Williamson (1992) investigated the effects of dynamic and three-dimensional presentation as a visual aid to college students' comprehension of a chemistry concept. The particulate nature of matter was realistically illustrated by animated three-dimensional visuals using computer. There were significant differences in the conceptual understanding and the number of misconceptions between the treatment group and the control group. The treatment group studied three-dimensional dynamic visuals. They showed an increase in conceptual understanding and a decrease in the number of misconceptions. This outcome can be attributed to having a realistic mental model of particulate behavior created by the three-dimensional graphics.

Tretheway (1991) found that female students with low visualization ability benefited from two and three-dimensional visualization training. She examined the effectiveness of computer-created animation on the improvement of visualization skills. All the subjects were trained using computer animated graphics of objects rotating in space. These objects were then transformed from three-dimensional to two-dimensional. The treatment was found to be much more effective for females who had low visual ability.

2.4.3 Virtual Reality and Learning Effects

Although virtual reality has the potential for instruction, there has been little research in this area. Learners can benefit from virtual reality, since it provides them with three-dimensional spatial information. If the learning task requiring a three-dimensional image is represented in two-dimensional form with traditional media such as 2D still pictures, the cognitive load remains on the learner to interpret the spatial information from two-dimensional to three-dimensional format.

Computer-based learning environment, called VREAM program, was developed by Ainge (1996) to allow students to construct and explore 3D shapes on computer-screen. Students could draw and manipulate the shapes freely from different viewpoint.

Compared to control group, virtual reality group greatly improved their scores on their post-test and showed considerable learning outcomes on recognition of 3D shapes. Students who were provided with virtual reality treatment were very enthusiastic about working with computers, while the control group did not show as much interest as the treatment group.

Regian, Shebilske, and Monk (1992) examined the effectiveness of virtual reality in the teaching of procedural and navigational tasks. Procedural tasks require the learners to perform a series of motor sequences. Virtual reality is regarded as an excellent interface for training in procedural tasks (Kreuger, 1991), because practice is needed to acquire procedural knowledge (Suppes & Morningstar, 1972; Anderson, 1982). To perform the navigational task, the learners navigate and learn through the virtual spatial environment. There are two virtual worlds in this experiment, one is a virtual console for the procedural console-operation task in two-dimensional format and the other is a virtual maze space representing a three-dimensional navigational task. The subjects participated in two virtual worlds to learn and perform procedural and navigational tasks. The results showed that subjects were able to learn spatial-procedural knowledge and spatial-navigational skills in two virtual worlds. The researchers also compared the learning effects between two-dimensional virtual reality representations and three-dimensional virtual reality representations of the navigational maze task. Learners under the two-dimensional condition were less motivated to learn the maze task and their test scores were found to be lower than those of the students under the three-dimensional maze representation.

Spatially-related and problem-solving abilities of children were improved by training with two-dimensional and three-dimensional computer-graphic models, in Merickel's Creative Technology Project (1990, 1992). Students between ages of eight to eleven participated in both a computer workstation treatment and a virtual reality system treatment. Children in the computer workstation group were instructed to solve spatial-relationship problems. In virtual reality treatment, students interacted with the computer-generated, three-dimensional environment and traveled in virtual space with a head-mounted display device and DataGlove. The two treatments enhanced the children's cognitive abilities to visualize and mentally manipulate two-dimensional figures, to displace and transform mental images of three-dimensional objects, and to solve spatially-related problems. These results imply that computer graphics and virtual reality technology have great potential as an instructional and training tool.

2.4.4 Rationales for using Virtual Reality Technology in Education

2.4.4.1 Reduction in Cognitive Load

In virtual reality, the emphasis is on visualization of three-dimensional images, although it deals with a multisensory system. As mentioned earlier, picture aids are helpful in recalling learning content that illustrates imageable facts, ideas, or concepts. One outstanding characteristic of virtual reality is its three-dimensional environment, which provides the users with the illusion of being present in a virtual world that resembles the real physical world. The highly visual characteristic of virtual reality technology reduces the cognitive load of translating the spatial information from a two-dimensional format to a three-dimensional format (Regian, Shebilske, & Monk, 1992).

2.4.4.2 Motivation and Virtual Reality

The highly visual factor of virtual reality incorporating three-dimensional images can strongly motivate students, since the designers can make the learning material more fun and curious so as to increase the student's participation in the learning task (Ainge, 1996; Regian, Shebilske, Monk, 1992). The learners can navigate and explore inside virtual space on their own. They can be fully immersed into the computer-generated artifacts and engaged in the real-time interactive environment as active participants, not as passive observers, since their sensory experiences in the three-dimensional virtual world are much like those in the physical world (Shapiro & McDonald, 1992; Chiou, 1995).

2.4.5 Summary of Virtual Reality and 3D Visuals

In this section, the new emerging technology, called virtual reality, was discussed. The importance of realistic pictures and their impact on learning, as well as the positive effects of virtual reality technology, was reviewed. Some rationales for the application of virtual reality technology in education were also suggested.

There are many areas in which virtual reality technology can be applied - education, entertainment, medical research, and training. Learners can explore their own experiences in realistic virtual settings, rather than dependence on the abstractness of a textbook. Knowledge is actively constructed by learners themselves, not passively transmitted to them. The highly visual characteristics of virtual reality can motivate students as they are immersed into the virtual system. However, educators should have intended goals in order to improve learning through the use of virtual reality technology. They need to understand the unique features of virtual reality, which can be incorporated into teaching strategies. In addition, instructional designers should have appropriate guidelines and rationales by which to integrate virtual reality technology into education.

2.5 Attitudes Toward Computer-Based Science Instruction

Fostering positive student attitudes toward school work is an important part of educational practices. Student attitudes toward instruction may play a crucial role in the success of their schooling. Researchers have investigated the influence of student attitudes toward science on achievement, indicating that science achievement is related to science attitudes (Geban, Askar, & Ozkan, 1992; Hofstein, Ben-Zvi, & Samuel, 1976; Hounshell & Hill, 1989; Schibeci & Riley, 1986). Student attitudes toward computers affect their future behaviors such as the intent to pursue a major in computer studies and to take more computer courses, as well as to learn about computers (Clarke & Chamber, 1989; Shashaani, 1994; Temple & Lips, 1989).

2.5.1 Attitudes Toward Science

Ugurogla and Walberg (1979) found that motivation accounts for 11.4 percent of the variance of achievement in his quantitative synthesis of forty studies on motivation and achievement. In a study of meta-analysis examining the relationship between student attitudes and achievement in secondary school science, Wilson (1980) reported a significant positive correlation. Student perceptions of science instruction influence their attitudes toward science and those attitudes in turn influence achievement (Schibeci &

Riley, 1986). Thus, promotion and maintenance of positive attitudes toward instruction is considered one of the major determinants in high performance of science learning. In addition, teachers should provide students with a more exciting and explorative learning environment which encourages students to be engaged in science activities.

Science laboratory work is one of the important parts in the science curriculum. Learning science concepts in laboratory is an appropriate teaching method regardless of gender. In a study of measurement of students' interests in laboratory work and their attitudes toward laboratory work, Hofstein, Ben-Zvi, & Samuel (1976) found that laboratory experience in high school chemistry instruction is worthwhile for girls as well as boys in that no differences were revealed when comparing the attitude scores between boys and girls. They also reported no differences in the attitudes toward chemistry laboratory work between students in the biology major and those in physics/math major. Freedman (1997) investigated how a hands-on laboratory experience plays an important role as a way of fostering students' attitudes toward science and improving students' achievement level in physical science knowledge. Laboratory experience positively influenced attitudes toward science instruction as well as achievement in learning physical science concepts. Students who received laboratory treatment scored significantly higher on achievement test in physical science knowledge, and had more positive attitudes toward science than those who did not receive the treatment, although it was not statistically significant. There was also positive correlations between their attitudes and achievement. Therefore, laboratory experience is an effective instructional method for science teaching.

Computers as well as laboratory work can facilitate student's science learning and can influence motivation, and ultimately attitudes toward science instruction (Geban, Askar, & Oakan, 1992; Hounshell & Hill, 1989). Computer-based instruction has a high potential to teach science concepts considered impossible to experiment with and conduct in other instructional systems. Geban et al. (1992) investigated the effects of computer simulations and problem-solving approaches on chemistry achievement and attitudes of high school students. The results showed that students in computer-simulation treatment and in problem-solving treatment achieved higher post-test scores than those in conventional approaches. The computer-simulation approaches produced more positive attitudes toward chemistry than the other instructional treatments.

Consistently, computers can be regarded as a technological tool not only to enrich and supplement lectures in high school biology teaching but also to improve the development of positive student attitudes toward biology class (Hounshell & Hill, 1989; Morrel, 1992). In a study of the effects of computer-assisted instruction on student learning of photosynthesis and introductory genetics, Morrel (1992) revealed that most students were enthusiastic about working with computers. Their attitudes were generally favorable toward computer-assisted instruction, whereas those in the photosynthesis unit had more positive attitudes than those in genetics unit had. The students in photosynthesis group felt that the computer-assisted instruction was time-efficient, were comfortable with the instruction, and even found computer-assisted instruction to be more motivating than the traditional classroom instruction.

It is noted that teachers should have positive attitudes toward the use of technology to integrate the computers facilitating science learning. Their positive attitudes concerning the instructional uses of computers are developed through the technology training (Berenson & Stiff, 1991). They can be trained to construct their knowledge about relevant technologies for the science subjects, and to learn how the technologies can be applied for science teaching. It is worthwhile for science teachers and school officials to consider the integration of modern computer technology into the science classroom, which provides the promise of enhancing student's attitudes and achievement in science learning.

2.5.2 Attitudes Toward Computers

Attitudes toward computers as well as attitudes toward science are considered one of the important factors in implementing computer-based science instruction. Computer attitude is defined as an individual's feeling about the personal and societal use of computers in appropriate ways (Simonson, Maurer, Montag-Torardi, & Whitaker, 1987). Loyd and Gressard (1986) developed the Computer Attitude Scale (CAS) to measure attitudes toward computers and observe computer-related behaviors. From their perspective, positive attitudes involve enjoyment in working with computers, freedom from anxiety about computers, confidence in ability to use and learn about computers, and a sense of computer usefulness.

2.6 Summary of Literature Review

The purpose of the literature review is to provide the background information of the present study. The literature was reviewed in four areas: theoretical justification for the use of instructional visuals; effects of animated visuals on learning; virtual reality and

3D visuals; and student's attitudes toward instruction. Several theories supporting the efficacy of visuals on learning were proposed by researchers (Craik & Lockhart, 1972; Mayer, 1997; Mayer, Steinhoff, Bower, & Mars, 1995; Paivio, 1990, 1991; Clark & Paivio, 1991; Kulhavy, 1992, 1994, 1997; Plass, Chun, Mayer, & Leutner, 1998; Schnotz, Picard, Henninger, 1994; Schnotz, Picard, & Hron, 1993). Many of those theories argue the advantages of visual information over verbal information.

There is general consensus that animation in computer-based instruction, whether it is interactive or not, can produce cognitive outcomes as well as affective outcomes under certain conditions. Instructional animation was found to be effective when the attributes of animation are consistent with the learning task requirement (Baek & Layne, 1988; Chanlin & Chan, 1996; Mayer, 1994, 1997; Mayer & Anderson, 1991, 1992; Mayer & Sims, 1994; Mayton, 1990; Park & Gittleman, 1992; Pookay & Szabo, 1995; Rieber, 1990a, 1990b, 1991a, 1996; Rieber, Boyce, & Assad, 1990; Rieber & Kini, 1991; Thompson & Riding, 1990; White & Horowitz, 1993). Researchers also agreed to a motivational and attitudinal value of animated graphics in computer-based instruction (Rieber, 1990b, 1996; Frederick & Lehman, 1992; Chanlin & Chan, 1996).

Students can also benefit from three-dimensional images (Hakerem, Dobrynina, & Shore, 1993; Williamson, 1992; Tretheway, 1991; Seddon, Tariq, & Veiga, 1982; Susten, Kastella, Conley, 1991) and virtual reality which is a new computer-generated and technological environment (Ainge, 1996; Merickel, 1992; Regian, Shebilske, and Monk, 1992). However, instructional designers need to be careful not to confuse the dramatic effects on learning, but to speculate the learning task prudently to determine if it requires realistic three-dimensional cues. With respect to attitudes toward computer-based science instruction, students were generally favorable to working with computers in learning science concepts (Geban, Askar, Oakan, 1992; Hounshell & Hill, 1989; Morrel, 1992).

Most research comparing the effects of animated visuals with those of static visuals are limited to two-dimensional images. Thus, it is interesting to examine the impact of animated graphics on achievement, attitudes, and information retrieval time, considering the level of realism (2D and 3D). In the present study, differential effects of animated and static visuals in two-dimensional and three-dimensional representation on student learning, attitudes, and retrieval time will be investigated based on the several theories supporting instructional visuals.

2.7 Research Hypotheses

Based on the literatures reviewed above, the model to be tested was proposed by the author in Figure 3 and Figure 4. The proposed model draws on *Dual-Coding Theory* (Paivio, 1990, 1991; Clark & Paivio, 1991) with the assumption of picture superiority over words and on *Level of Processing Theory*. Both three-dimensional images and animated graphics were provided as two encoding stimuli which are visual analogies to reality. It was assumed that the external stimuli, i.e. three-dimensional images and animation would facilitate encoding from visual information into internal visual representation in memory, and thus facilitate creating internal verbal representation in memory. The assumption in cognitive processing was tested by assessing the post-test scores and time to answer test questions. It was also assumed that more affective outcomes would be produced from visual analogies such as three-dimensional images and animated visuals. The assumption for affective domain was tested by assessing scores of attitude questionnaire.

Based on the model in Figure 3 and Figure 4, nine hypotheses were generated as follows.

Hypothesis 1. Students under three-dimensional graphic condition exhibit more positive attitudes toward instruction than those in two-dimensional graphic condition.

Hypothesis 2. Students under animated graphic condition exhibit more positive attitudes toward instruction than those in static graphic condition.

Hypothesis 3. Students under three-dimensional animated graphic condition exhibit more positive attitudes toward instruction than those under other treatment conditions, which are two-dimensional static, two-dimensional animated, and three-dimensional static graphic conditions.

Hypothesis 4. Students under three-dimensional graphic condition achieve higher post-test scores than those in two-dimensional graphic condition.

Hypothesis 5. Students under animated graphic condition achieve higher post-test scores than those in static graphic condition.

Hypothesis 6. Students under three-dimensional animated graphic condition achieve higher post-test scores than those under other treatment conditions, which are two-dimensional static, two-dimensional animated, and three-dimensional static graphic conditions.

Hypothesis 7. Students under three-dimensional graphic condition take less time to answer post-test questions than those under two-dimensional graphic condition.

Hypothesis 8. Students under animated graphic condition take less time to answer post-test questions than those under static graphic condition.

Hypothesis 9. Students under three-dimensional animated graphic condition take less time to answer post-test questions than those under other treatment conditions which are two-dimensional static, two-dimensional animated, and three-dimensional static graphic conditions.

Figure 3. Hypothesized Model of the Effects of 3D animated graphics in Cognitive Processing Paradigm

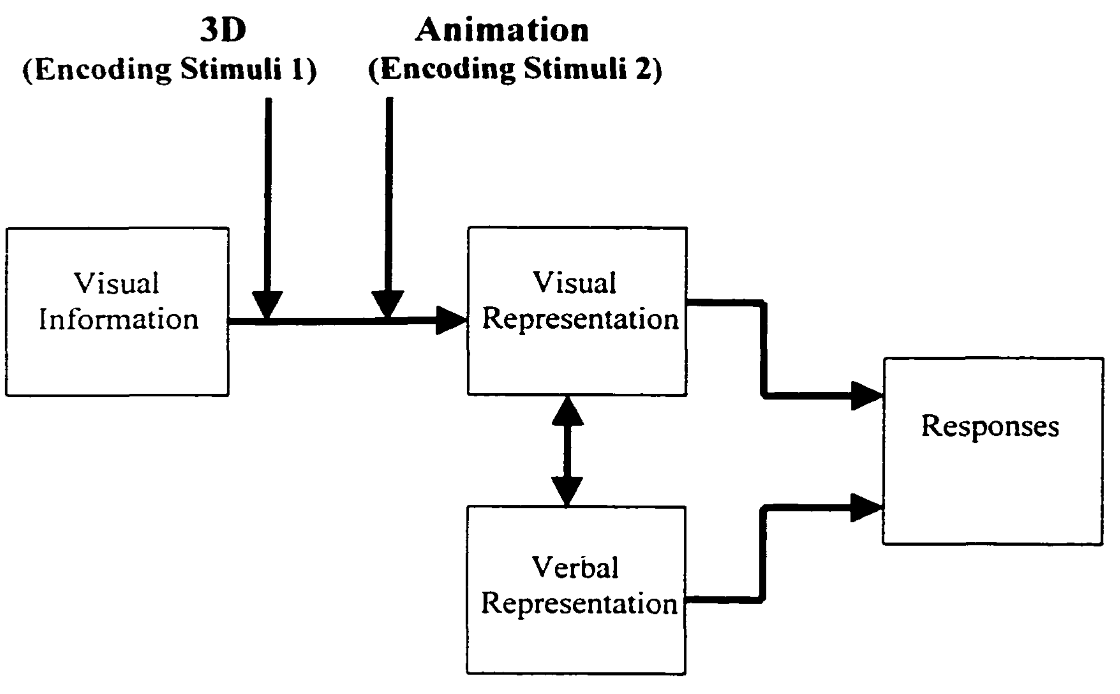
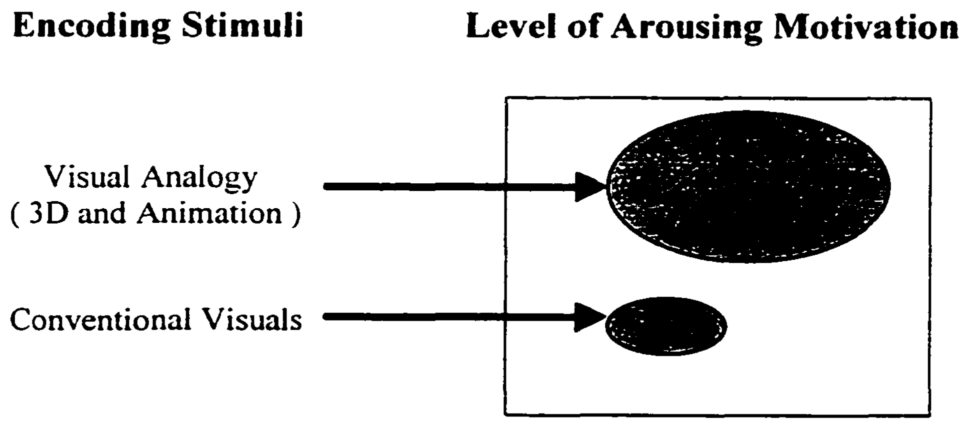


Figure 4. Hypothesized Model of the Effects of 3D animated graphics in Affective Processing Paradigm



Chapter 3

Method

3.1 Introduction

This research investigated the effects of animated graphics and three-dimensional graphics on student learning and attitudes. Three purposes are explored in the present study : (1) to investigate how three-dimensional graphics affects student learning, attitude toward instruction, and information retrieval time in comparison with two-dimensional graphics; (2) to investigate how animated graphics affects student learning, attitude toward instruction, and information retrieval time in comparison with static graphics; and (3) to investigate whether three-dimensional graphics, when they are supported by animation (virtual reality technology), is the most effective visual cues to improve learning, to develop positive attitudes, and to have the students retrieve the information quickly.

In this chapter, the methods to conduct an experiment for the present study are discussed. The participants in the experiment are described first, and the design of the research is explained. Then, learning material employed in the computer-based instruction is presented, followed by the description of the four computer-based instructional programs in detail. Next, measures and instrument to assess the participants' responses are provided, and computer equipment needed for the experiment is presented. A description of experiment procedures is also provided, and a statistical method is suggested for data analysis.

3.2 Subjects

The participants of the present study consisted of 145 eighth-grade students from a public junior high school of the inner-city area in Los Angeles. One teacher, who was responsible for teaching science in the school, was willing to incorporate the CBI activity of this study as part of the students' science learning. The lesson content of CBI program was consistent with a chapter of the students' science textbook and they participated in this experiment two weeks prior to studying the chapter. Therefore, it was assumed that the students had little or no prior knowledge of the CBI learning content.

To ensure that they would be able to proceed by themselves through the CBI learning module of this study, background information on the students was collected. More than 85 % of the students knew how to use the computer keyboard and mouse, and about 75 % of the students had computer experience computers such as word-processing, Internet, and computer gaming for longer than six months. The subjects were 72 boys and 73 girls, and the range of age was from 13 to 14.5 years. The subjects were recruited from five classrooms, each consisting of approximately 30 students.

3.3 Design

The experimental design used in this study was a 2X2 factorial design with three dependent variables. The dependent variables were: post-test scores, attitudes toward instruction, and response time in answering the post-test questions. There were two independent variables. Dimension, the first independent variable, included two types: 3D and 2D. The two levels of motion, the second independent variable, were: animated graphics and static graphics. The conceptual design for the impact of the dimension level and animation on students' achievement, attitudes toward instruction, and response time is described as follows:

	2D	**3D**
static graphics	static graphics in 2D representation	static graphics in 3D representation
animated graphics	animated graphics in 2D representation	animated graphics in 3D representation

3.4 CBI Learning Material

The learning material in this Computer-Based Instruction unit is the "Motion of the Earth and the Moon" in the space. This learning material is useful for animation and three-dimensional (3D) representation because it deals with the revolving of the Moon and the Earth in our solar system, and the 3D realistic representation of their movements in virtual environment can facilitate a student's perception of the spatial relationship. The rotation of those planets in space can be implemented with 3D animated visuals.

The CBI learning material consisted of two modules. The first module demonstrated how the Earth moves. It showed the self-rotation of the Earth and why we have day and night. The module also illustrated the Earth's revolution around the Sun and how it causes the four seasons. The second learning module showed the moon phase, which is the changing shape of the Moon according to its movement around the Earth. The text and graphics on the computer screen, either animated or static, described how the shape of the Moon seems to change.

The learning objectives of the two learning modules are as follows:

Module 1. Motion of the Earth

(1) Understand self-rotation of the Earth on its axis.

(2) Explain the effects of the self-rotation of the Earth.

(3) Understand the revolution of the Earth.

(4) Explain the effects of the revolution of the Earth.

Module 2. Moon Phases

(1) Understand self-rotation of the Moon and revolution of the Moon around the Earth.

(2) Explain the effects of the revolution of the Moon around the Earth.

(3) List eight major phases of the Moon ordered from the new moon to the next new moon. (i.e. New Moon, Waxing Crescent, Half Moon (First Quarter), Waxing Gibbous, Full Moon, Waning Gibbous, Half Moon (Last Quarter), Waning Crescent)

(4) Explain how the shape of the Moon seems to change as the Moon circles the Earth.

3.5 Computer-Based Instructional Program and Treatment Groups

Four versions of Computer-Based Instructional Program were developed, combining two modes of visual display (static visuals vs. animated visuals) with two levels of visual dimension (2D and 3D). For the static visuals, the learning module was presented with static pictures on a computer screen. The motion was described with an arrow and a series of still pictures. For the animated visual version, the movement of the planets in the space was explained by animated motion pictures, increasing the student's perception of realism. In the 2D program version, the pictures were represented in two-dimensional space without shadowing and rendering, which induced the student's low spatial relationship. The 3D program version provided the students with the realistic three-dimensional image of planets and space.

Each treatment group was instructed using the identical learning materials "Movement of the Earth and the Moon in space", by a different version of the Computer-Based Instructional Program which was developed in a different mode of graphical presentation. The students were given control of the program sequence, selecting options to go to the previous screen, to the next screen, or to review from the beginning. The information presented by text on the computer screen was uniform in all treatment program versions except one, the 3DA (Three-Dimensional Animated) version that included the navigation-through-space. The 3DA program version enabled the students to navigate through the space on the computer screen, and therefore extra text was added explaining how to navigate through the computer screen.

3.5.1 Arrangement of Computer Screen

The computer screen of the instructional program was composed of three subwindows: Change Window in small size on the top of the screen; Main Window in large size in the middle of the screen; and Information (Control) Window in small size on the bottom of the screen. The Change Window displayed the changing amount of sunlight the Earth receives from the Sun depending on the season. The color representing the amount of sunlight was changed from light yellow to red according to the position of the Earth in its orbit around the Sun, i.e. light yellow in winter, orange in spring, red in summer, orange again in fall. The changing shape of the Moon was also provided in this Change Window. The moon phases as seen from the Earth were shown on this top portion of the screen, which depended upon the revolution of the Moon around the Earth.

The majority of the learning content was presented on the large Main Window, including text and pictures. It presented the revolution of the Earth in its orbit around the Sun and the self-rotation on its axis, as well as the revolution of the Moon in its orbit around the Earth and its self-rotation. The topic of the learning module and instructions on how to operate the program were also provided on the Main Window.

The Information (Control) Window gave the users controlling information so that they could control the flow of the software program. There were two options for 2DS, 2DA, 3DS treatment groups: P (to review previous screen) and Space Bar (to go next). 3DA treatment group had one more optional icon at the right corner, which was the navigational control button.

3.5.2 Visual Grouping

Visual grouping or chunking (Rieber, 1990a, 1991a) was selected as a design strategy in all treatment conditions, particularly in 2DA and 3DA graphics treatments. For example, the animation of the Earth's revolution around the Sun was divided into four visual chunks. In the process of animation for the Earth's revolution, the Earth stopped its revolution around the Sun temporarily at each season until the student pressed the space bar to go to the next step. The animated spectrum of color also stopped concurrently, displaying one fixed color. Otherwise, students might not have focused on the important knowledge, but rather might have been distracted by the motion and miss it. The dynamic attributes of such animation can negatively influence student's learning if not carefully designed. In other words, the student could figure out the position of the Earth and the corresponding amount of sunlight the Earth gets from the Sun by way of visual grouping.

In the learning module of "Moon Phases", it was not until the subjects pressed the space bar as an input to go forward, that the Moon resumed its revolution in its orbit around the Earth. In this way, the Moon suspended its revolution at eight positions of major moon phases. The shape of the Moon as seen from the Earth displayed on Change Window, stopped accordingly its dynamic change and started again eight times.

3.5.3 Treatment Groups

The four treatment groups are described as follows:

3.5.3.1 2DS (Two-Dimensional Static) Graphics.

The pictures of the Sun, Moon, and Earth were displayed on a computer screen in a two-dimensional format. No shadow to show the depth of three-dimensional images was applied to the pictures. Therefore, the two-dimensional images of the planets looked like those from God's Eye View.

The motions of the Earth and the Moon were presented by circled arrows, which represents not only the orbit of those planets but also their self-rotations. The four different colors, light yellow for winter, orange for spring, red for summer, and orange for fall, each of which represented the amount of sunlight in each season, were displayed on the Change Window. In the second learning module, the subjects could also see the pictures of the moon phases on the Change Window. Instead of animation, the changing shape of the Moon was shown as a series of static pictures of eight major moon phases.

3.5.3.2 2DA (Two-Dimensional Animated) Graphics.

All the pictures of planets were described in a two-dimensional format, and the depth which enables an object to be three-dimensional image were excluded as in the 2DS Graphics group. However, the movements of the planets were animated along their orbits or axes, such as the revolution of the Earth around the Sun and that of the Moon around the Earth. The only difference between 2DS Graphics group and 2DA Graphics group was the ‘motion,’ which was applied to changing color to represent the amount of sunlight and to changing shapes of the Moon, as well as to the movement of the planets.

The color which depicted the amount of sunlight the Earth get from the Sun, was being dynamically changed while the Earth was travelling around the Sun. This change of color was synchronized with the changing position of the Earth along its orbit. The animated spectrum of changing colors looked more natural and smoother than the four fixed kinds of colors in 2DS Graphics condition.

Both the change of the moon phases and the revolution of the Moon around the Earth were manipulated by animated graphics at the same time. Therefore, as the Moon circled the Earth, the moon phases were being dynamically enlarged into a full moon or shrunken into the new moon. The changing shape of the Moon was synchronized with the position of the Moon in its orbit as it went around the Earth. In this way, the subjects could understand the relationship between the moon phase and the movement of the Moon.

3.5.3.3 3DS (Three-Dimensional Static) Graphics.

The pictures of the Sun, Moon, and Earth were displayed on a computer screen in a three-dimensional format, which looked more realistic than in 2DS or 2DA Graphics condition. Shadows and color textures as visual cues of three-dimensional images were added to the pictures of the treatment program to show the depth of three-dimensional images. Color textures for Sun, Earth, and Moon were made up of real 3D pictures taken from satellites. Three spheres representing the Sun, Earth, and Moon were covered with those textures in the process of programming. The effects of shadowing were implemented by 3D modeling and rendering of stationary planets from fixed viewpoint. More accurate and natural images were shown on the computer screen, which were designed to increase students' perception of realistic images and spatial relationship.

Circled arrows were used to present the movements of the Earth and the Moon as in 2DS treatment program. The motion of those planets was displayed on Main Window in the middle of the screen. In learning module of "Motion of the Earth", the different amount of sunlight of four seasons was expressed on the Change Window by discrete colors like light yellow for winter, orange for spring, red for summer, and orange for fall. The changing moon phase in second learning module was also seen on the Change Window in a series of eight moon phases without any dynamic motion.

3.5.3.4 3DA (Three-Dimensional Animated) Graphics.

The 3DA treatment program embodied the highest level of visual cues in instruction among four treatment groups. To provide students with realistic visual images, both motion and 3D representations were reflected in graphical presentation throughout the learning module. Color textures to show the surface of the planets as well as shadow prompt to describe the depth of an object were applied to the 3D visuals.

The realistic dynamic images of the Sun, Moon, and Earth were displayed by way of 3D modeling and rendering from changing viewpoint. The students could navigate through the screen and then change their viewpoint by clicking navigation buttons at the corner of the screen. In other words, they were given the control to explore and navigate through the space on the computer screen, changing their viewpoint in a virtual reality environment of the solar system. Subjects in this treatment were trained to know how to use navigation button and how to navigate on the screen before they started 3DA program version.

The 3D visual images of Earth and Moon were animated along their orbits to show their revolutions, while they were spinning on their axes at the same time. The students could also see those moving planets from different perspective by handling the mouse and navigation buttons. Consequently, by way of three-dimensional animated graphics, they navigated interactive virtual space looking at the moving planets. The appearance of the planets, such as their size or shade, were being dynamically changed and looked different according to the user's view. Therefore, the pictures of the objects looked most real and natural among the four treatment programs.

The 'animation' factor was reflected in spectrum of color change and the moon phases as well as in moving planets. The amount of sunlight the Earth receives from the Sun was described by animated spectrum of colors from light yellow to red. The color animation occurred simultaneously with the revolution of the Earth around the Sun. The color changed gradually as the Earth went around the Sun.

The moon phases in the second learning module were being dynamically altered from new moon to full moon and vice versa, while the Moon was travelling around the Earth. Thus, the position of the Moon in its orbit around the Earth was synchronized with the moon phases as seen from the Earth. The synchronization was designed to aim at students' better understanding the relationship between the motion of the Moon and its changing shape.

3.6 Measures and Instrument

3.6.1 Background Information

Before the subjects participated in this experiment, a survey questionnaire was given to each subject to answer background questions such as demographic information and prior computer experience (See Appendix B). Demographic questions asked about their birth date and gender. The purpose of computer experience questions was to see whether they were familiar with handling a computer keyboard and a mouse and to see how long they had worked with computers.

3.6.2 Questionnaire of Attitude Toward Computer-Based Science Instruction

Promotion of positive attitude toward school subjects is an important part of the teaching and learning process. In the present study, a survey questionnaire was used to measure the student attitudes toward instruction. The scale was originally designed to investigate two major concerns: Perceived Realism of Pictures in CBI, and Computer Usefulness in Science Learning. Eleven items on those subscales were developed by the author (See Appendix E).

These survey questions consisted of Y (Yes) or N (No) scales, with Y being positive, N being negative. It was supposed that for young children, questions with two options (Y/N) would be preferred to Likert-type scales having anchors such as "strongly agree", "neutral", and "strongly disagree. There was no negative statement in items, which might confuse young children. Item response "Y" was coded as point "1" and "N" coded as point "0". The total score was calculated by summing the scores of each item so that higher scores represented positive attitudes toward computer-based science instruction, whereas lower scores indicated negative attitudes toward instruction. Cronbach alpha was computed (.60) for eleven survey questions to determine the internal consistency.

The factor analysis of Attitude Toward Instruction indicated that four factors exist. Each of these can be considered as a subscale. Four factors explored were Computer Graphics Usefulness in Space Science Instruction, Computer Usefulness as a Learning Tool, Perceived Resalism of Pictures, and Perceived Motion of Pictures. Detailed description of factor analysis is presented in Chapter 4: Results.

Items on Computer Graphics Usefulness in Space Science Instruction consisted of three statements, to give an example "The pictures on the computer screen helped me understand space science." Typical statement in Computer Usefulness as a Learning Tool was "I feel a computer makes it easy to learn how the Earth and the Moon are moving in the space." Perceived Realism of Pictures included such items as "I feel the pictures on the computer screen looked real." An item of Perceived Motion of Pictures was "I feel the Moon and the Earth looked really moving."

3.6.3 Posttest Questions

Posttest questions were formed by the author with the aid of a teacher and an expert in science education, and the content was validated by them. The test items were developed to see if the learning objectives of the two learning modules "Motion of the Earth" and "Moon Phase" were attained through the computer-based instruction. A total of 30 questions was given to the students to assess their performance. This measure consisted of 24 multiple choice questions and six true/false questions as testing forms (See Appendix F). Cronbach alpha used to measure reliability was .61 for the thirty posttest questions.

3.6.4 Response Time to Posttest

Amount of time spent on posttest was measured to see how fast the students could retrieve from their memory the information that was taught in the CBI. The time from start to end of the post-test session was automatically recorded on a computer diskette. Survey time for attitude questionnaire was not counted as part of response time.

3.7 Dependent Measures

There were three dependent measures: attitude survey score; post-test score; and response time to the post-test. Attitude survey was administered to assess how their perceived realism and computer usefulness in learning module affected student attitudes toward instruction. Post-test score was to measure the learning outcomes after the students finished CBI. Response time as well as post-test score was used as a means of predicting cognitive outcomes.

3.8 Computer Equipment

The computer laboratory in this study had 26 Power Macs. To process large amount of data such as 3D animated graphics, high CPU speed and substantial memory size were required. The school computer lab met those needs for the experiment. Twenty four computers in the lab had CPU speed of 180 to 230 megahertz and 16 megabytes of RAM. The size of monitor was 14 inches, supporting resolution of 1024x768 with thousands of colors. Two Power Macs had CPU speed of 66 megahertz, which was enough to process simple graphics like 2DS program. Running 2DS program using lower speed CPU did not look different to viewers from processing using Power Macs of 180 or 230 megahertz. The two computers with low speed were assigned 2DS program. Six computers were installed with 2DS and another six installed with 3DS program. Hence, seven computers were assigned 2DA and another seven ones assigned 3DA program.

The four different versions of learning program were developed with C ++ programming language. Two of them, namely 3DS and 3DA, used extra texture files for displaying the realistic 3D images of Sun, Earth, and Moon while they were executing.

3.9 Procedures

The experiment was conducted in the well-equipped computer lab at the junior high school. In the classroom, the students were asked to answer background questions such as their computer experience and demographic information before they went to the computer lab (Appendix B). The CBI learning modules, attitude surveys, and post-test questions were administered by computers. The training module of 3DA program was attached to the beginning of the learning module. Therefore, the students to whom it was assigned were trained how to navigate on the computer screen before they started the learning module. For this reason, it seemed to take longer time for the students who were assigned 3DA program to complete this experiment than for those who were assigned the other three programs.

As the subjects arrived in the computer lab for the experiment, they were randomly assigned to one computer station (See Appendix D). Each station had only one of the four treatment programs preinstalled. About 30 students participated in CBI activity in each learning session, which was repeated five times for 145 students (See Appendix C). Subjects were given general direction of the CBI learning modules before the instruction started so as to minimize their confusion (See Appendix A). Once the subjects started the CBI activity, they were asked not to collaborate with each other but to complete it individually. After the CBI learning module, a survey of attitude questions was administered, and then post-test questions were provided. The time to take posttest was automatically recorded in the computer diskette. Upon completion of the posttest, they raised their hands and left the computer lab. They were rewarded with some Halloween goodies for their participation when they went back to their classroom.

3.10 Data Analysis

The data analysis consisted of a 2X2 factorial analysis of variance (ANOVA) of three dependent variables: scores of attitudes toward computer-based science instruction, scores of posttest, and the total amount of response time. The univariate analysis of variance on each dependent variable was conducted to see whether there was a main effect for dimension level (2D and 3D) and the type of graphics (static and animated), and the interaction effect between two independent variables.

A factor analysis was also conducted on one dependent variable, attitudes toward science instruction, to explore the factor structure of the scale and to see its properties. Four factors were found as a result of exploratory factor analysis of the attitude scale, which were Computer Graphics Usefulness in Space Science Instruction, Computer Usefulness as a Learning Tool, Perceived Realism of Pictures, and Perceived Motion of Pictures. Four separate univariate analyses of variance were completed for those four factors, each of which was considered as a subscale and also a dependent variable.

Chapter 4

Results

4.1 Introduction

This chapter provides the results of statistical analysis and the interpretation of the findings. Demographic information of subjects who participated in this study is presented first, followed by descriptive statistic, reliability, and the result of factor analysis of *attitude* measure. Next, the descriptive statistics and reliability of *post-test* measure and *response time* measure are discussed. Experimental group differences in total *attitudes* score and attitudes subscales are also presented, followed by group differences in *post-test* scores and in *response time* to post-test questions.

4.2 Demographic Information of Participants

Frequencies and percentage of students who participated in the present study are described in Table 1.

Table 1 : Demographic Information of Participants

Variables	N	Percentage (%)
1. Gender		
girl	73	50.3
boy	72	49.7
Total	145	100.0

Variable	N	Percentage (%)
2. Age		
13-14	145	100.0
Total	145	100.0
3. Computer Experience		
0 months	14	9.7
6 months	26	17.9
1 year	10	6.9
More than 1 year	76	52.4
Missing cases	19	13.1
Total	145	100.0
4. Keyboard and Mouse experience		
Yes	120	82.8
No	6	4.1
Missing cases	19	13.1
Total	145	100.0

4.3 Measures of Attitudes toward Computer-Based Science Instruction

Eleven post-activity questionnaire items were asked to determine the students' attitudes toward computer-based instruction(CBI) treatment. Cronbach alpha was computed to check internal consistency across eleven survey questions. To analyze the characteristics of the attitudes items, factor analysis was conducted. The results of 2-way analysis of variance (ANOVA) to access differences with regard to total score of attitude scale and its subscales which were obtained from factor analysis, are presented in sixth section.

4.3.1 General description of Measures of Attitudes toward Computer-Based Science Instruction

Means, standard deviations, and reliability of the attitude scale which was developed by the author, are presented in Table 2. To observe the internal consistency across items of the attitude scale Cronbach alpha was calculated based on the average inter-item correlation. The descriptive statistic of its subscales and their reliabilities will be provided later after factor analysis.

Table 2 : Descriptive Statistic and Reliability of Measure of Attitudes toward Computer-Based Science Instruction

Attitude Measure	Mean	SD	N	Alpha Reliability
Scale of Attitudes toward Computer-Based Science Instruction	8.48	1.92	145	.60

The results in Table 2 show that the students who participated in CBI activity had generally favorable attitudes about the treatment. The coefficient alpha reliability of the eleven items was .60, which can be acceptable reliability measure in experimental study.

4.3.2 Factor Analysis of Attitude Scale

The attitude scale, which was formed by the author, was used in the present study for the first time. Therefore, factor analysis was conducted for the purpose of identifying the underlying factors. Exploring factors revealed the number of factors and what underlying properties of attitudes scale led the students to answer the questionnaire items. The measure of attitude toward CBI activity was originally concerned with two major variables : Perceived Realism of Pictures in CBI and Computer Usefulness in Science Learning. The results of factor analysis were fairly consistent with these two variables. Four factors were extracted as a result of exploratory factor analysis. Two factors represented Perceived Realism of Pictures and the other two factors explained Computer Usefulness in Science Learning.

In Table 3, the rotated factor matrix, was presented for the attitude scale. The rotated factor loadings only greater than .40 were displayed. There was a consistent factor loading between an item and a factor. An item had only one high loading greater than .40 on one factor. As a factor extraction method, principal components analysis, which organizes uncorrelated combinations of the observed factors, was used. An orthogonal rotation method (Varimax) was employed to simplify the interpretation of factors, minimizing the number of variables that have high loadings on each factors. The eigenvalues of the first four factors from principal component analysis with varimax rotation were 2.313, 1.800, 1.296, and 1.024. These results of the exploratory factor analysis indicated that four underlying factors exist across the items of the scale of attitudes toward computer-based science instruction.

The items that comprise each factor were presented in Table 4. From the factor structure, factor 1 could be defined as "Computer Graphics Usefulness in Space Science Instruction", factor 2 as "Computer Usefulness as a Learning Tool", factor 3 as "Perceived Realism of Pictures", and "Perceived Motion of Pictures". Accordingly, the attitude scale could be reported that it consisted of four subscales. Means, standard deviations, and alpha reliabilities of each subscale are given in Table5 and inter-correlations between four subscales in Table 6. Four of six inter-correlations were statistically significant. Those moderate correlations, which were neither too high nor so low, induced good discriminant validity of the scale characterizing fairly well-organized structure of four factors.

Descriptive statistic in Table 5 implied that the participants in CBI activity had fairly positive attitudes toward instruction. Reliability coefficient of the attitude scale was .60, which is reasonable in experimental study, even though the reliabilities of the subscales were .57, .59, .49, .54 respectively.

Table 3 : Rotated Factor Matrix of Attitude Scale

Item Numbers	Factors			
	1	**2**	**3**	**4**
#11	.729			
#10	.728			
#3	.644			
#4		.742		
#5		.656		
#7		.640		
#6			.846	
#9			.766	
#1			.409	
#2				.829
#8				.635

Only high factor loadings (>.40) displayed above

Extraction Method: Principal Component Analysis.

Rotation Method: Varimax with Kaiser Normalization.

Rotation converged in 6 iterations.

Table 4 : Underlying Factor Structure of Attitude Scale

Factors	Items
1	#3. Now I understand the movement of the Earth and the Moon in space. #10. The pictures on the computer screen helped me understand space science. #11. The pictures on the computer screen told me how the Moon and the Earth are travelling in universe.
2	#4. I feel a computer makes it easy to learn how the Earth and the Moon are moving in the space. #5. I feel like I could interact and communicate with computer. #7. I feel like I could control and play with the computer all by myself.
3	#1. I feel the pictures on the computer screen looked real. #6. I like the pictures of the Earth, the Moon, and the Sun on the computer screen. #9. Next time, I would like to learn more space science with these real-like pictures.
4	#2. I feel the Moon and the Earth looked really moving. #8. I feel like I was taking a tour to space between the Sun and the Moon.

Table 5 : Descriptive Statistics of Four Attitude Subscales

Measures of Attitudes toward CBI	Mean	SD	Alpha Reliability
Subscale 1 (Computer Graphics Usefulness in Space Science Instruction)	2.69	.67	.57
Subscale 2 (Computer Usefulness as a Learning Tool)	2.34	.87	.51
Subscale 3 (Perceived Realism of Pictures)	2.44	.78	.49
Subscale 4 (Perceived Motion of Pictures)	1.01	.82	.54
Total Attitude Scale	8.48	1.92	.60

Table 6 : Correlation Coefficients between Four Attitude Subscales

Pearson Correlations

	Graphics Usefulness	Learning Usefulness	Picture Realism	Picture Motion
Graphics Usefulness	1.000	.229**	-.015	.208*
Learning Usefulness	.229**	1.000	-.047	.294**
Picture Realism	-.015	-.047	1.000	.271**
Picture Motion	.208*	.294**	.271**	1.000

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

* Correlation is significant at the 0.05 level (2-tailed).

4.3.3 Summary of Results about Measures of Attitude toward Computer-Based Science Instruction

Overall, students who received CBI treatment in the present study had favorable attitudes toward the activity: score of eleven attitude items ranged from 2 to 11 with mean of 8.48. The attitude measure showed reliability coefficient of .60, which was reasonable. Factor analysis of the attitude scale explored four existing factors: Computer Graphics Usefulness in Space Science Instruction; Computer Usefulness as a Learning Tool; Perceived Realism of Pictures; and Perceived Motion of Pictures. Moderate correlations between four subscales brought about good discriminant validity across factors.

4.4 Posttest Score Measures

As a first index to assess the students' learning outcomes from computer-based instruction(CBI) treatment, thirty test items were administered at the end of the CBI activity. To check internal consistency across test items and how fairly the instrument items measured learning gains from instruction, Cronbach alpha reliability was calculated. Table 7 presents descriptive statistic and reliability coefficient.

Mean of post-test (15.11) pointed out that students scored 50 % of test items, suggesting reasonable level of difficulty of the test items. Alpha coefficient was .61 across post-test items, which was acceptable in the experimental study.

Table 7 : Descriptive Statistic of Post-Test Measure

Measure	Minimum	Maximum	Mean	SD	N	Alpha Reliability
Post-Test	7	27	15.11	4.04	145	.61

4.5 Measure of Response Time to Post-Test

As a second index assessing students' performance after they finished CBI activity, amount of time spent on post-test was recorded (Table 8). The average time for which they spent on taking test was 13.66 minutes. Shorter time can be considered as an indicator of faster information retrieval from the memory, while longer time as one of slower retrieval from the memory.

Table 8 : Descriptive Statistic of Measure of Response Time

Measure	Minimum	Maximum	Mean	SD	N
Response Time to Take Post-Test	4.35	28.10	13.66	4.08	145

4.6 Experimental Group Differences in Attitudes Toward Computer-Based Science Instruction

Means and standard deviations of the four treatment groups characterized by the mode of visual display (Animation vs. Static) and the level of visual dimension (3D vs. 2D), are summarized in Table 9 for the attitude scale and its subscales (2DS ; Two Dimensional Static, 2DA ; Two Dimensional Animation, 3DS ; Three-Dimensional Static, and 3DA ; Three-Dimensional Animation). Full scores of the total attitude scale and its subscales were 11, 3, 3, 3, 2 respectively. Total attitude score of 2DS group was lowest and that of 3DA group was highest between four groups. In other words, the attitude score increased as the treatment components (Animation and 3D) were added. Graphs of mean scores of Total Attitude Scale and four subscales were provided in Figure 5, Figure 8, Figure 11, Figure 14, Figure 17 respectively, for each experimental group.

Five separate 2-way factorial analyses of variance (2X2 ANOVA) were conducted on total attitude scale and its subscales. Four experimental groups received different dimension (2D vs. 3D) by motion (animation vs. static) treatments. Factorial ANOVA performed analysis of variance of factorial design with 2 grouping variables, called 2-way. It analyzed if group means of attitude scores were different along the grouping variables (visual dimension and visual display) and tested if there was interaction between grouping variables. The results of five analyses of variance were presented next one by one.

Table 9. Means and Standard Deviations of Four Attitude Subscales with Experimental Groups

Groups	Graphics Usefulness	Learning Usefulness	Realistic Pictures	Moving Pictures	Total Attitude Score
2DS					
M	2.39	2.39	2.39	.76	7.94
SD	(.97)	(.86)	(.70)	(.83)	(2.05)
N	33	33	33	33	33
2DA					
M	2.73	2.30	2.11	1.05	8.19
SD	(.51)	(.97)	(.91)	(.78)	(1.87)
N	37	37	37	37	37
3DS					
M	2.68	2.34	2.55	.84	8.42
SD	(.70)	(.78)	(.83)	(.89)	(2.09)
N	38	38	38	38	38
3DA					
M	2.92	2.32	2.70	1.38	9.32
SD	(.28)	(.88)	(.52)	(.68)	(1.40)
N	37	37	37	37	38

4.6.1 ANOVA on the Total Attitude Score

First ANOVA on total attitude score was tested to see the differences in attitude toward instruction between experimental groups who experienced different treatments. In factorial ANOVA, the analysis of total variance in attitude scores was subdivided into separate components: variance explained by dimension factor; variance explained by motion factor; variance explained by interaction of those two factors; and finally, variance unexplained by analysis. Therefore, the result of the omnibus test for ANOVA was provided, then followed by two main effects and interaction.

(1) Omnibus Test of Variance Explained

The first task of the 2X2 factorial ANOVA is to test if the two factors have an overall significant effect. From the Table 10, the omnibus F for the variance explained is 3.761, which is significant at .05 level. As a whole, a significant amount of variance was explained in this study with p-value of .012. Therefore, the treatment of motion and dimension can be said to have some effects on attitude score.

(2) Test of Significance of Interaction

As a next step of 2-way ANOVA, dimension by motion interaction was examined. In Table 10, the F ratio for the interaction was 1.108, which was not significant at .05 level ($p = .294$). No interaction was found between visual display and visual dimension, implying that the effect of visual dimension was uniform across different visual display groups. Since there was no interaction effect, main effects will be tested as the next procedure.

Table 10 : 2X2 (Dimension X Motion) Analysis of Variance on Total Attitude Scale

Source of Variation	df	MS	F-ratio	*probability*
Main Effects	2	17.711	5.087	.007
Dimension	1	24.077	6.915	.009
Motion	1	12.525	3.597	.060
2-way Interaction Dimension * Motion	1	3.859	1.108	.294
Explained	3	13.094	3.761	.012
Residual	141	3.482		
Total	144	3.682		

(3) Omnibus Test of Main Effects

The omnibus F tested the joint (dimension and motion) main effects. The p-value of .007 in Table 10 showed significant main effects at .01 level. Further testing was proceeded for specific main effect for each grouping variable. Main effects for each grouping variable were tested as if there were no other grouping variable.

(3-1) Main Effect of Dimension factor

Hypothesis 1. Students under three-dimensional graphic condition exhibit more positive attitudes toward instruction than those in two-dimensional graphic condition.

Main effect of the dimension factor refers to a contrast between the two means of 3D group and 2D group. It was calculated using marginal means for each factor regardless of motion factor. Graph of marginal mean was given in Figure 6 and Figure 7. From Table 10, a significant main effect was found for visual dimension at .01 level ($F = 6.915$, $p = .009$). From the graph in Figure 6 and the significance of main effect, the groups who received 3D visual dimension (M=8.87) were found to have higher attitude score than those who received 2D visual dimension (M=8.07).

(3-2) Main Effect of motion factor

Hypothesis 2. Students under animated graphic condition exhibit more positive attitudes toward instruction than those in static graphic condition.

Main effect of motion factor was on the edge of significance ($F = 3.597$, $p = .06$). The bounding main effect of motion factor and the graph of marginal means of animated and static graphics group in Figure 7 indicated a slightly higher attitude score of animated graphics group (M=8.76) than static graphics group (M=8.20).

(4) Summary of ANOVA on Total Attitude Scale

Factorial analysis of variance conducted on total attitude score reported a significant main effect of dimension factor, indicating superiority of 3D to 2D. The students who participated in three-dimensional CBI activity had more positive attitudes toward instruction than those who did in two-dimensional CBI activity. A marginal significance was found for main effect of motion factor. Animated graphics group was slightly more favorable about instruction than static graphics group was. However, there was no interaction between dimension and motion. Thus, the effect of dimension was found to be uniform across animated or static graphics group.

Figure 5 : Group Means of Total Attitude Score

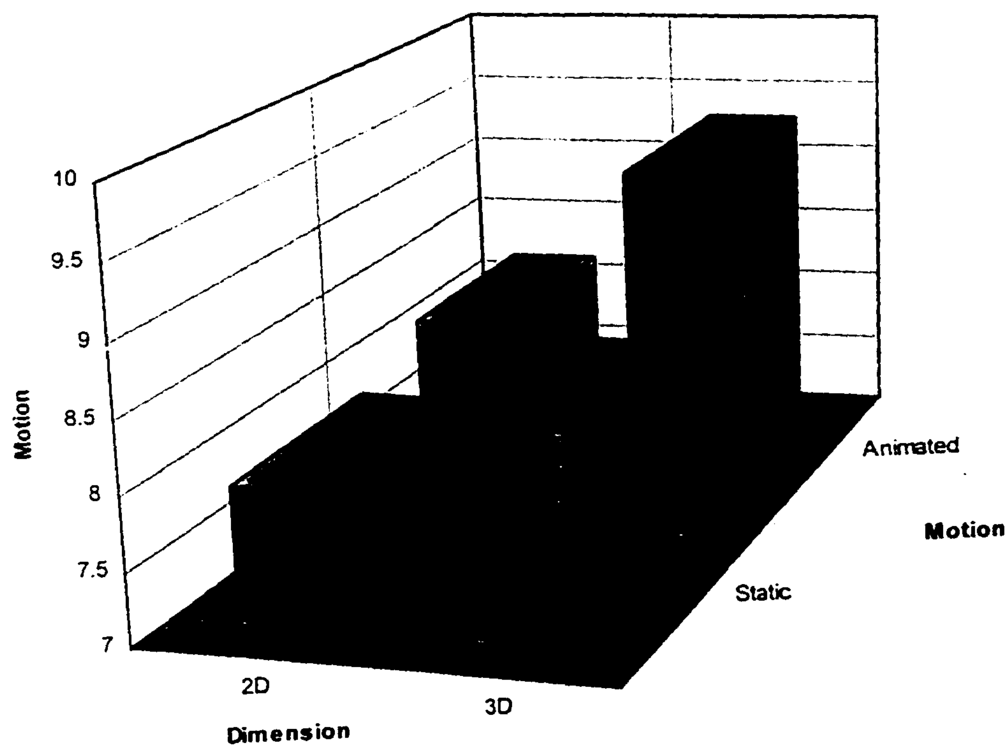


Figure 6 : Marginal Means of Dimension for Total Attitude Score

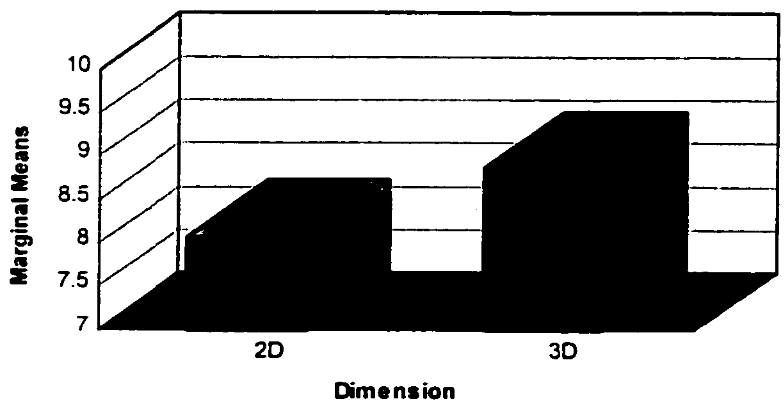
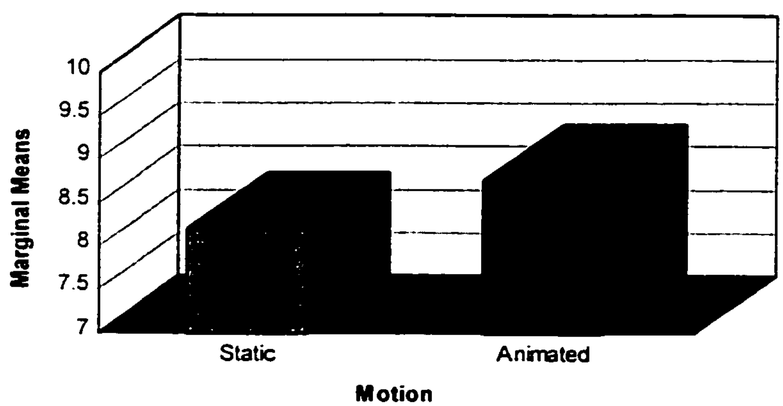


Figure 7 : Marginal Means of Motion for Total Attitude Score



4.6.2 T-test of Total Attitude Score between 3DA group and other three groups (2DS, 2DA, 3DS)

Hypothesis 3. Students under three-dimensional animated graphic condition (3DA) exhibit more positive attitudes toward instruction than those under other treatment conditions (2DS, 2DA, 3DS).

T-test between attitude score of 3DA group and composite attitudes scores of the other three groups (2DS. 2DA, 3DS) was conducted to see if 3DA is superior to other three treatments with respect to attitude score. The p-value is less than .05 in Table 11, which indicates significance. Thus, 3DA group has more favorable attitudes than the other three groups.

Table 11 : T-test Between Attitudes Score of 3DA group and Composite Attitude Score of other three groups (2DS, 2DA, 3DS)

	Standard Error	**T-value**	df	**Sig (2-tailed)**
Total Attitude Scale.	5334	3.209	141	.002

4.6.3 ANOVA on the Subscale of Computer Graphics Usefulness

The subscale of Computer Graphics Usefulness in Science Instruction was to examine if the students had feeling that the pictures in CBI could help them understand the movement of the Earth and the Moon. To test the group differences with regard to the subscale of Computer Graphics Usefulness in Science Instruction, 2-way factorial ANOVA was conducted on the score of this subscale. ANOVA procedure was presented in next three steps, which consist of omnibus test for ANOVA, test of significance of interaction effect, omnibus test of main effects followed by two tests for the significance of each factor.

(1) Omnibus Test of Variance Explained

There was an overall significant amount of variance explained in the present study. The omnibus F test for the total variance explained was 3.822 as seen from Table 12, which is significant at .05 level. The significance of omnibus F leaded to a further investigation of possible interaction or main effects.

(2) Test of Significance of Interaction

As the next step following the significance of omnibus F, interaction effect between dimension and motion was tested. The F ratio of .206 in Table 12 indicated no significance of interaction at .05 level. The effect of dimension factor did not vary from animated graphics group to static graphics group. No significance of interaction effect leaded to test of significance of main effects.

(3) Omnibus Test of Main Effects

The effects of each grouping variable (dimension and motion) on the scores of the dependent variable (subscale of Computer Graphics Usefulness) are determined using factorial ANOVA. The omnibus test of main effects investigated joint main effects of two factors. There was a significant joint main effects with F = 5.625, p = .004 (Table 12). Specific main effect of each factor was examined next. .

Table 12 : 2x2 (Dimension X Motion) Analysis of Variance

On Subscale of Computer Graphics Usefulness

Source of Variation	**df**	**MS**	**F-ratio**	***probability***
Main Effects	2	2.399	5.625	.004
Dimension	1	2.058	4.825	.030
Motion	1	2.907	6.816	.010
2-way Interaction				
Dimension * Motion	1	9.232E-02	.216	.642
Explained	3	1.630	3.822	.011
Residual	141	.427		
Total	144	.452		

(3-1) Main Effect of Dimension Factor

There was a significant main effect for dimensional factor, $F = 4.825$, $p = .030$ (Table 12). From the result of main effect in Table 12 and the graphs of Figure 9, the groups of 3D treatment scored the subscale of Computer Graphics Usefulness higher than those of 2D treatment did.

(3-2) Main Effect of Motion Factor

In terms of motion, significant main effect was found, $F = 3.822$, $p = .010$ (see Table 12 and Figure 10). Therefore, the score of subscale of Computer Graphics Usefulness was higher for animated graphics group than for static graphics groups.

(4) Summary of ANOVA on Subscale of Computer Graphics Usefulness

Significant main effects were found for both of two factors, i.e. dimension and motion. With respect to Computer Graphics Usefulness, 3D treatment group had more favorable attitudes than 2D treatment group did, and animated graphics group had more than static graphics group did. No significance was found for interaction effect.

Figure 8 : Group Means of Subscale "Computer Graphics Usefulness"

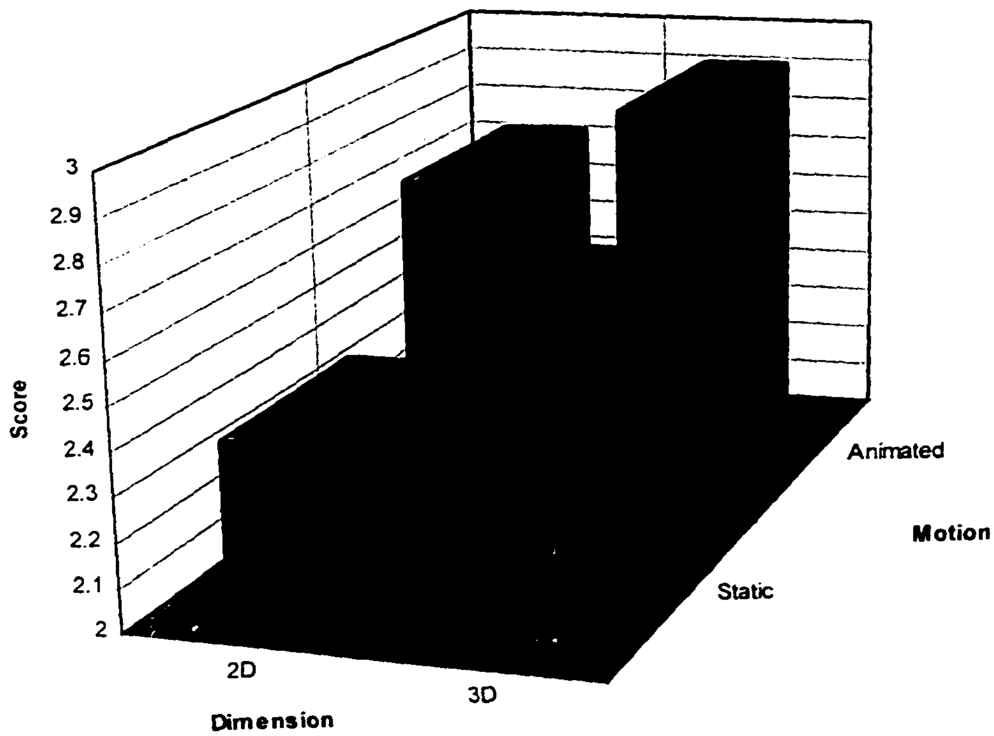


Figure 9 : Marginal Means of Dimension for Subscale "Computer Graphics Usefulness"

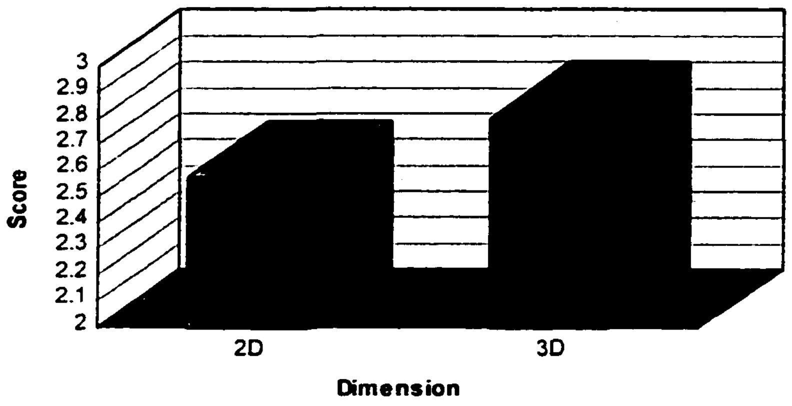
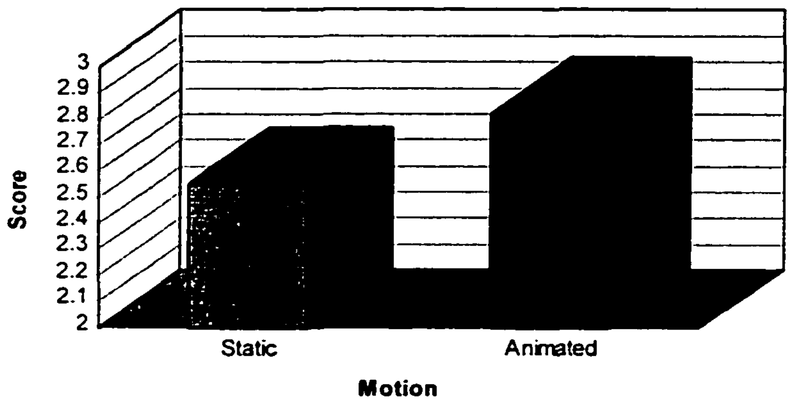


Figure 10 : Marginal Means of Motion for Subscale " Computer Graphics Usefulness"



4.6.4 ANOVA on the Subscale of Computer Usefulness as a Learning Tool

Third ANOVA was conducted on the subscale of Computer Usefulness as a Learning Tool. This scale was used to see if the students thought of computer usefulness as a learning tool to interact and control. Several steps for 2-way factorial ANOVA conducted on the subscale of Computer Usefulness as a Learning Tool are explained next.

(1) Omnibus Test of Variance Explained

First of all, omnibus F was examined as a result of 2-way ANOVA. In Table 13, no overall significant effect was reported ($F = .075$, $p = .973$). It means that amount of variance explained in this model was not significant concerning the subscale of Computer Usefulness as a Learning Tool. The treatment (visual display and visual dimension) can be said that it did not have any effect on the subscale of Computer Usefulness as a Learning Tool. In other words, neither main effects nor interaction effects were significant. No further procedure was necessary for analysis. However, next two subsections will be continued to explain the ANOVA summary of Table 13.

(2) Test of Significance of Interaction

As mentioned in subsection 1 above, no significance was found for interaction effect ($F = .073$, $p = 787$, see Table 13). The effect of motion factor was evenly distributed through three-dimensional or two-dimensional group.

Table 13 : 2X2 (Dimension X Motion) Analysis of Variance

On Subscale of Computer Usefulness as a Learning Tool

Source of Variation	**df**	**MS**	**F-ratio**	***probability***
Main Effects	2	5.796E-02	.075	.927
Dimension	1	4.744E-03	.006	.937
Motion	1	.113	.147	.702
2-way Interaction Dimension * Motion	1	5.619E-02	.073	.787
Explained	3	5.737E-02	.075	.973
Residual	141	.768		
Total	144	.753		

(3) Omnibus Test of Main Effects

The omnibus F ratio to test the combined effects of two factors was .075, which was not significant at .05 level (p = .927). No main effects were significant for two factors.

(3-1) Main Effect of Dimension Factor

From Table 13 and Figure 12, there was no significant main effect of dimension factor (F = .006, p = .937). In terms of Computer Usefulness as a Learning Tool, no differences were found between three-dimensional group and two-dimensional group.

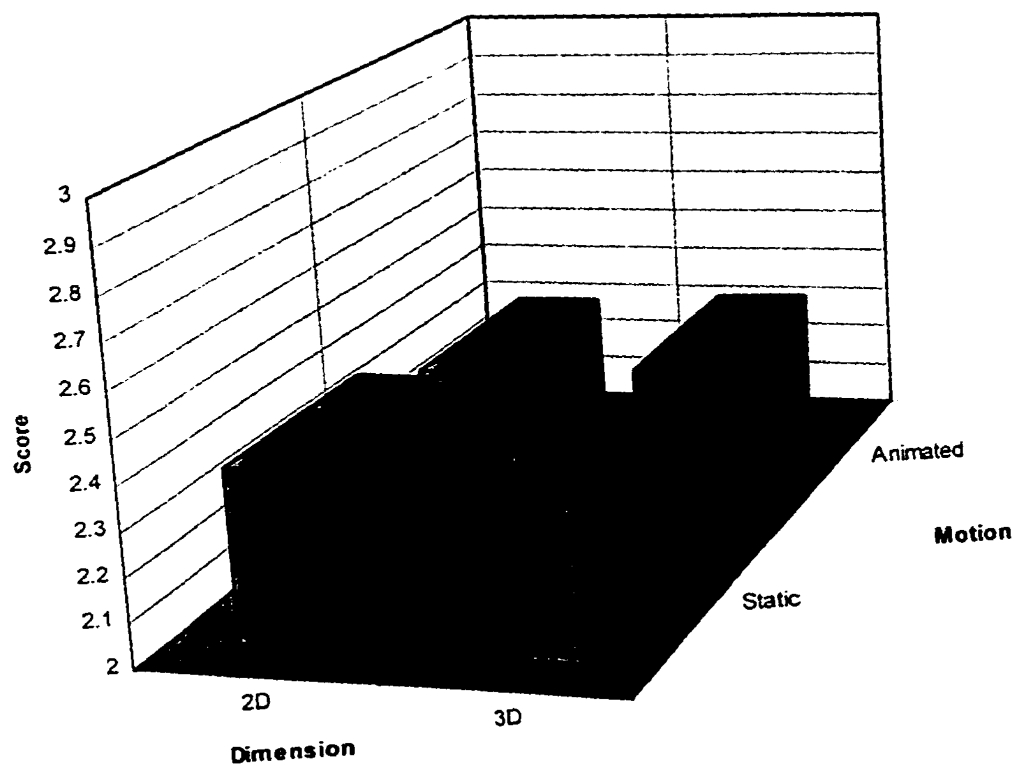
(3-2) Main Effect of Motion Factor

The F ratio in Table 13 (F = .147, p = 702) and the graph of Figure 13 revealed that animated graphics group did not differ from static graphics group.

(3) Summary of ANOVA on Subscale of Computer Usefulness as a Learning Tool

There was neither significant main effects nor significant interaction effects. Therefore, both of the two independent variables did not influence the attitude subscale of Computer Usefulness as a Learning Tool.

Figure 11 : Group Means of Subscale "Computer Usefulness as a Learning Tool"



Figire 12 : Marinal Means of Dimension for Subscale "Computer Usefulness as a Learning Tool"

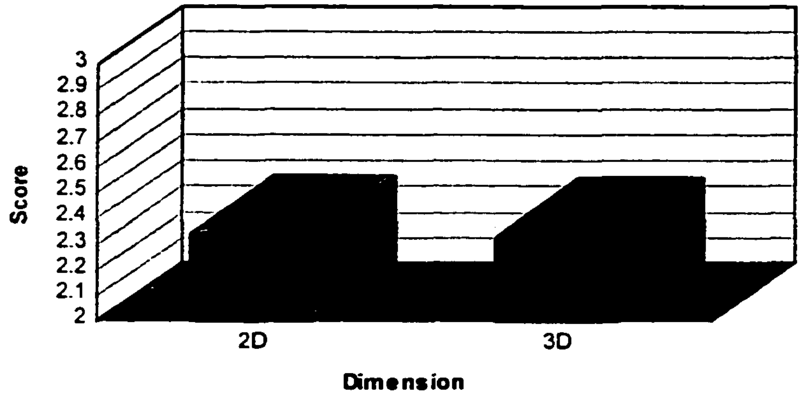
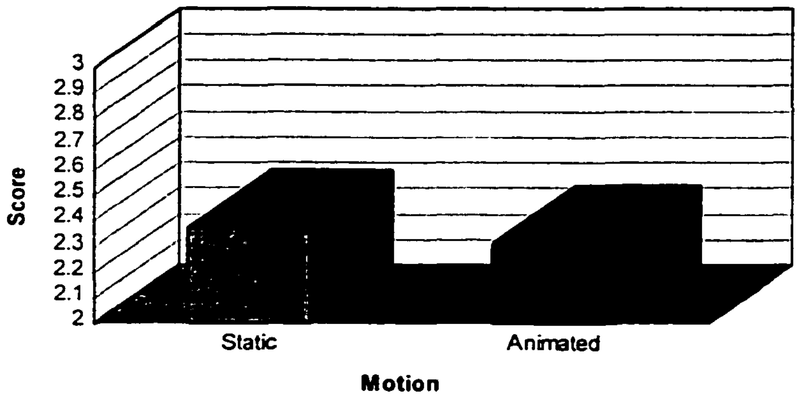


Figure 13 : Marginal Means of Motion for Subsclae "Computer Usefulness as a Learning Tool"



4.6.5 ANOVA on the Subscale of Perceived Realism of Pictures

To examine the differences between experimental groups with respect to Perceived Realism of Pictures, fourth ANOVA was tested on the subscale. The purpose of this subscale was to see how much the participants liked the three-dimensional realistic pictures in CBI and to assess their continuing motivation (Rieber, 1991b). The procedure of 2-way ANOVA is reported in the next three subsections.

(1) Omnibus Test of Variance Explained

As a first step of 2X2 factorial ANOVA, omnibus test of variance was analyzed. An overall significant effect was found on Perceived Realism of Pictures at .05 level ($F = 4.189$, $p = .007$ in Table 14). It implied that grouping variables (dimension and motion) had some effects on the subscale score of Perceived Realism of Pictures.

(2) Test of Significance of Interaction

To determine the source from where the significance of omnibus test came, significance of interaction effect was tested first. There was no interaction effect on Perceived Realism of Pictures between dimension and motion at .05 level ($F = 3.005$, $p = .085$ in Table 14). The effect of dimension did not vary from the animated graphics group to the static graphics group. Main effects were investigated in next subsection since there was no interaction.

Table 14 : 2X2 (Dimension X Motion) Analysis of Variance

On Subscale of Perceived Realism of Pictures

Source	**df**	**MS**	**F-ratio**	***probability***
Main Effects	2	2.732	4.781	.010
Dimension	1	5.268	9.220	.003
Motion	1	.130	.228	.634
2-way Interaction Dimension * Motion	1	1.717	3.005	.085
Explained	3	2.394	4.189	.007
Residual	141	.571		
Total	144	.609		

(3) Omnibus Test of Main Effects

The combined main effects were significant at .05 level ($F = 4.781$, $p = .010$ in Table 14). The significance of omnibus test of main effects indicated that at least one main effect of two factors existed.

(3-1) Main Effect of Dimension Factor

From Table 14, a significant main effect was found for dimension factor at .05 level ($F = 9.220$, $p = .003$). From the graph in Figure 15, it was inferred that the Perceived Realism of three-dimensional group was greater than two-dimensional one. As implied from the name of subscale "Perceived Realism of Pictures", students in three-dimensional graphics instruction were in more favor of pictures than those in two-dimensional graphics instruction.

(3-2) Main Effect of Motion Factor

There was no significance for motion factor in Table 14 ($F = .228$, $p = .634$). Thus, motion variable, whether animated or static, does not have any effect on Perceived Realism of Pictures as seen from Figure 16.

(3) Summary of ANOVA on the subscale of Perceived Realism of Pictures

No interaction effect was found for Perceived Realism of Pictures. However, a main effect of dimension factor was found to be significant, while there was no main effect for motion factor. It accounted for higher score of the three-dimensional group than two-dimensional group, with respect to Perceived Realism Subscale. No differences were explored between animated graphics group and static graphics group on the subscale score.

Figure 14 : Group Means of Subscale " Perceived Realism of Pictures"

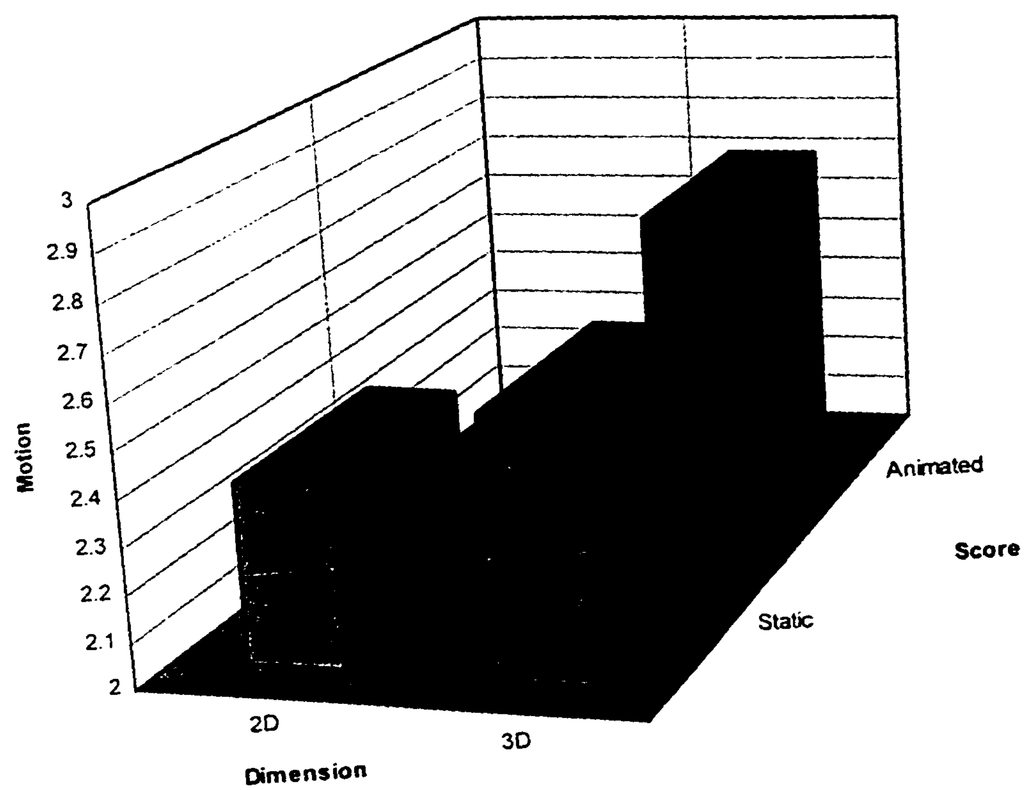


Figure 15 : Marginal Means of Motion for Subscale "Perceived Realism of Pictures"

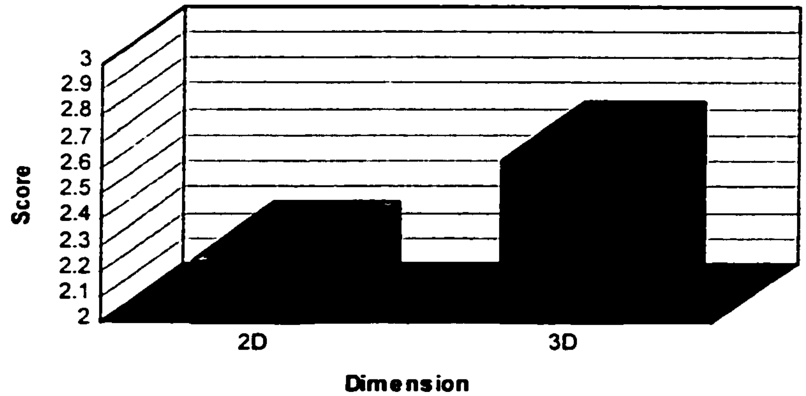
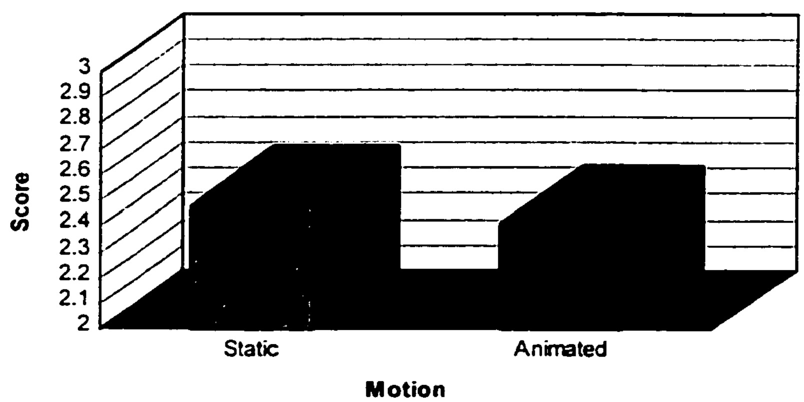


Figure 16 : Marginal Means of Motion for Subscale " Perceived Realism of Pictures"



4.6.6 ANOVA on Subscale of Perceived Motion of Pictures

Fifth ANOVA was performed to analyze the differential effects of CBI activity on the Perceived Motion of Pictures. This subscale examined how much the students in different experimental groups felt realistic motion in CBI activity. The results of ANOVA, which consists of overall effects, main effects, and interaction effects, are provided below.

(1) Omnibus Test of Variance Explained

An overall significant effect of ANOVA was found in first step of analysis. Omnibus F ratio for the total variance explained was 4.330 with p-value of .006 in Table 15. This result implied that there were main effects, interaction effects, or both. For this reason, further observation of the remaining result in analysis was continued next.

(2) Test of Significance of Interaction

The interaction effects of dimension by motion were tested as a next step of factorial ANOVA. Table 15 indicated no significance of interaction. The F ratio for interaction was .817, which was not significant at .05 level ($p = .368$). Visual dimension could be said that its effect was evenly spread across animated graphics group and static graphics group.

(3) Omnibus Test of Main Effects

The omnibus F ratio for joint main effects was 6.087, which was statistically significant at .05 level ($p = .003$, see Table 15). The result means that there was significant main effect for dimension factor, motion factor, or both. Next, possible main effects for each factor were examined.

Table 15 : 2X2 (Dimension X Motion) Analysis of Variance

On Subscale of Perceived Motion of Pictures

Source of Variation	**df**	**MS**	**F-ratio**	***probability***
Main Effects	2	3.873	6.087	.003
Dimension	1	1.553	2.440	.120
Motion	1	6.405	10.067	.002
2-way Interaction Dimension * Motion	1	.520	.817	.368
Explained	3	2.755	4.330	.006
Residual	141	.636		
Total	144	.680		

(3-1) Main effect of Dimension Factor

Main effect of dimension was not significant at .05 level (F = 2.440, p = .120 from Table 15). From the result of no significance and the graph in Figure 18, it could be concluded that the three-dimensional visual group did not differ in the subscale score of Perceived Motion of Pictures.

(3-2) Main Effect of Motion Factor

There was a significant main effect of motion factor (F = 10.067, p = .002 from Table 15). As implied in the name of this subscale "Perceived Motion of Pictures", the result was consistent with differential treatment of the motion in CBI activity. Therefore, the statistical significance of motion effects and the graph in Figure 19, showed that animated graphics group scored higher on the Perceived Motion of Pictures than static graphics group did.

(3) Summary of ANOVA on Subscale of Percieved Motion of Pictures

2-way analysis of variance which was conducted on the subscale of Perceived Motion of Pictures, indicated a significant main effect for motion, while no significance was found for the main effect of dimension and for the interaction between motion and dimension. The students who participated in the animated visual displays had higher scores on the Perceived Motion of Pictures than those who participated in the static visual display.

Figure 17 : Group Means for Subscale "Perceived Motion of Pictures"

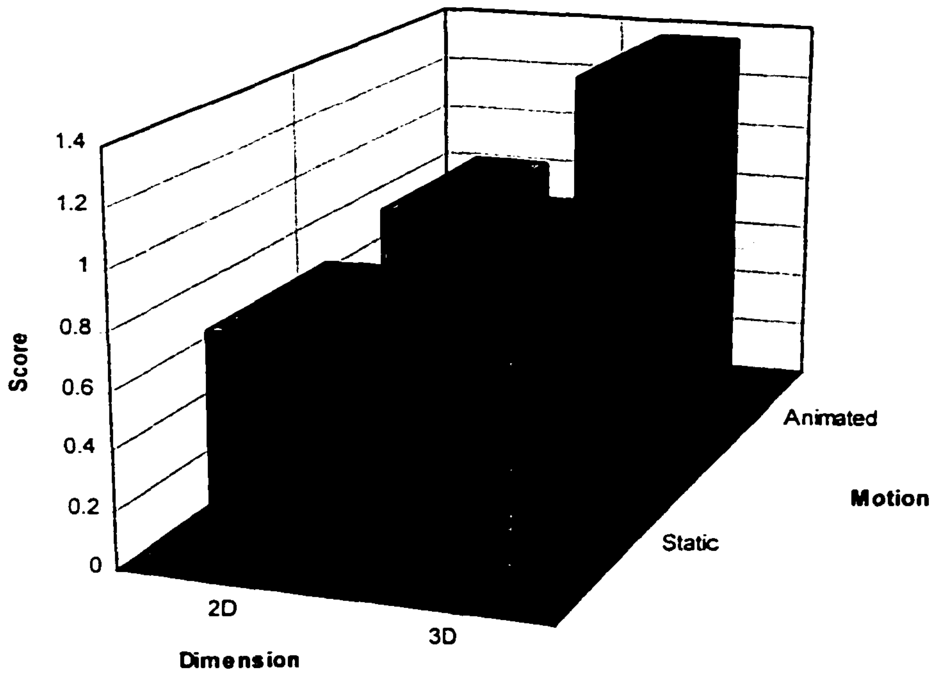


Figure 18 : Marginal Means of Dimension for Subscale "Perceived Motion of Pictures"

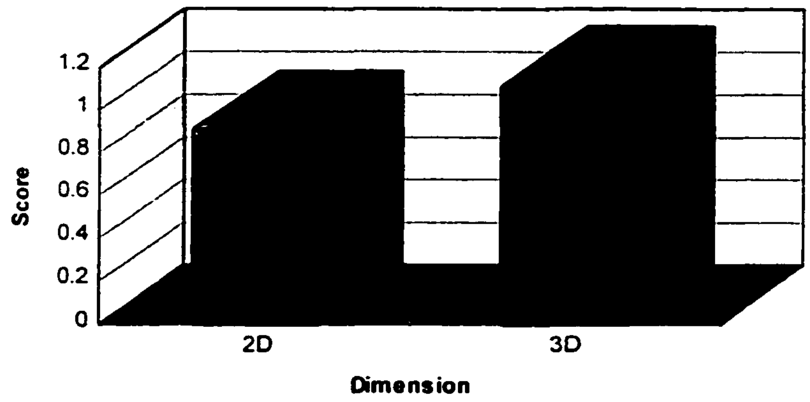
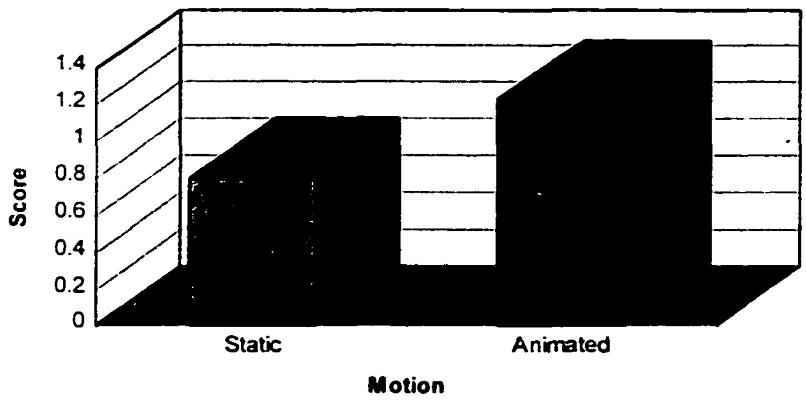


Figure 19 : Marginal Means of Motion for Subscale "Perceived Motion of Pictures"



4.6.7 Summary of Experimental Group Differences in Attitude

A 2x2 ANOVA conducted on total attitude scale demonstrated a significant main effect of dimension factor, reporting advantage of 3D graphic over 2D graphic. A moderate significant main effect was found for motion factor indicating advantage of animated graphic over static graphic. The students under 3D condition exhibited more positive attitudes than those under 2D condition, and the students under animated condition exhibited slightly more positive attitudes than those under static condition. Those results supported hypothesis 1 and 2. Since no interaction was found, the effects of visual dimension, whether it was 3D or 2D, were uniform across animated or static graphic condition. A T-test of total attitude score between 3DA group and the other three groups (2DS, 2DA, 3DS) indicated a statistical significance. The attitudes score of 3DA group were higher than to the other three groups, supporting hypothesis 3.

Statistical analysis of four attitude subscales revealed reasonable results generally supporting hypothesis 1 and 2. An ANOVA on subscale of Computer Graphics Usefulness reported significant main effects for both dimension and motion factor, indicating superiority of 3D over 2D and superiority of animated graphic over static graphic. With respect to the subscale of Computer Usefulness as a Learning Tool, no significant main effects were found for both factors. However, a main effect for dimension factor was found from an ANOVA conducted on the subscale of Perceived Realism of Pictures. It pointed out higher scores of the 3D group than 2D group. In addition, statistical analysis on the subscale of Perceived Motion of Pictures reported a main effect for motion factor indicating advantage of animated graphics over static graphics.

4.7 Experimental Group Differences in Post-Test Scores

The post-test scores, standard deviation, and number of subjects of four different experimental groups were presented in Table 16. Graph of mean scores of each group was also presented in Figure 18 to easily understand the group differences of post-test scores. Full point of post-test was 30. The mean score of 15.11 implied reasonable level of difficulty. The graph of Figure 18 showed little differences in post-test score between experimental groups. 2X2 factorial ANOVA was conducted on the post-test scores to statistically analyze those differences. The result was shown in Table 16 and described in next subsection.

4.7.1 ANOVA on Post-Test Scores

(1) Omnibus Test of Variance Explained

No significance was found in the total variance explained ($F = 1.027$, $p = .383$ from Table 17). The non-significance of omnibus F means that neither interaction nor main effects exists in the 2X2 factorial design. In other words, the treatment of dimension and motion did not have any effect on the post-test scores. Further steps to see the interaction and main effects could be ignored. However, to clarify the ANOVA results in Table 17, next two subsections will be continued.

(2) Test of Significance of Interaction

There was no interaction between dimension and motion ($F = 2.676$, $p = .104$ in Table 17) as mentioned in previous section. The effects of dimension factor were uniform through the groups.

Table 16. Means and Standard Deviations of Post-Test Score with Experimental Groups

Groups	Total Post-Test Score
2DS	
M	14.45
SD	(3.92)
N	33
2DA	
M	15.35
SD	(4.47)
N	37
3DS	
M	15.92
SD	(4.30)
N	38
3DA	
M	14.62
SD	(3.32)
N	37

Table 17 : 2X2 (Dimension X Motion) Analysis of Variance on Post-Test Score

Source of Variation	df	MS	F-ratio	*probability*
Main Effects	2	3.286	.202	.818
Dimension	1	4.253	.261	.610
Motion	1	2.100	.129	.720
2-way Interaction Dimension * Motion	1	43.583	2.676	.104
Explained	3	16.718	1.027	.383
Residual	141	16.284		
Total	144	16.293		

(3) Omnibus Test of Main Effects

The omnibus F ratio for combined main effects of two factors was .202, which was not significant at .05 level (Table 17). This means that neither main effects of motion factor nor main effects of dimension factor existed in the analysis.

(3-1) Main Effects of Dimension Factor

Hypothesis 4. Students under three-dimensional graphic condition achieve higher post-test scores than those in two-dimensional graphic condition.

There were no significant main effects of dimension factor (F = .261, p = .610 in Table 17). From the Table 17 and the graph in Figure 21, the three-dimensional group did not differ in test scores from the two-dimensional group.

(3-2) Main Effects of Motion Factor

Hypothesis 5. Students under animated graphic condition achieve higher post-test scores than those in static graphic condition.

No significance was found for motion factor at all (F = .129, p = 720 in Table 17). There was no advantage of animated visual group over static visual group concerning the post-test scores (Figure 22).

(4) Summary of ANOVA on Post-Test

There was neither significant main effects nor significant interaction effects for the post-test scores. Group difference was found neither in terms of motion and nor in term of dimension. The effects of motion were uniform from three-dimensional group to two-dimensional group.

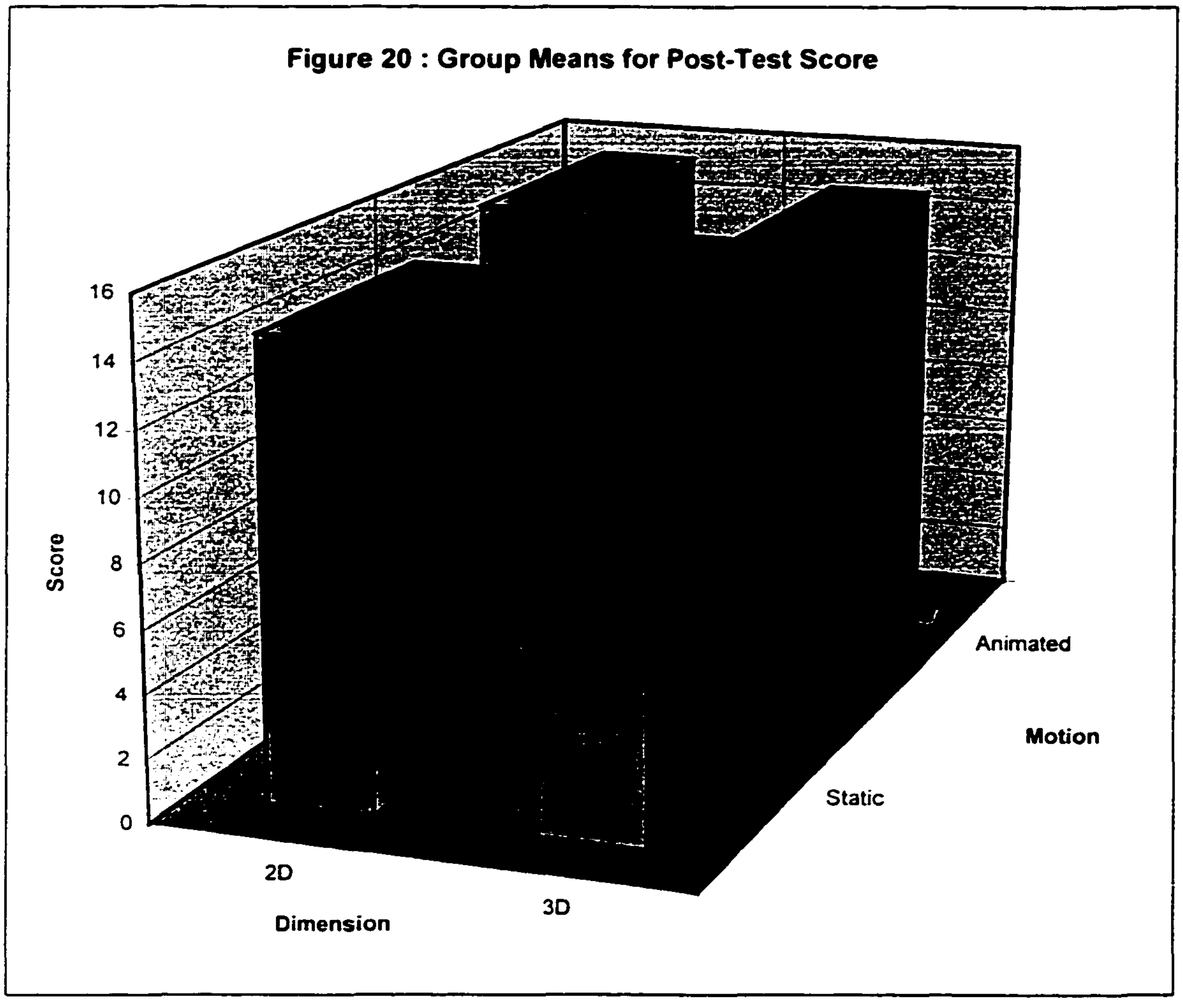


Figure 20 : Group Means for Post-Test Score
16
14
12
10
8
6
4
2
0
Score
2D
3D
Dimension
Static
Animated
Motion

Figure 21 : Marginal Means of Dimension for Post-Test Score

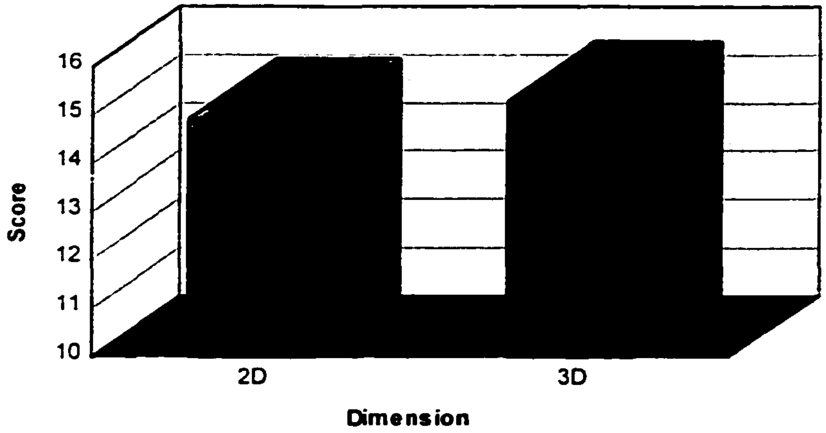
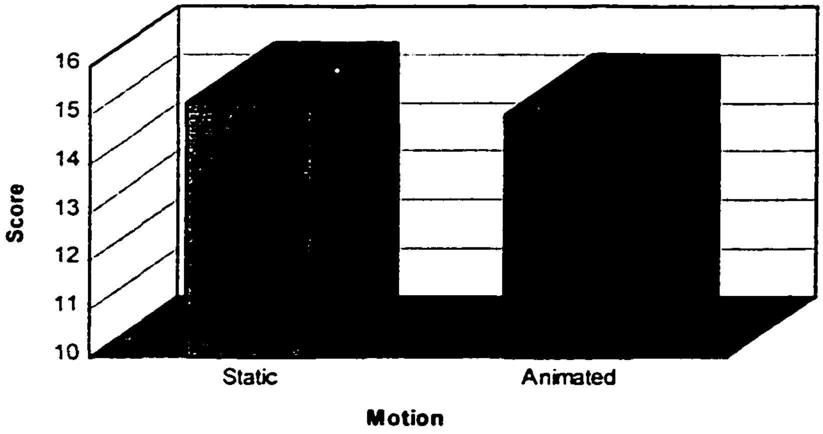


Figure 22 : Marginal Means of Motion for Post-Test Score



4.7.2 T-test of Post-test Score between 3DA group and other three groups (2DS, 2DA, 3DS)

Hypothesis 6. Students under three-dimensional animated graphic condition (3DA) achieve higher post-test score than those under other treatment conditions (2DS, 2DA, 3DS).

T-test between post-test score of 3DA group and composite post-test scores of the other three groups (2DS, 2DA, 3DS) was conducted to see if 3DA is superior to other three treatments with respect to post-test. The p-value is greater than .05 in Table 18, which indicates non-significance. Thus, 3DA group did not achieve higher post-test score than the other three groups.

Table 18 : T-test Between Post-Test Score of 3DA group and Composite Post-Test Score of other three groups (2DS, 2DA, 3DS)

	Standard Error	**T-value**	df	**Sig (2-tailed)**
Post-Test Score	1.1536	-.807	141	.421

4.7.3 Summary on Experimental Group Differences in Post-test Score

An ANOVA conducted on post-test score showed no main effects for both dimension and motion factors. No group differences were detected as results of either treatments. The students under 3D condition did not achieved higher post-test score than those under 2D condition. Similarly, the post-test scores in animated graphic group were not higher than those in static graphic group. Consequently, a T-test of post-test score between 3DA and the other three groups did not reach a statistical significance.

No interaction effects between dimension and motion were found to be significant. This result explained that the effect of dimension factor did not vary from animated graphic group to static graphic group, with respect to post-test score.

4.8 Experimental Group Differences in Response Time to Post-Test

It is worth evaluating the time differences in answering the post-test questions, whereas there was no group difference in test scores. Time can be considered as an index of information retrieval speed from the memory. Therefore, even though no group differences were found in the test scores, the group differences in information retrieval time could stand for cognitive gains.

2-way factorial ANOVA was performed on the test time, which was measured in unit of minutes. Means, standard deviation, and number of participants in each experimental group were presented in Table 19. From the graph of Figure 23, the time differences could be easily understood. Three steps to investigate the ANOVA results were described below.

4.8.1 ANOVA on Response Time to Post-Test

(1) Omnibus Test of Variance Explained

First indicator of overall significance was omnibus F ratio of 6.612, which was significant at .05 level (p = .000 in Table 20). As a whole, the amount of variance explained was significant with regard to test time. There must be main effects, interaction effects, or both. Thus, the motion factor and dimension factor can be considered to have some effects on response time.

(2) Test of Significance of Interaction

Dimension by motion interaction was examined as a next step following the significance of omnibus F. The F ratio of interaction effects was .520, which reported no significance (p = .472 in Table 20). The effect of dimension factor did not vary from animated visual group to static visual group, with respect to test time.

Table 19. Means and Standard Deviations of Response Time with Experimental Groups

Groups	Total Time to Take Post-Test (Minutes)
2DS	
M	15.38
SD	
N	33
2DA	
M	13.31
SD	
N	37
3DS	
M	14.56
SD	
N	38
3DA	
M	11.56
SD	
N	37

Table 20 : 2X2 (Dimension X Motion) Analysis of Variance on Response Time

Source of Variation	df	MS	F-ratio	*probability*
Main Effects	2	143.786	9.658	.000
Dimension	1	60.399	4.057	.046
Motion	1	235.213	15.799	.000
2-way Interaction Dimension * Motion	1	7.746	.520	.472
Explained	3	98.439	6.612	.000
Residual	141	14.888		
Total	144	16.629		

(3) Omnibus Test of Main Effects

The joint main effects of dimension and motion were significant at .05 level (See Table 20). It implied that there exists main effects of dimension factor, motion factor, or both. Detailed description of main effects of each factor was provided in next subsections.

(3-1) Main Effect of Dimension Factor

Hypothesis 7. Students under three-dimensional graphic condition takes less time to answer post-test questions than those under two-dimensional graphic condition.

There was a significant main effect of dimension factor at .05 level ($F = 9.658$, $p = .046$ in Table 20). Marginal means in Figure 24 were used to calculate main effects regardless of motion factor. As seen from the graph in Figure 24, it took longer for the two-dimensional visual group to answer test questions than the three-dimensional visual group to do, while there was no group differences in test scores. This result means that three-dimensional visual group ($M = 13.08$ minutes) retrieved information faster than two-dimensional group did ($M = 14.28$ minutes).

(3-2) Main Effects of Motion Factor

Hypothesis 8. Students under animated graphic condition takes less time to answer post-test questions than those under static graphic condition.

A highly significant main effect was found for motion factor ($F = 15.799$, $p = .000$ in Table 20). The graph in Figure 23 displayed the differences in test time. The marginal mean of animated graphics group was much less than that of static graphics group. Therefore, students who participated in animated graphics treatment answered test questions much faster than those who participated in static graphics treatment did.

Figure 23 : Group Means for Response Time to Post-Test

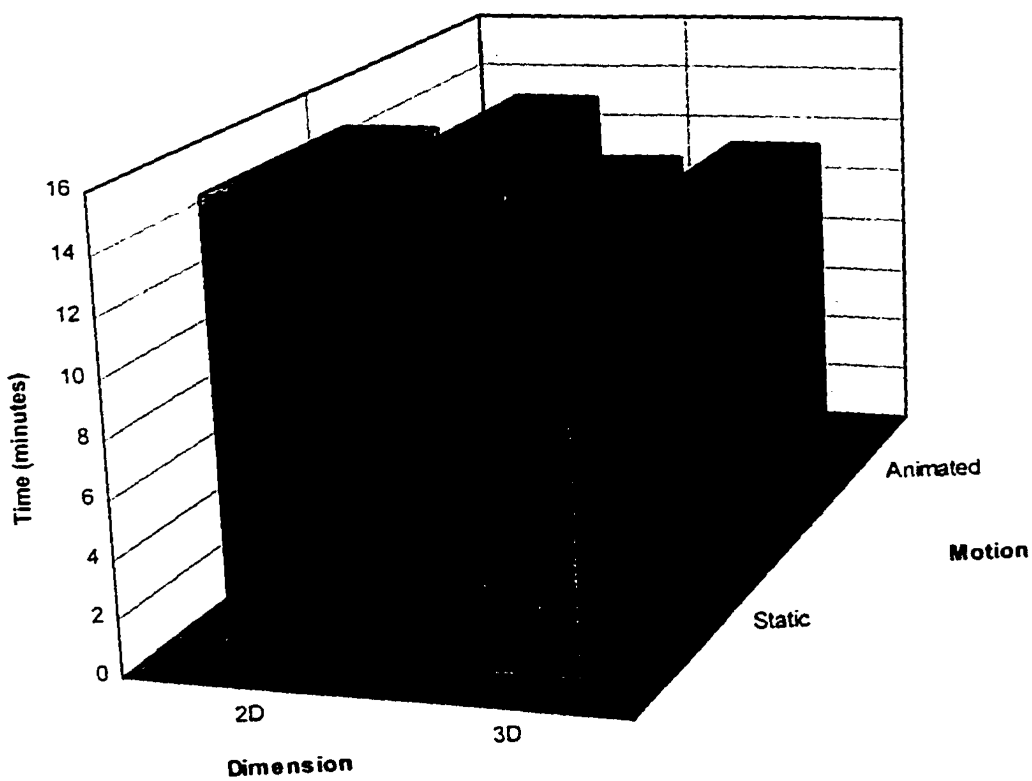


Figure 24 : Marginal Means of Dimension for Response Time to Post-Test

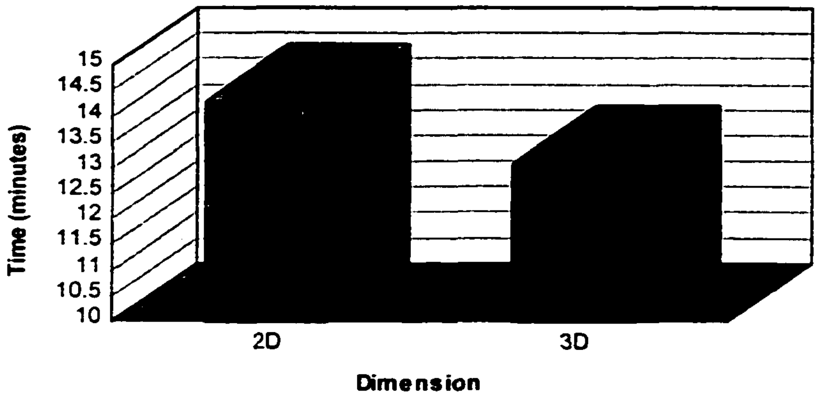
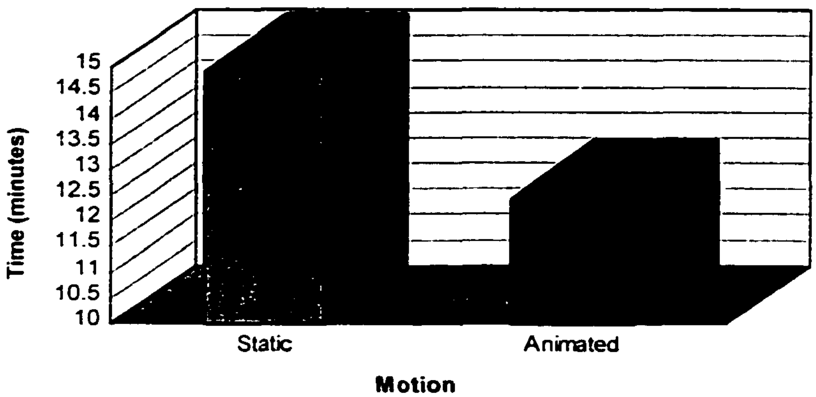


Figure 25 : Marginal Means of Motion for Response Time to Post-Test



(4) Summary of ANOVA on Time to Take Post-Test

Factorial ANOVA performed on response time of test questions revealed significant main effects for both dimension and motion factors, whereas no significant interaction was found between two factors. The students in animated visual treatment answered post-test questions in shorter time than those in static visual treatment. So did the students in three-dimensional visual group than those in two-dimensional visual group.

4.8.2 T-test of Response Time between 3DA group and other three groups (2DS, 2DA, 3DS)

Hypothesis 9. Students under three-dimensional animated graphic condition (3DA) take less time to answer post-test questions than those under other treatment conditions (2DS, 2DA, 3DS).

T-test between response time of 3DA group and composite response time of the other three groups (2DS, 2DA, 3DS) was conducted to see if 3DA is superior to other three treatments with respect to retrieval time. The p-value is less than .05 in Table 21, which indicates significance. Thus, 3DA group retrieved information faster than the other three groups.

Table 21 : T-test Between Response Time of 3DA group and Composite Response Time of other three groups (2DS, 2DA, 3DS)

	Standard Error	**T-value**	df	**Sig (2-tailed)**
Response Time	1.1030	-3.878	141	.000

4.8.3. Summary of Experimental Group Differences in Response Time

A 2x2 factorial ANOVA conducted on response time in answering post-test questions reported significant main effects for both dimension and animation factors, although no interaction was indicated. The students under 3D visual group answered post-test questions faster than those under 2D visual group. So did the students in animated visual group than those in static visual group.

As a result of T-test between response time of 3DA group and that of the other three groups (2DS, 2DA, 3DS), statistical significant differences were indicated. The response time of 3DA group was significantly shorter than that of the other three groups.

Chapter 5

Conclusions

5.1 Introduction

The purpose of this study was to investigate how dimension and motion of visual representation affect student learning and attitudes toward computer-based instruction. Students showed different responses to three-dimensional representation and two-dimensional representation. The effects of animated graphics on students were found to be different from those of static graphics. This final chapter provides an overview of the statistical results and discusses the results, followed by some implications and recommendations for future research.

5.2 Summary and Discussion

5.2.1 Effects of Dimension and Motion on the Attitudes toward Computer-Based Instruction

Students' attitudes toward instruction were assessed by attitude scale developed by the author and the attitude scale was found to consist of four underlying factors : Computer Graphics Usefulness; Computer Usefulness as a Learning Tool; Perceived Realism of Pictures; and Perceived Motion of Pictures. The effects of dimension and motion on students' attitudes will be discussed in this section.

Hypothesis 1. Students under three-dimensional graphic condition exhibit more positive attitudes toward instruction than those in two-dimensional graphic condition.

The statistical analysis revealed that students who participated in computer-based learning by three-dimensional graphics exhibited more positive attitudes than those who participated in computer-based learning by two-dimensional graphics. The result supported Hypothesis 1, indicating that three-dimensional visuals are worthy to be instructional visual aids for purpose of generating affective outcomes. The students appeared to think that the three-dimensional computer graphic is useful for learning and seemed to realize its motivational value. In addition, it seemed that they enjoyed the three-dimensional realistic pictures on the computer screen more than two-dimensional pictures.

As attending to and *selecting* information from the learning contents is the first step toward learning (Mayer, 1997), learner's attitudes and motivation play important roles in learning. Learners respond more affectively to pictures than to words (Paivio, 1991). Interesting pictures containing novelty and drama gain more attention and motivate the learners (Keller & Burkman, 1994). Learners interpret the information easily when it is supported by visual stimuli (Keller & Burkman, 1994). Three-dimensional graphics look more realistic than two-dimensional graphics and have motivational appeal. In the experiment of the present study, students seemed to be more favorable toward three-dimensional, realistic pictures than two-dimensional pictures. The learning material in the study was "Motion of the Earth and the Moon," which was fitting for three-dimensional representation. It appeared that the students preferred the realistic representation of our space and planets to the simple 2D counterpart. Rieber

(1990b) contended that both learners and learning task are related to the conditions for the efficacy of visual displays in learning. In the present study, subjects who participated in the computer-based learning activity were 8th grade students. Learning task, which has innate spatial nature, was consistent to the unique features of 3D.

The results supported affective processing paradigm of visual analog cues in the model of Chapter 2. Three-dimensional graphics is visually analogical to our real world. It is concluded that three-dimensional representation of learning material as visual analog is useful for producing affective outcomes. It heightened the level of aroused motivation and positive attitudes. Even though the consistent finding was reported by Ainge (1996), it only compared learning in virtual reality environment with traditional instruction. It did not investigate the differential effects of 2D representation and 3D representation on students' attitudes. In that sense, the result of the present study suggests that, in order to develop positive attitudes, computer-based instruction that includes three-dimensional graphics is superior to computer-based instruction that includes two-dimensional graphics as well as traditional instruction.

Statistical analysis was also conducted on each factor comprising total attitude scale. With respect to Computer Graphics Usefulness and Perceived Realism of Pictures Pictures, students in three-dimensional treatment showed more positive attitudes than those in two-dimensional treatment. They felt that the 3D graphics were more useful and motivating than 2D graphics in understanding science concepts.

Hypothesis 2. Students under animated graphic condition exhibit more positive attitudes toward instruction than those in static graphic condition.

The results of the present study moderately supported the hypothesis that students in animated graphics condition exhibit more positive attitudes toward instruction than those in static graphics condition. The fact that animated visuals played an important role in motivating and developing students' favorable attitudes toward instruction, but not as significantly as 3D visuals, reasonably supported Hypothesis 2. Students seemed to have favorable attitudes toward instruction when they were provided with animation as well as when they were provided with 3D graphics. These results account for the model of affective processing paradigm in Chapter 2, in that visual analog such as animation can be utilized as visual stimuli in motivating students. Attitudinal value of animated graphics is in accordance with that of 3D graphics.

Rieber (1991b) reported similar findings in a study of investigating the motivational characteristic of simulation activity in computer-based instruction. The design of this simulation activity was founded on the computer-generated animation technique. The researcher used "continuing motivation" to assess the students' willingness to choose simulation activity even after the instruction was over. Students in the experimental group liked to return to the activity. The motivational value of simulation activity was replicated in his later study (1996). In the present study, different measurement was developed by the author and was used to analyze the characteristics of the attitudes. Four components – Computer Graphics Usefulness, Computer Usefulness as a Learning Tool, Perceived Realism of Pictures, and Perceived Motion of Pictures were found to comprise students' attitudes toward computer-based instruction incorporating computer graphics. Additionally, the proposed study compared the differential effects of animated and static graphics on attitudes. In that sense, the present study has contributed to identifying the value of visual analog as instructional visual aids in producing affective outcomes.

More analysis was performed on each underlying component of the total attitude scale. With respect to Computer Graphics Usefulness and Perceived Motion of Pictures, the superiority of animated graphics over static graphics in the level of positive attitudes was reported. Students in animated graphics condition felt that the pictures on the computer screen were more helpful than those in static graphics condition did.

Hypothesis 3. Students under three-dimensional animated graphic condition exhibit more positive attitudes toward instruction than those under other treatment conditions, which are two-dimensional static, two-dimensional animated, and three-dimensional static graphic conditions.

The superiority of three-dimensional animated graphics (3DA) over other experimental groups was manifested in the statistical analysis, which supports Hypothesis 3. The students who participated in 3DA computer-based instruction exhibited more positive attitudes than those who participated in the other groups, i.e. 2DS, 2DA, 3DS. The learning program of 3DA included nature of virtual reality. Students could navigate through the virtual space on the computer screen by mouse-clicking. They could also view the planets such as the Sun and the Moon from diverse perspectives. Those learner-controlled virtual environments, though not perfect analogy to reality, encouraged the students to be motivated, to enjoy, and then to have favorable attitudes toward learning.

Although some researchers have argued the affective appeal of virtual reality technology (Ainge, 1996; Regian, Shelbiski, & Monk, 1992), no systematic research has yet been conducted on the effects of virtual reality on attitudes. The present study, which identified underlying components directing to positive attitudes and examined differential effects of four experimental groups on attitudes, contributes to the research on the affective outcomes of virtual reality technology.

5.2.2 Effects of Dimension and Motion on Achievement Gains

Post-test items developed by the author were used to measure students' achievement gains through the different versions of computer-based instruction. This section will discuss the results regarding the effects of dimension and motion on student learning.

Hypothesis 4. Students under three-dimensional graphic condition achieve higher post-test scores than those in two-dimensional graphic condition.

No advantage of three-dimensional graphics over two-dimensional graphics in generating higher achievement score was found in the present study. No group differences were found between the post-test score of three-dimensional graphics and that of two-dimensional graphics. Both groups achieved similar level of learning gains in terms of test scores. Hypothesis 4 was not supported in the present study.

The non-significance can be explained from two standpoints. First, the differences of visual cues at encoding and retrieval time negatively influenced learning gains. The post-test questions in the experiment were presented in two-dimensional format for all experimental groups. The students under the condition of three-dimensional graphics studied the learning material in three-dimensional format, while they were provided with post-test questions in two-dimensional format. Three-dimensional representation was used as an encoding cue, but two-dimensional representation as a retrieval cue. The differences between encoding and retrieval cue confused the students in three-dimensional graphics, and they did not take advantage of three-dimensional representation of learning material.

Consistency between encoding cues and retrieval cues was suggested by Paivio (1991). The effects of instructional visuals are maximized when the same kinds of pictorial cues are used at retrieving and encoding. Kirby and Lanca (1993) found that students in spatial condition performed better on 3D questions than on 2D questions. The 3D questions were related to the 3D information such as the shape of terrain, whereas the 2D questions were associated with the locations of some named place in the map. Similar findings were found in a study of map structure and retrieval task conducted by Kulhavy et al. (1994). The subjects studied a city map and were given different conditions at retrieval. The more the original encoding structure of the map was disrupted at retrieval time, the more the students were bewildered. Students recalled better when the intact map structure was provided at retrieval time, which had been also provided at encoding time.

On the other hand, no group differences in the post-test scores can be explained by students' unfamiliarity with three-dimensional picture. In general, most students in school are instructed using two-dimensional illustrations, and thus are not familiar with three-dimensional representation of learning tasks. Specifically, they do not have enough experience to work on innovative technology such as 3D virtual reality. These situations seem to inhibit learning outcomes of three-dimensional visual cues. However, it is noticeable that the students in three-dimensional representation were not inferior to those in two-dimensional representation with respect to test scores, even though they faced visual cues at retrieval time which were different from those at encoding time. The three-dimensional pictures in learning did no harm on later recall.

Hypothesis 5. Students under animated graphic condition achieve higher post-test scores than those in static graphic condition.

Hypothesis 5 was rejected in the same manner as Hypothesis 4. Students in animated graphics group did not achieve higher post-test scores than those in static graphics. Similar explanation as discussed in the previous section can be applied to the no group differences in test scores between animated and static graphics. The pictures of post-test questions were stationary in two-dimensional format, namely, in two-dimensional static representation. Accordingly, the students in animated graphics group as well as three-dimensional graphics group were at a disadvantage with respect to the retrieval cues. They confronted different pictorial representation when they retrieved information from their memory, which was encoded in animated representation or three-dimensional representation.

Lack of superiority of animated graphics over static graphics in learning outcomes can be construed as the fact that the learners failed to properly focus on the animated visual cues and did not take advantage of the instructional aid. Although the visual grouping strategy (Rieber, 1990b) was applied to designing computer-based instruction, the learners were not likely to pay attention to the information provided by animated visual cues. In spite of the lack of advantage in animated visual condition, the students under the condition did not achieve lower scores than those under static condition. The achievement level of animated graphics group was similar to that of static graphics group. It is important to note that the animated graphics did not produce any negative effects on learning compared to static graphics.

Hypothesis 6. Students under three-dimensional animated graphic condition achieve higher post-test scores than those under other treatment conditions, which are two-dimensional static, two-dimensional animated, and three-dimensional static graphic conditions.

The students who participated in the learning with three-dimensional animated graphics did not outperform those who participated in the other experimental conditions. Hypothesis 6 was not supported by research results. In terms of the similarity between the encoding and retrieval cues, the experimental group of three-dimensional animated representation was under the greatest disadvantage among the four experimental groups. The distance from the two-dimensional static graphics as retrieval cues to the three-dimensional animated graphics as encoding cues was farthest in the continuum of visual analog. Nonetheless, it should be noted that the fact that the students who studied three-dimensional animated visual cues still had similar achievement gains as those who studied the other visual cues did not disappoint the researcher.

The 3DA instruction incorporated virtual reality technology, though it was primitive. The learners were given control over navigating the virtual space on the computer screen. They were able to have various sights of the Earth and the Moon, which were continuously travelling in our space. The dynamic representation of our space in three-dimensional format looked unusual to the learners. Even though a training session had been provided to practice how to control the learning environment before they started the learning activity, it seems that the students still had difficulty in proper handling of virtual world. The training in a short time did not compensate for the students' inexperience with 3D images.

5.2.3 Effects of Dimension and Motion on Retrieval Time

Time appropriated to answer the post-test questions was used to assess the information retrieval time from the memory. This section discusses how importantly the three-dimensional and animated graphics affect the retrieval time.

Hypothesis 7. Students under three-dimensional graphic condition take less time to answer post-test questions than those under two-dimensional graphic condition.

The total time that the students spent on taking the post-test was recorded to assess how efficiently the students retrieve information from the memory. The time data demonstrated the effectiveness of three-dimensional graphics compared to static graphics, supporting Hypothesis 7. Students who had studied with three-dimensional visual cues took significantly less time to answer post-test questions than those who had studied with two-dimensional visual cues. Even though the three-dimensional visual cues did not improve achievement gains, they seemed to promote the retrieval efficiency by reducing the response time required to take test.

The information retrieval processing involves retrieving information from long-term memory and reconstructing its mental images in short-term memory (Rieber, Boyd, & Assad, 1990). The three-dimensional graphics played an important role as encoding cues, which helped the later reconstruction of the mental images. At encoding time, the three-dimensional cues facilitated encoding from external visual stimuli such as 3D visuals into internal visual representation of the human memory. The cognitive process of encoding mechanism appeared to be supported by three-dimensional realistic cues. Those results supported the author's model of cognitive processing paradigm given in Chapter 2. The three-dimensional visual stimuli as visual analogy to reality facilitate encoding process, which promote subsequent retrieval of information.

External visual cues such as three-dimensional visual analogy decrease the cognitive load for encoding in working memory (Perkins & Unger, 1994). If some spatial information is represented in two-dimensional format, the learners should translate the information from two-dimensional format into three-dimensional format in their working memory. In other words, the three-dimensional visual cues reduce the learner's cognitive load to interpret the spatial information from two-dimensional to three-dimensional format.

Realism theories (Dale, 1946; Carpenter, 1953) indicated the instructional value of realistic visual cues in learning, suggesting that the more realistic the visual cues are, the more likely it is to facilitate learning. The results of the proposed study supported the theories in that the three-dimensional graphics, which have more realistic visual cues, aided learning better than two-dimensional graphics, which have less realistic visual cues. According to "level of processing" theory, deeper processing of the information leads to better retention of the information (Craik & Lockhart, 1972). It seemed that the three-dimensional graphics helped deep processing of spatial information more than two-dimensional graphics did.

Consistency between learning task and the nature of instructional visual aid is the necessary conditions for its effectiveness. (Levin & Lesgold, 1978; Norman, 1993; Rieber, 1990a; Winn & Schill, 1991). Norman (1993) suggested three recommendations for ideal representations : (1) Appropriately show important, critical features of a domain; (2) Be appropriate for the person; and (3) Be appropriate for the task. The unique features of three-dimensional graphics can be utilized to represent our space and planets, and are appropriate for the learning task. The 8^{th} grade students who study this learning topic are young children for whom the realistic pictures are well used as visual cues.

Hypothesis 8. Students under animated graphic condition take less time to answer post-test questions than those under static graphic condition.

The differences in time spent on test-taking between animated graphics group and static graphics group indicated the superiority of animated graphics over static graphics with respect to retrieval time. The students under the animated condition answered the questions faster than those under the static condition did, while no group differences were found in test scores. Not only three-dimensional visuals but also animated visuals as encoding cues positively affect encoding processes. The model of cognitive processing paradigm proposed in Chapter 2 was supported by those results. Animated visual stimuli, which is more analogous to reality than static visual stimuli, facilitate encoding mechanism to build internal mental representation from presented visual information. The level of processing theory as well as realism theories was advocated as a result of the present experiment. The fact that animated graphics as visual cues was more effective for subsequent retrieval task than the static graphics indicated the value of an increase of realistic detail in visual illustrations. Motion was a critical factor to realistically describing the dynamics of the Sun and the Moon in our space. Also, the animated visual cues appeared to help process the information more deeply than the static visual cues.

The results of the present study agree with Rieber et al.'s finding (1990b). They conducted a study to compare the differences between animated graphics condition and static graphics condition with respect to response latency. The time required to answer each question was used to measure response latency. The students in animated graphics group answered the post-test questions faster than those in static graphics group. The learning task in their research was Newton's Law of Motion. Students benefit from animated representation when the subject matters lend themselves to dynamic attributes.

Hypothesis 9. Students under three-dimensional animated graphic condition take less time to answer post-test questions than those under other treatment condition,s which

are two-dimensional static, two-dimensional animated, and three-dimensional static graphic conditions.

As discussed above, three-dimensional graphics is superior to two-dimensional graphics as encoding stimuli, as animated graphics is to static graphics. From the results of Hypothesis 7 and Hypothesis 8, it is reasonable to infer that three-dimensional animated graphics is advantageous for retrieval time compared to the other experimental conditions. Statistical analysis was in accordance with the inference indicating the superiority of three-dimensional animated graphics over the other graphics : 2DS, 2DA, and 3DS. The students who participated in the condition of three-dimensional animated graphics answered the post-test question faster than those who participated in the other three conditions.

From the perspective of realism theory, three-dimensional animated graphics has the highest realism among four conditions : 2DS, 2DA, 3DS, and 3DA. Therefore, both three-dimensional and animated graphics as encoding stimuli that are visually analogous to reality, promote encoding mechanism. The efficient encoding using both visual cues seemed to have positive influence on subsequent retrieval tasks. The students retrieved the information efficiently from the memory. According to "level of processing theory" (Craik & Lockhart, 1972), three-dimensional animated cues encourage the learners to process the visual information more deeply than the other three visual cues. The deeper processing of information decreased the level of abstraction included in the information and enhanced retrieval task.

5.3 Implications for Instructional Design

Several implications are demonstrated based on the research findings of the present study. The affective outcomes of realistic instructional visuals such as 3D animated graphics were confirmed in the study. The results validated the advantage of animated graphics over static graphics and three-dimensional graphics over two-dimensional graphics in terms of attitudes toward instruction. The learners are more likely to enjoy the instruction and be aware of the computer graphic usefulness when the three-dimensional and animated graphics are presented rather than two-dimensional or static graphics. Instructional designers can utilize those cutting edge technologies in designing computer-based instruction to promote the learner's motivation and positive attitudes.

Even though the three-dimensional and animated graphics as visual analogy cues did not produce significant cognitive outcomes in terms of test scores, it was proved that those visual aids played important roles in efficient information retrieval. Students who studied using three-dimensional and animated visual cues were able to respond to test questions faster than those who studied using two-dimensional or static visual cues. These results indicated that the visual analogy cues facilitate encoding mechanism, which aids later recall. Therefore, the effectiveness of recent computer technology integrated into science instruction was supported. Selective and pedagogical application of the technological resources to the subject matter has produced positive effects on the learner's performance as well as attitudes performance. Computer application in learning and instruction based on consideration of how to organize and incorporate technological resources in the classroom will make significant contributions to K-12 education.

5.4 Recommendations for Future Research

For future research as an extension of the present study, several recommendations are suggested as follows.

(1) It is recommended that individual differences be considered as a factor affecting the effectiveness of visual analogy cues. Spatial ability as well as verbal ability is different for each learner. As an individual difference variable, ability might play an important role for learning outcomes of three-dimensional and animated visual aids.

(2) This study was conducted with inner-city junior high school students. If older adults in college or younger children in elementary school had participated in the experiment, there would have been different results. The research on the efficacy of computer graphic features in learning can be more solidly validated with various populations.

(3) In the present study, different cues were used between learning time and testing time. Four kinds of encoding visual cues were used at learning time, which were two-dimensional static, two-dimensional animated, three-dimensional static, and three-dimensional animated graphics, whereas only two-dimensional static graphics as retrieval cues was used on post-test questions. No significant effects of three-dimensional and animated graphics on achievement gains may be due to those differences between encoding cues and retrieval cues. Future research is recommended to conduct an experiment using same encoding and retrieval cues.

(4) It is advised that the students be engaged in learning activity for a longer period of time in order to investigate the maximum effects of visual cues in future study. The

time that the students spent on the computer-based instruction activity in the present experiment was not enough to see the differential effects of motion and dimension.

(5) For future research, narration instead of text can be considered in the computer-based instruction. In the present experiment, text was employed to supplement the pictures on the computer screen. The use of narration with computer graphics may produce different effects from the use of text.

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APPENDIX A

General Directions of the Computer-Based Instruction

Directions :

1. **Listen to Teachers and Researchers.**
2. **You are not permitted to talk each other in Computer Lab.**
3. **Do not collaborate with others when you work on the computer**

5. **Concentrate on the text and pictures on the computer screen while you are learning with computer.**
6. **You will be given test questions after you finish to study Earth Science Concept. Do your best on this test.**
7. **If you have any question, raise your hand.**

APPENDIX B

Background Questionnaire

Please answer the next questions:

1. What is your name ? ___________

2. Are you a boy or a girl ? __________

3. When is your Birth Date ? ______/______
(month/year) for example, (July/1985)

4. Do you know how to use computer keyboard and mouse (Yes / No) ? _____

5. How long have you experienced computers ? ________
(e.g. wordprocessing, internet, computer game, etc...)

(1) 0 months (2) 6 months (3) 1 year (4) more than 1 year

APPENDIX C

Schedule for Computer-Based Science Instruction

Schedule for Science Learning Activity in Computer Lab

Day 1 (10-29-97) Wed

Session 1. (Period 1) : 31 Students

7:30am-8:30am : 26 Students
8:30am-9:25am : 5 Students

Session 2. (Period 3) : 29 Students

10:12am-11:12am : 26 Students
11:12am-12:10am : 3 Students

Session 3. (Period 5) : 30 Students

12:43pm-1:43pm : 20 Students
1:43pm-2:43pm : 10 Students

Day 2 (10-30-97) Thu

Session 1. (Period 2) : 26 Students

8:00am-9:00am : 26 Students

Session 3. (Period 6) : 29 Students

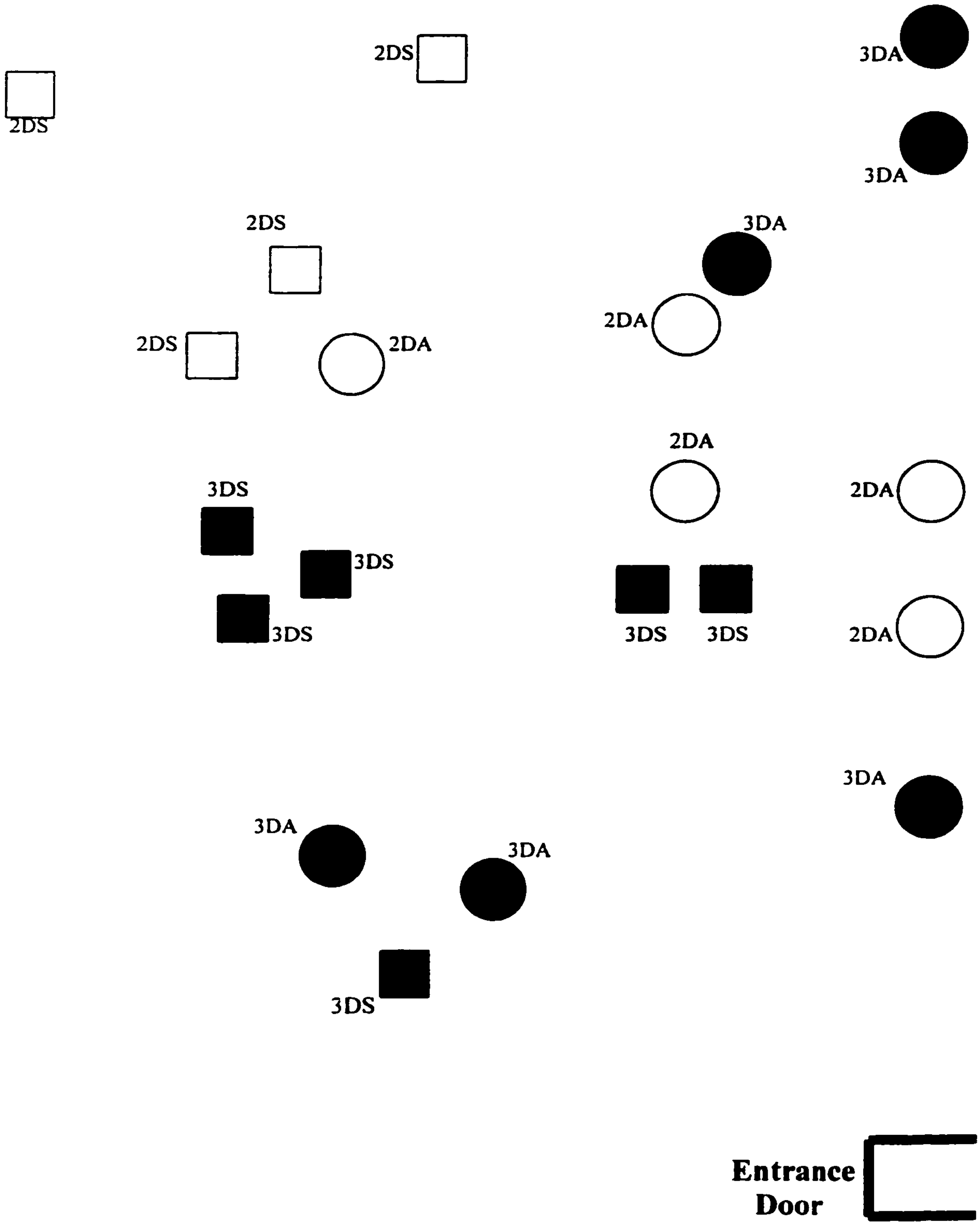
1:10pm-2:10pm : 20 Students
2:10pm-3:10pm : 9 Students

APPENDIX D

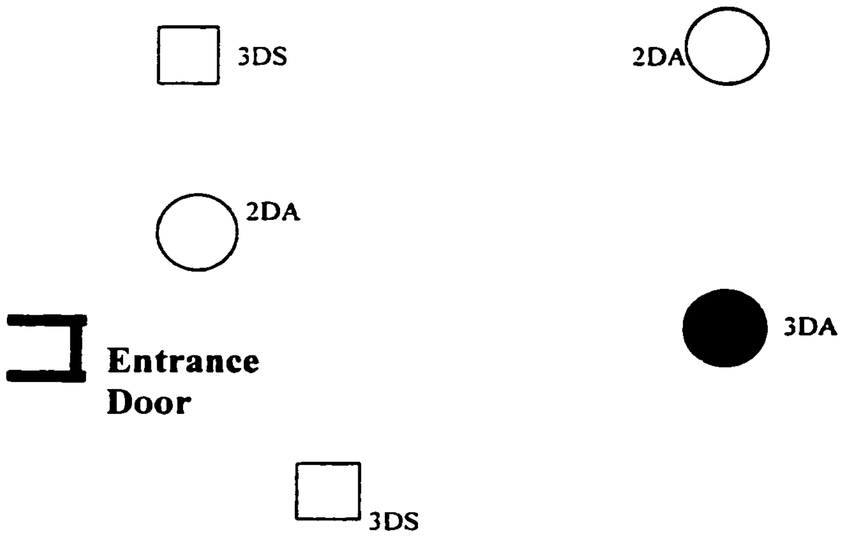
Inside Map of Computer Laboratory

and Computer Stations Installed with Treatment Programs

< First Computer Room >



< Second Computer Room >



APPENDIX E

Questionnaire of Attitude Toward Computer-Based Science Instruction

Your Name: ______________________________

Please answer Y or N for the following sentences.

Press Y(Yes) if you agree.
Press N(No) if you do not agree.

1. I feel the pictures on the computer screen looked real. _____ (Y/N)

2. I feel the Moon and the Earth looked really moving. _____ (Y/N)

3. Now I understand the movement of the Earth and the Moon

   in the space. _____ (Y/N)

4. I feel a computer makes it easy to learn how the Earth and Moon are moving

   in the space. _____ (Y/N)

5. I feel like I could interact and communicate with computer.

6. I like the pictures of the Earth, the Moon, and the Sun on the computer screen.

   _____ (Y/N)

7. I feel like I could control and play with the computer all by myself. ______ (Y/N)

8. I feel like I was taking a tour to space between the Sun and the Moon. _____ (Y/N)

9. Next time, I would like to learn more space science with these real-like pictures.

   _______ (Y/N)

10. The pictures on the computer screen helped me understand space science.

    _____ (Y/N)

11. The pictures on the computer screen told me how the Moon and the Earth are

    traveling in universe. _____ (Y/N)

APPENDIX F

Post-Test Questions

Your Name: ________________

Please enter the number of right answer.

1. The **Earth** moves in two ways. Which one best describes these two ways ? _____

(1) The Earth moves around the Moon, and it also moves around the sun.
(2) The Earth moves around the Moon, and it also spins around its axis (self-rotation).
(3) The sun moves around the Moon and the Moon moves around the Earth.
(4) The Earth moves around the sun and spins on its axis (self-rotation).

2. Why do we have day and night ? _____

(1) because the Earth spins on its axis(self-rotation)
(2) because the Earth travels around the Sun
(3) because the sun moves around the Earth
(4) because the Moon goes around the Earth

3. How long does it take for the **Earth** to spin on its axis once for self-rotation ? _____

(1) 1 month
(2) 1 year
(3) 1 day
(4) 1 hour

4. How long does it take for the **Earth** to make one trip (to revolve) around the sun ?
_____

(1) 1 year
(2) 1 month
(3) 1 day
(4) 1 hour

5. The real shape of the **Moon** is like a _____.

(1) cone
(2) cube (box)
(3) sphere (ball)
(4) round plate

6. The **Moon** revolves around the _____ , just as the Earth travels around the Sun.

(1) Earth
(2) satellite
(3) stars
(4) rocket

7. Why do we see different shapes of the **Moon** ? _____

(1) As the Moon spins (self-rotate) around its axis,
we see more or less of the moon lighted up by the sun.
(2) As the Moon travels around the Earth,
we see more or less of the moon lighted up by the sun.
(3) As the Earth revolves around the sun,
we see more or less of the moon lighted up by the sun.
(4) As the planets revolves around the sun,
we see more or less of the moon lighted up by the sun.

8. About how long does it take for the **Moon** to travel once around the **Earth** ? _____

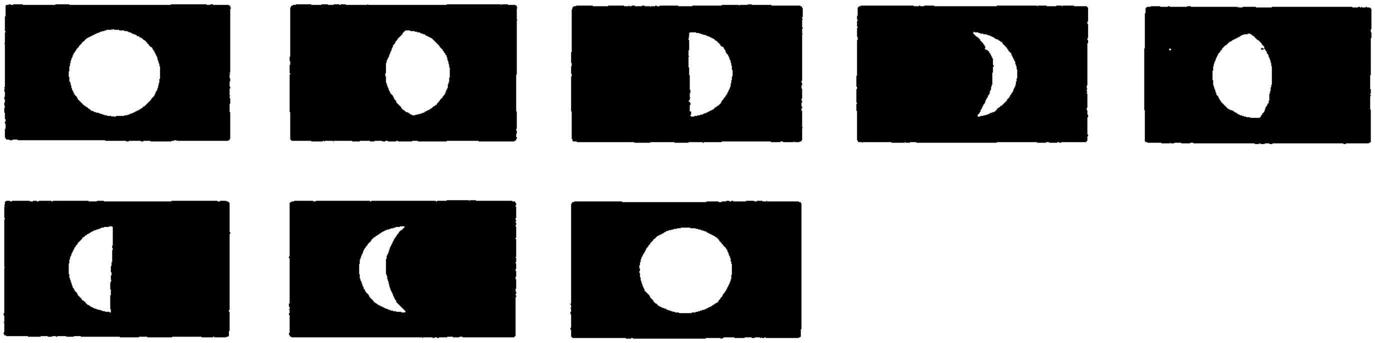
(1) 1 day
(2) 1 hour
(3) 1 year
(4) 1 month

9. Approximately how long does it take for the **Moon**
to start its patterns of shapes over again ? _____

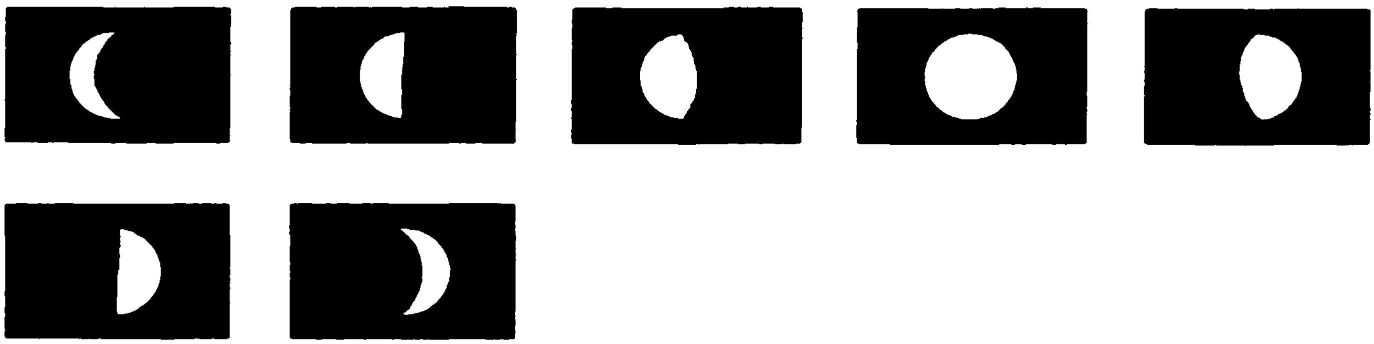
(1) 1 year
(2) 1 week
(3) 1 month
(4) 1 day

10. What is the correct sequence of **moon phases** ? _____

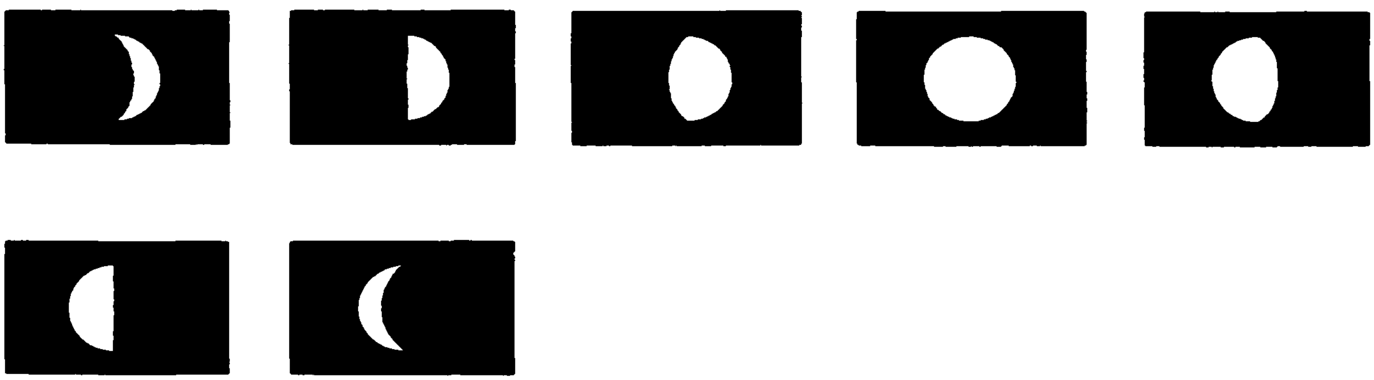
(1)



(2)



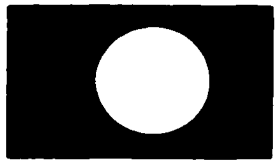
(3)



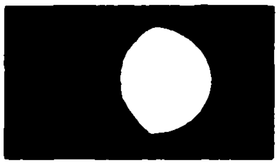
11-13. Use the **following pictures below for questions 13-18.**

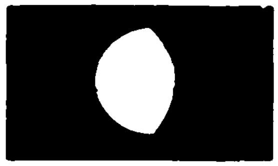
Example:

(1) new **moon** **(2) full moon**



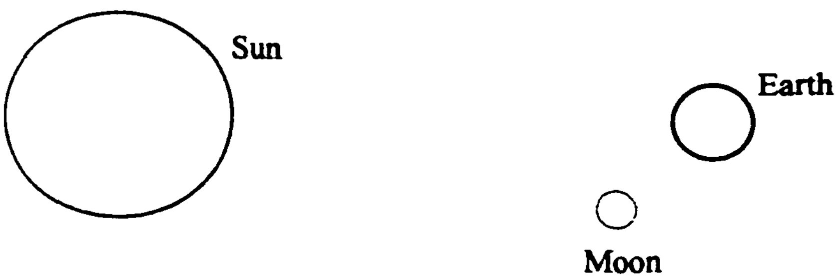
(3) **waxing(growing) gibbous (4) waning(shrinking) gibbous**





11. Which shape **is seen when the Moon is located between Sun and the Earth** like the following picture ? _____ **(Use the pictures in Example above.)**

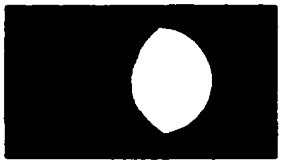
12. Which shape **of the Moon can you see in the sky at night, when the Moon** is located as following picture ? _____ **(Use the pictures in Example on page 4.)**



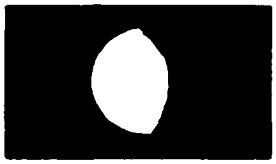
13. Which phase occurs when the **Earth** is between **Moon** and **Sun** like the following picture ? _______ (Use the pictures in Example on page 4.)

14-16. Use the following pictures below for questions 13-18.

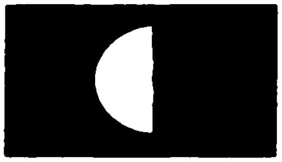
(1) waxing(growing) gibbous



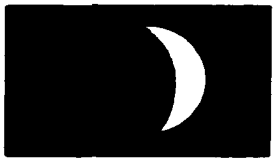
(2) waning(shrinking) gibbous



(3) half moon (last quarter)

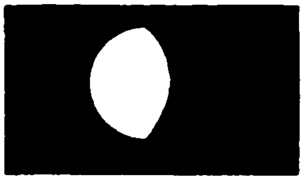


(4) waxing(growing) crescent

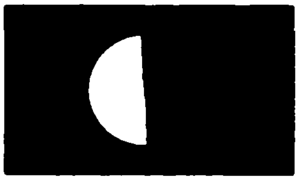


14. Which shape of the **Moon** can you see in the sky two or three days after the **new moon** ? ______
(Use the pictures in Example on page 4)

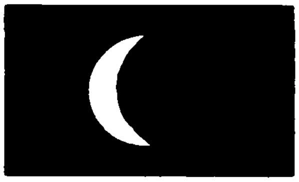
15. What shape of the **Moon** comes in Question Mark (?) after the **waning(shrinking) crescent moon** in the sequence of Moon phases ? _____ (Use the pictures in Example on page 4)



waning(shrinking) gibbous (18th day of month)



half moon(last quarter) (22nd day of month)



waning(shrinking) crescent (25th day of month)

?

16. What shape of the **Moon** comes in Question Mark (?) after the **full moon** in the sequence of Moon phases ? _____ (Use the pictures in Example on page 4)

half moon (first quarter) (8th day of month)	waxing gibbous (11th day of month)	full moon (15th day of month)	?

17. When the whole sunlit side of the **Moon** faces Earth, the Moon is is called _____.

(1) full moon
(2) new moon
(3) half moon
(4) crescent moon

18. At the **new moon** phase, what side of the **Moon** do we see from the **Earth** ? _____

(1) bright side
(2) dark side
(3) sunny side
(4) cloudy side

19. At the **new moon** phase, you see ______.

(1) no moon at all
(2) a bright full moon
(3) a crescent moon
(4) a half moon

20. We usually see _____ **full moon** phase(s) in every month.

(1) one
(2) two
(3) three
(4) four

21. The shape of the **Moon** we see depends on two facts. What are these facts ? _____

(1) It depends on how much of the sunlit side of the Moon is facing Earth and the position of the Moon in its orbit around the sun.
(2) It depends on how much of the sunlit side of the Moon is facing Earth and the position of the Moon in its orbit around the Earth.
(3) It depends on the position of the Earth in its orbit around the sun and the position of the Moon in its orbit around the Earth.

22. At the full moon phase, what side of the Moon do we see from the Earth ? _____
(1) bright side
(2) dark side
(3) foggy side
(4) cloudy side

23. Which one best describes the **Moon** ? _____
(1) The Moon has no light of its own but it reflects the light of the sun.
(2) The Moon has no light of its own and it doesn't reflect the light of the sun.
(3) The Moon glows like the sun with its own light.

24. Both the **Earth** and the **Moon** spin on their axis. Which one rotates faster ? _____.
(1) Earth
(2) Moon

25-30. Please mark the following statements T(True) or F(False).

25. After the **Moon** is full, you will see more and more of the **Moon**. _____ (T/F)

26. After the **new moon** phase, you will see more and more of the **Moon**. _____ (T/F)

27. The **Moon** really changes its actual shape and size. ______ (T/F)

28. The seasons(Spring, Summer, Fall, Winter) changes according to the position of the Earth
in its orbit around the Sun. _______ (T/F)

29. In each season(Spring, Summer, Fall, Winter), we have different amount of sunlight. _______ (T/F)

30. In Summer, north pole of the Earth is facing toward the Sun. So, northern part(America, Canada) of the Earth gets large amount of sunlight. _______ (T/F)