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ABSTRACT

The computer planetarium is a type of software program for Astronomy. It is designed to produce full-motion simulations of sky objects and to provide a variety of photographic and text-based information in Astronomy. A computer planetarium called RedShift was used to improve college students' understanding of Moon phases and eclipses, two topics that have traditionally been difficult for students to grasp.

Following regular classroom instruction in Moon phases and eclipses, two groups of participants each received a different form of instruction employing RedShift. Participants in the computer group worked in groups of three at one computer station for approximately 45 minutes. Following a step-by-step procedures list and an instructional script read aloud by one of the group members, they investigated a series of simulations using RedShift. The video group watched a 21-minute videotape of the same simulations and audible instructional script. The primary focus of the study was to determine which method would be more effective at helping students to better understand and visualize the

phenomena of Moon phases and eclipses. A 32-question multiple-choice test was used to measure students' understanding before and after the respective treatments. A separate questionnaire was used to evaluate students' attitudes toward the treatment and their perceptions of its effectiveness.

Both methods were found to have significant, though small, positive effects on student test scores. Though test score improvement was similar for the two methods, students receiving the computer method had more positive attitudes toward the mode of instruction as well as the subject matter. The computer group also rated the treatment's effectiveness higher than did the video group. Finally, the treatment was found to have a positive effect on certain misconceptions which were held by some of the participants in the study.

EFFECTIVE USE OF A COMPUTER PLANETARIUM TO IMPROVE STUDENTS' UNDERSTANDING OF MOON PHASES AND ECLIPSES

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By

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TABLE OF CONTENTS

TABLES

FIGURES

CHAPTER 1

INTRODUCTION TO STUDY

The Status of Science Education in America

Identifying the Problem

Over the last several decades, science education in America has been the focus of much concern and as a result, several major reform efforts have been launched. Yet, according to the U.S. Department of Education (as cited in Dobson, 1998), American high school students ranked 19th in math achievement 16th in science achievement in a recent study involving 41 nations. Many researchers attribute our students' poor standing to fundamental problems in the way science is taught in this country. As the body of scientific knowledge has grown, science textbooks and science course content have also expanded in an effort to "cover all the material." The result has been an approach to science education that has been called the "facts and formulas" approach (Tinker and Papert, 1989). Students who are products of this approach may learn to use equations to solve textbook problems and to regurgitate facts and scientific vocabulary, but when asked to use scientific knowledge to solve real problems, it becomes evident that most do not understand what science is really all about. Consequently, many students fail to see the relevance of science and far too few are being turned on to science as a career option (Tinker and Papert, 1989).

One important aspect of the problem has been clarified by such researchers as Driver, Easley, and Novak (as cited in Vosniadou, 1991b) who have found that students of all ages possess incomplete or incorrect versions of even the most fundamental scientific concepts. This problem has been well-documented in the domain of astronomy (Lightman and Sadler, 1993; Vosniadou, 1991a; Dai and Capie, 1990). Members of the education community were astonished at the documentary film *Private Universe* (Pyramid Films, 1986). In this film, graduating seniors and faculty members at Harvard University were shown to hold fundamental misconceptions in astronomy.

One reason for misconceptions in science may be that students possess "pieces" of scientific knowledge arising in part from everyday experience and that these pieces are in a highly fragmented form. Some feel that the goal of science education should be to help students refine and systematize these pieces of knowledge into a coherent framework (diSessa, 1988).

Many researchers and educators believe that the best approaches to science education are those which use the "constructivist" learning model as a referent (Baxter, 1990; Yager, 1991). In the constructivist model, the learner is seen as active and self-regulating. The learner plays the active role in processing, organizing, and storing all learning experiences. In effect, the learner invents or constructs his own reality based on these experiences (Fosnot, 1984). The Swiss psychologist Jean Piaget once stated, "I'm convinced that one could develop a marvelous method of participatory education by giving a child the apparatus to do experiments and thus discover a lot of things by himself....For me education means making creators..." (Bringuier, 1980, p.2). This statement by Piaget reflects his insight into the process of human learning and expresses the essence of the constructivist learning model.

As result of this new model of learning, science educators are encouraged to create classroom environments in which learning is approached as an active process requiring "attention, active participation, communication, inquiry and thought" (Tinker and Papert, 1989, p.3). According to the model, it is through these types of learning experiences that the learner constructs scientific knowledge and learns to apply that knowledge to understanding and solving real problems of a scientific nature. Cooperative learning activities are desirable because they allow students to interact with and critique one other, much like real scientists. When engaged in cooperative activities, students are more apt to engage in verbalization of ideas and concepts than when learning independently.

Computer Technology: A Constructivist Tool

Computer technology is beginning to provide the tools which can help facilitate the type of active learning called for in the constructivist model. Computer programs known as "interactive simulations" represent one such tool. These interactive simulations are also known as "computer microworlds." Through integrating various combinations of digitized media such as computer-generated images, animations, still photos, video, and sound, interactive simulations allow students to study and interact with a variety of scientific phenomena or physical systems.

Interactive computer simulations of this type can be effective learning tools for developing good conceptual understanding. Zietsman and Hewson (1986) successfully used a microcomputer simulation program to diagnose and cure an alternative conception of velocity. They concluded that students who worked with a computer simulation of velocity in one dimension were able to transfer their conceptual understanding over to the velocity of real objects. In another study (Reiber, 1990), computer animations were used to teach Newton's laws of motion to fourth and fifth-grade students. The author concluded that when lesson content requires students to visualize motion and trajectory attributes, interactive computer animations can be an effective teaching tool.

In the field of astronomy, computer simulations and multimedia programming are being successfully used in undergraduate instruction. For example, Ivan Policoff at the University of Minnesota has reported success in using astronomy computer simulations to actively engage his under-prepared astronomy students (Policoff, 1995). At Catonsville Community College in Catonsville, MD, astronomy courses are being taught entirely by computer. Videodiscs, digital images, animations, and sound are used to present the information. Students then take written tests over the material (Wilson, 1992).

Specific Context and Purpose of the Study

With the growing quantity of software and the increasing availability of computers, astronomy educators now have more options than ever before. Choosing software and deciding how to use it can present quite a dilemma. First, they must identify those programs which are capable of meeting their instructional goals. Then they must identify effective ways to utilize a given program within a given instructional context. Finally, there is the need to determine those astronomy concepts which are affected most by the utilization of the program.

The focus of this investigation is the effective use of a computer program for astronomy known as RedShift. It is a type of computer program known as a computer planetarium. Using detailed color images, computer planetarium programs specialize in simulating the positions and motions of planetary bodies and other objects in the solar system and beyond. For example, using any of the various computer planetaria such as PC-SKY, Voyager II, or RedShift, a student can view a simulation of the entire solar system from outside the ecliptic plane. The planets' orbital motions can be simulated by simply clicking the control button icons on the screen. The student can zoom in to take a closer look at the Earth-Moon system or zoom out to include the orbits of Neptune and Pluto. Programs of this type are many-faceted, typically including large databases of NASA space photographs and astronomy encyclopedia. They may also include full motion video clips with audio.

RedShift can be adapted to a variety of instructional applications. It can be used by the instructor for demonstrations during class. It can be used by students for individual study. It can also be used as the focal point for small group cooperative learning activities.

In this study, two different instructional applications of the computer planetarium RedShift were designed, tested, and compared. In one application, students worked cooperatively in groups of three to explore a series of RedShift simulations of Moon phases and eclipses. In the other, students in a large group watched a videotape of the same simulations. Both methods were used as supplements to traditional classroom instruction and were designed to help students improve their understanding of how the motions of the Solar system produce Moon phases and eclipses. The simulations included actual photos and computer-generated graphics depicting the Moon phases, eclipses, and views of the three bodies in motion from different perspectives in space.

Research Questions

There were two primary objectives in this study. The first objective was to determine whether either of the suggested applications would be effective at helping students improve their comprehension of Moon phases and eclipses. The second objective was to determine which of the two would be the more effective method. Using these objectives, the following research questions were formulated:

1) Will either of the two proposed applications of RedShift result in significant test gains?

2) Which of the two applications will result in the greater test gains?

Secondary goals of the investigation included the assessment of students' perceptions about the effectiveness of the treatment and determining their attitudes regarding the use of the computer technology. Another secondary goal was to pinpoint those concepts affected most by the treatment. This was done by performing a chi square analysis to identify those test items on which there was significant posttest improvement.

Definitions of Terms

The following terms of a specialized nature have been used in this report. To help the reader better understand the report, they are defined here.

misconception (or alternative conception) - a belief or understanding of natural phenomena which differs from the currently accepted scientific view. For example, a common misconception is that the seasons on Earth are caused by the Earth's variable distance from the Sun.

Moon phase - the appearance of the Moon for an Earth-based observer; determined by that portion of the Moon's illuminated hemisphere visible from Earth at any given time. For example, during the full phase, an Earth-based observer sees a bright circular disk because the entire illuminated hemisphere is facing Earth.

eclipse - results from a perfect or near perfect alignment of the Sun, Earth, and Moon. In a solar eclipse, the Moon passes between the Sun and Earth, blocking out or eclipsing the Sun from the view of an Earth-based observer. In a lunar eclipse, the Earth is between the Sun and Moon. An Earth-based observer sees the Earth's shadow passing slowly across the Moon's surface.

cooperative learning - a learning environment in which students work together in small groups to accomplish common learning goals. Important elements include interdependence, interaction, accountability, and group processing (Johnson, Johnson, and Smith, 1991).

interactive - a quality attributed to computer programs in which the user is allowed to "modify, experiment with, or customize information" (Cartwright, 1993)

microworlds - interactive computer simulations which model real world phenomena. Students interact with microworlds by experimenting with different parameters and variables in order to learn how the simulated system operates.

animations - computer-generated graphics which exhibit motion; in this study, RedShift was used to create animations simulating the Sun, Earth, and Moon and their motions.

multimedia programs - computer programs which integrate various combinations of sound, text, graphics, still photography, and full motion video.

computer planetarium - a type of software program for astronomy designed to produce full-motion simulations of sky objects such as planets and stars and to provide a variety of photographic and text-based information; RedShift is one example of a computer planetarium.

spatial skills (or ability) - the ability to predict or imagine the appearance of three dimensional objects from different physical perspectives; a skill known to correlate significantly to success in most fields of science and mathematics (Bishop, 1978).

preservice teachers - undergraduate college students pursuing a degree and/or certification in teaching (usually at the elementary or secondary level).

Design

The design utilized in this experiment was a two-group, pretest/posttest design. The treatment group known as the "computer" group was divided into lab groups of three members each. These small groups were exposed to the RedShift program in the form of a computer lab activity in which one group member operated the computer, one read the instructions, and the third read the instructional narrative. The other treatment group, called the "video" group, received their treatment in the form of a VHS format video presentation. This group viewed the video together as one group. The video presentation was recorded using the RedShift program . The simulations and their sequence of presentation were the same as those explored by the computer group. The instructional narrative was recorded onto the video along with the simulations.

The experiment was conducted twice, each time using a different sample. The two samples consisted of students from two separate colleges. All were non-science majors who had recently studied the topics of Moon phases and eclipses as part of a course. In both samples, students were randomly assigned to treatment groups, with one group receiving the computer treatment and the other group receiving the video treatment.

Two different types of instruments were used to collect data. Students' concepts of the Moon's phases and eclipses were measured using a thirty-two item multiple choice pretest and posttest. Students' attitudes toward the experience and the subject matter as well as their perceptions regarding the effectiveness of the treatment were measured using a Likert scale questionnaire. Both instruments were administered using pencil and paper.

Significance of the Study

The motivation to perform this study arose primarily from two issues in astronomy instruction. The first issue involves the difficulty many students have in learning concepts in astronomy. In previous studies, researchers have documented some of the more common weaknesses in students' astronomy concepts (e.g., Vosniadou, 1991a). These areas of weakness are known as alternative conceptions or misconceptions. Many of these alternative conceptions are partly due to poor spatial skills. The second issue involves the use of computer simulations to improve spatial skills, which has been done successfully in other studies (e.g., Zavotka, 1987). In this investigation, the impact of computer simulations of Moon phases and eclipses on students' concepts in these areas is explored. Students are prone to misconceptions in these two areas and mastery over them requires spatial skills.

This study is particularly relevant to instructors who are looking for practical ways to use computer technology as part of their approach to teaching difficult astronomy concepts. With computers playing an ever-expanding role in science education, instructors at all levels are seeking ways to incorporate computer-based materials in their teaching. With simulation programs like RedShift becoming more widely available and affordable, the opportunities for making this happen are increasing. It is hoped that, as a result of this study, instructors will be encouraged to try new ways of using these programs effectively in the astronomy classroom.

Overview

The remainder of this study is presented in the four chapters that follow. Chapter 2 provides a review of research and discussion relevant to this study. Chapter 3 provides a detailed description of the experimental design and procedures. In chapter 4, experimental results and analysis are presented. Results of the analysis are then used to answer the research questions. Chapter 5 presents a discussion of the results and their implications for teaching astronomy along with suggestions for further research.

CHAPTER 2

LITERATURE REVIEW

This chapter consists of three main parts. The first major section deals with the large issue of computers-based instruction. It begins with a background of traditional computer-based instruction, followed by a discussion about the characteristics of the computer which distinguish it from other instructional media. Also included is a review of the progressive role of computer technology in science education. The section ends with a discussion of research involving a special type of instructional computer program known as the computer microworld. In section two, research involving alternative conceptions in the domain of astronomy is discussed and related to the present study. Section three provides a limited review of research related to cooperative learning activities.

Learning with Computer Technology

A Review of Computer-Based Instruction

Computers have been used in the instruction process almost from their inception. As early as the 1960's, education researchers began evaluating the usefulness of computers in the instruction process. At that time, and into the 1970's, the term "computer-based instruction" (also called "computer-assisted instruction") meant using a computer programmed specifically to deliver information about a given subject to the student. This information was in the form of text and graphic images and was delivered in a linear, lock-step fashion giving the student little or no control over the process (Cartwright, 1993). In this role, computers served merely as a new method of implementing the old strategy of instructing the student through drill, practice, and tutorial.

Though somewhat less revolutionary than many had anticipated, computer-based instruction was not without its merits. Hundreds of studies were performed in which computer-based instruction was compared to teacher-delivered instruction. Kulik, Bangert, and Williams (1983), following their meta-analysis of 51 such studies, concluded that computer-based instruction had positive effects on student achievement, attitude towards subject, and attitude towards computers. They also found that instruction time was reduced with computer-based instruction.

Computer-based instruction is most effective when the student has some degree of control over the lesson. Kinzie, Sullivan, and Berdel (1988) found that with computer-assisted instruction (CAI), students having some control over the instruction sequence scored higher on the posttest than students not having control. The CAI consisted of a series of screens containing text and graphics, with fifteen multiple choice questions interspersed throughout. In this study, students in the learner control group were given the option of reviewing lesson content after missing a question. For students in the program control group, the program automatically presented a review of lesson content following a missed question.

Distinguishing Characteristics of the Computer

A medium is defined in terms of the symbol systems it uses and the operations it can perform on them (Kozma, 1991). Whatever the medium, students will benefit most from those capabilities of that medium which enable it to "provide certain representations or perform or model certain cognitive operations...which the learners cannot or do not provide or perform for themselves" (p.182).

Books, television, and the computer each have characteristics which distinguish them as media. Books employ the symbol systems of text, diagrams, and pictures. The stability of these symbols gives the learner total control over the rate at which the information is delivered. The reader can slow down, stop, or reread any portion of the text. Television differs from books not so much in the symbol systems it employs but in the operations it can perform on those symbols. For example, the symbols are usually in motion. Television normally employs two symbol systems simultaneously: video and audio. This results in better recall than the use of either symbol system alone. The symbols are usually transient (short duration), making learning dependant upon the visual attention of the learner. If the viewer is familiar with the content, he may be able to process at the same pace as the symbols are being presented. If he is not familiar with the content, or if the content is very difficult, the learner may not be able to keep pace and comprehension becomes impossible.

The computer differs from television in the operations it can perform on the symbol systems. Computers have the capacity to transform information from one symbol system to another. For example, a computer can be programmed to transform numerical data into a graph. Computers also have the capacity to "proceduralize" information, that is they can operate on symbols according to specified rules. For example, in the ThinkerTools (White and Horwitz, 1987) project discussed later in this chapter, the program was designed to cause the moving dots to behave according to principles of

Newtonian physics. Computers can transform information from the real world into symbols. In microcomputer-based laboratories (MBL's), information such as temperature, pH, velocity, or sound etc. can be collected, stored and transformed by the computer. In this way, the student can begin to understand the relationship between symbols and the real world information being represented.

There has been much debate on the question of whether any instructional medium, including computer technology, really has any direct influence on learning. Richard Clark (1994) maintains that a particular medium is merely the delivery vehicle for instruction and has no direct effect on learning. However, Robert Kozma (1991) sees the interactive component of some computer-based instruction as having the potential to affect learning. According to him, "If there is no relationship between media and learning it may be because we have not yet made one" (p.7). Perhaps new technologies and new ways to apply them will supply evidence for Kozma's argument.

<u>The Stages of Technology in Science Education</u>

Computer technology has earned its place in most areas of academics, especially the sciences. Marcia Linn (1989) maintains that the influence of technology on science education in America has occurred in two previous stages and that we are on the threshold of the third stage. Stage One was defined by the use of computer technology to help accomplish the existing goals of science education. It was characterized by computer programs designed for the drill and practice of scientific information, word processing, and demonstration of scientific phenomena. Stage Two has been characterized by a greater influence of computer technology on the goals of science education. There has been a greater emphasis on teaching problem-solving by utilizing the same computer programs used by professional scientists. This has been driven by the idea that using the technological tools of the experts will help make experts out of the students. Computer microworlds were developed, such as Dynaturtle and Logo, which involved teaching programming languages to children. With these programs, students used mathematics to accomplish tasks in physics, music, and other fields. Interface devices were designed to collect all sorts of scientific data and to model scientific phenomena.

Science education is now treading the threshold of Stage Three, which may redefine the traditional roles of teacher, technology, textbooks, and the learner. The goals of science education will have to be reevaluated and restructured in order to prepare students to succeed in this information age. Stage three will require the development of interactive instructional software capable of automatically adapting to the learning needs of individual students (Bork, 1997). It must be developed by experienced teachers who can anticipate where students will need help in understanding concepts. This software must be programmed so that it can be updated often in order to accommodate new pedagogical strategies and changes in current knowledge about the subject. It must also be able to track the progress of the individual student over time and over distance. The new courseware would place new emphasis on the process of science, rather than on the techniques and terminology of scientists. This new role for technology will not come easy or quickly. It will require fundamental changes in teacher preparation and school organization. In order to accomplish this change, there must be increased collaboration among educators, educational researchers, school administrators, parents, students, curriculum developers, and government officials. This collaboration is necessary to create an environment in which innovations can be tried and refined in real school settings (Linn, 1989).

Characteristics of Effective Instructional Software

In the mid-1980's, the higher education organization for academic computing known as EDUCOM sponsored a project known as Educational Uses of Information Technology (EUIT). This project had as its goal to identify and officially recognize exemplary applications of computer-based technologies to undergraduate instruction. In 1993, an EUIT group chaired by Judith Boettcher published the volume *101 Success Stories of Information Technology in Higher Education*. This work identifies 101 successful models which clearly demonstrated a positive return on technology investment in terms of learning gains. These projects were also selected for their transportability to other institutions and their effectiveness at helping students learn particularly difficult concepts (Cartwright, 1994).

In this endeavor to identify effective instructional software, it was found that one of the fastest-growing trends involves using the computer to simulate complex systems. These may be chemical or biological systems where the student experiments by manipulating the system's parameters and then observes the results. Medical training programs can simulate clinical environments in which students can practice diagnosis and treatment of simulated patients. In the social sciences, programs exist which can simulate historical events and people, allowing the user to participate in critical decision-making processes and observe the social and political ramifications of those decisions (Cartwright, 1994). Technology applications of this sort are in a sense "removing the walls" of today's classrooms by allowing students to experience more of the real world through computer simulation. Through the use of such programs, students are able to sharpen their critical thinking and problem-solving skills and to apply these skills to a variety of issues of real importance.

A second important trend noted in the EUIT report is the creation of multimedia instructional programs. Multimedia programs are so called because they successfully integrate the media of sound, text, graphics, still photography, and full motion video. Multimedia computer programs used in instruction offer a new and interesting approach to presenting materials. "By taking an active part in their learning and using their senses to experience new situations, students can begin to gain a broader, more in-depth understanding" (Oblinger, 1992, p.4).

A distinctive characteristic of multimedia programs is the ability to provide a multisensory experience. This is considered to be a more natural way of presenting information in that the learner can quickly move from words to images to sounds. This more accurately mirrors the way in which the human mind thinks, learns and remembers (Oblinger, 1992). Oblinger also notes that in short-term memory, an individual retains 75% of what is simultaneously seen, heard, and done. This compares to the retention of only 20% of information that is heard and 40% of what is seen and heard.

The more advanced multimedia programs are also "interactive." Used in this sense, the term interactive means that the user is allowed to "modify, experiment with, or customize information" (Cartwright, 1993). Learner interaction with the program is seen as one of the greatest benefits of interactive computer programs.

Computer Microworlds

Computer microworlds are interactive computer simulations which model real world phenomena. A defining attribute is their ability to function as "artificial realities that intersect enough with students' ideas that they can begin to manipulate them." (diSessa, 1988, p.62). Students interact with microworlds by experimenting with different parameters and variables in order to learn how the simulated system operates. Instructors from many different disciplines are finding microworlds useful in their courses. Chemistry students can use 3D Molecule by Mosby to explore the three-dimensional geometry of molecules. Physics students can use Logal's Explorer to experiment with pendulums of different masses and lengths to determine their effects on the pendulum's period.

One of the first successful computer microworlds was developed by White and Horwitz (1987). The program, known as ThinkerTools, was designed to teach middle school students the Newtonian mechanics of simple forces and motion, and "in the process, introduce them to powerful methods of scientific inquiry and inductive reasoning" (Horwitz, 1988; p.60). The ThinkerTools curriculum is developed around a series of microworlds in which students manipulate the velocities of computer-generated dots by applying forces to them using a joy stick. Students are challenged to make the dot stop in a certain place, avoid obstacles, or collide with another object. When students complete one level, they move on to a new level which is more complex than the previous. Within each level, the curriculum guides students through a four-step process: prediction, experimentation, formalization, and generalization. In the last two steps, students are asked to conceive a set of laws governing the behavior of the dots and then apply their laws to real world problems.

As a result of the ThinkerTools project, it became clear that computer microworlds can be used to achieve a number of desirable goals in science education. The students remained motivated and actively engaged throughout the course (two months). Students in the study exhibited characteristics of real scientists. They collaborated often within their respective groups and critiqued one another's mental models. They utilized the program's flexible design to devise new experiments in an effort to test their predictions. They were able to apply their mental models to the behavior of objects in the real world with confidence. In one test, sixth graders who completed the ThinkerTools curriculum performed better at solving a set of classical force-motion problems than did high school students who were taught using traditional methods (White, 1993).

In Chapter 1, the point was made that the goal of science education should be to help students learn to think more like real scientists. How can interactive computer programs help accomplish this? Computer microworlds can give students the freedom to explore the qualitative nature of phenomena in ways that are richer and more intuitive than the more formal, quantitative methods which have been so common and unfruitful (diSessa, 1988). A microworld is designed to engage a student's existing knowledge by creating an environment familiar to the student, one which is easily manipulated. The student can then move through levels of increasing complexity with increasing freedom to explore, make predictions, and design experiments. In this way, microworlds can help students see the connection between the formalisms of science and the more familiar experiential aspects (diSessa, 1988).

Computer microworlds may aid students in their formation of mental models. This is because microworlds can produce graphic representations of events, situations, or physical systems. Mental models are often used as the first approach in solving a physics problem. The mental model is often used to perform a qualitative analysis of the problem. It helps the problem solver decide on how to proceed with a quantitative solution to the problem.

The mental models of novices (students) are known to differ significantly from the mental models of experts (scientists). The mental model of an expert consists of physical entities or images (corresponding to concrete objects in the real world) as well as the more abstract concepts (such as force or acceleration). The expert possesses highly organized "chunks" of knowledge (schemata) in the physics domain (i.e., the laws of physics) which help to establish the proper relationships between the concrete and abstract elements of the mental model. The result is a mental model which corresponds well to the physical phenomenon being considered and enables accurate predictions and problem solving. The mental model of a novice is usually less complete. The domain-specific knowledge on which the novice can draw to construct the model is often incomplete and organized differently from that of the expert. The result is a mental model which is insufficient to determine a solution or leads to an erroneous solution (Kozma, 1991).

The computer microworld is powerful because it proceduralizes the relationships between the parts of the model. This means it is programmed to make the model move or otherwise behave according to a set of prescribed laws or formulas. The strength of this attribute is that, for the novice, it may serve as a sort of substitute for the organized knowledge of the expert. The microworld model can be manipulated by the novice, enabling him to see the effects of changing certain relationships or variables. As a result, the learner can modify his mental model to bring it more in line with the computer model.

In addition to its ability to provide a visual likeness of the system (such as the solar system), the computer model can be designed to represent abstract concepts by visual means. An example of this is the "wake" symbols which trail behind the moving dots in the ThinkerTools microworld. The spacing of these wake symbols provides a clear visual indication of the velocity of each moving dot, in effect acting as a speedometer.

Spatial ability is the ability to predict or imagine the appearance of three dimensional objects from different physical perspectives. Spatial ability is a skill known to correlate significantly to success in most fields of science and mathematics (Bishop, 1978), including astronomy. For example, understanding the cycle of day and night on earth involves imagining the earth's appearance from the perspective of an observer in space.

Some computer programs have been used to strengthen the user's spatial ability. Zavotka (1987) found that the use of computer animated graphics which replicate mental images of rotation and dimensional transformation are useful in the development of spatial skills. Reiber (1990) concluded that when lesson content requires students to visualize motion and trajectory attributes, computer animations are an effective teaching tool. In that study, computer animations were used to teach Newton's laws of motion to fourth and fifth-grade students.

Misconceptions and Conceptual Change

Introduction

The process by which science students learn scientific concepts has been the target of much research over the last three decades. Researchers have found that prior knowledge and conceptions have a great impact on what students are able to learn and how they learn it. Because of this research, the science education community is beginning to realize that the most important thing students bring to science class is their concepts. In order to understand how a computer program such as RedShift might be of use in reducing misconceptions in astronomy, it is important to review some of the major research on learning and misconceptions in science.

Misconceptions Defined

From childhood, all people construct knowledge about the material world. By the time they reach high school and college, most people have developed a way of thinking about physics based on common experience. This spontaneously acquired knowledge has be referred to as "intuitive physics" (diSessa, 1988). The problem with intuitive physics is that it represents a "fragmented collection of ideas, loosely connected and....having none of the systematicity that one attributes to [actual] theories" (p.50).

This way of thinking that diSessa calls intuitive physics, is usually riddled with "misconceptions", or concepts which are at odds with accepted scientific knowledge in that field. The term "alternative conception" is also used, connoting that the concept may not be completely invalid, just different from that of the experts (Nussbaum and Novick, 1982).

A prominent researcher in this field, Stella Vosniadou believes that misconceptions are rooted in that portion of a person's knowledge known as "intuitive knowledge." Our intuitive knowledge represents our own personal understanding of natural events based on experiences we have had during the course of our human experience. For example, many young children think that the earth is flat because their senses encourage this belief (Vosniadou, 1991b). Indeed, young children have very little evidence for anything but a flat earth.

Misconceptions may also be formed during the learning of new concepts in the instruction process. This is because new concepts are interpreted within the framework of existing knowledge. Sometimes the new concept is misinterpreted so that it will not be in conflict with previously-held ideas (Osborne, 1981). For example, when young children with the idea of a flat earth are told by their teacher that the earth is round (like a ball), some misinterpret the teacher to mean that the earth is like a disk - both round and flat (Vosniadou, 1991b).

Misconceptions in Astronomy

Cohen (1983), Sadler (1987), and numerous others have conducted studies in an effort to determine what misconceptions people have in the area of astronomy. From these studies, it is immediately clear that students of all ages demonstrate a variety of misconceptions involving the day-night cycle, earth's seasons, moon phases and eclipses and many others. One common misconception in astronomy is the explanation for the earth's seasons. Current scientific knowledge attributes the changing seasons to the tilt of the earth's axis relative to its plane of revolution. Lightman and Sadler (1993) found that

46% of high school students in their study reasoned that the earth's seasons were caused by the earth's changing distance from the sun. It is not difficult to see why the students exhibit this misconception. Students are taught in school that the earth-sun distance changes throughout its revolution. To reinforce this fact, textbook diagrams often show the earth's elliptical orbit around the sun with the eccentricity of the ellipse being greatly exaggerated. Now consider this experience that most people have had: as one moves away from a hot object, the intensity of the heat decreases. It seems reasonable that this same principle should apply to the earth-sun system (and indeed it does but the effects are negligible compared to the effect produced by the axial tilt).

Changing Misconceptions.

Not only are misconceptions common in science, they are extremely resistant to change by traditional instructional methods (Champagne, Klopfer, and Gunstone, 1982). Even after instruction (in some cases, even a course in astronomy) involving lectures and traditional lab activities, the vast majority of students continue to hold misconceptions (Lightman and Sadler, 1993; Vosniadou, 1991; Baxter, 1990).

It is also clear that while some teachers may recognize their students' misconceptions, nearly all overestimate the effects their instruction has on these misconceptions (Lightman and Sadler, 1993). So what steps should the science instructor take to reduce these misconceptions?

The answer, in many researchers' opinions is an approach known as "conceptual change." This is a methodology requiring the student to realize the conflict between his concept and reality and to closely examine his mental model for imperfections.

Conceptual change is thought to occur when a student can exchange his mental model of a concept for a new model that is consistent with the accepted scientific model.

A somewhat different approach is advocated by diSessa (1988). Rather than a simple exchange of one model for another, she calls for a "major structural change toward systematicity" (p.49). This structural change involves the use of activities which help the learner build upon and integrate his knowledge fragments so that they become a coherent, unified system of ideas.

Any effort to help students learn science must begin with assessing the knowledge already present and the misconceptions which have already been formed (Zietsman and Hewson, 1986). Vosniadou's research suggests that certain "entrenched beliefs" which underlie "synthetic mental models" (misconceptions) must first be identified then removed. This will allow the formation of an acceptable "scientific" mental model (Vosniadou, 1991b). The next step involves motivating the students to question their own misconceptions. Baxter (1990) suggests that at the very least, instructors should be aware of the common misconceptions and design lessons which challenge their alternative frameworks. He also recommends giving students the chance to test the validity of their ideas and form conclusions. The final step is helping the students understand the correct scientific explanation (Vosniadou, 1991a).

Group Learning at the Computer

In general, environments in which learners work together in small groups to accomplish common learning goals are more fruitful than environments in which the individual learns alone or competes with others. Yet cooperative learning is used very little in college classrooms (Johnson, Johnson, and Smith, 1991). Cooperative learning involves five basic elements: "positive interdependence, face-to-face promotive interaction, individual accountability, social skills, and group processing" (p. 6). If these five elements are present and correctly structured, learning is maximized.

There are several advantages to combining group learning strategies with instructional computer activities. One obvious advantage is that it allows more students access to computers (Orr and Davidson, 1993) . This is especially important where computers are in short supply. A second advantage was noted by Trowbridge and Durnin (1984) who observed that students working in groups at the computer were more likely to interpret program questions correctly and to avoid taking a wrong path in the program. Another advantage is that members of groups exhibit more verbalization relevant to the material being learned. Finally, computer-based group learning activities encourage group collaboration and cooperation in solving problems. These types of interaction are important parts of a constructivist educational strategy (Yager, 1991).

Group size is an important consideration when using computer based materials. Trowbridge and Durnin (1984) found that in groups of four learners each, the group members were unable to maintain sufficient levels of interactivity with the program and other members in the group. Members of groups of two were more likely to cooperate with one another than were groups of three members, while members of triads showed a greater tendency to compete with one another.

In this study, a group size of three was utilized for several reasons. Having three members per group helped to maximize computer access, since limited copies of the program were available. Using groups of three also enabled the investigator to carry out the experiment in less time. Having three students in each group also increased the likelihood that at least one of them would be familiar with using a Windows program such as RedShift.

Summary and Rationale

Several attributes of computer microworlds stand out as having strong potential to promote learning in astronomy, which often involves the modification or replacement of alternative concepts. First and foremost is active involvement on the part of the learner. Second, they can provide credible simulations of reality and allow the learner to make predictions and test those predictions. Learning which takes place using these programs is transferrable to real world situations. Third, microworlds are interactive, giving the learner more control over the learning experience. Fourth, microworlds can help improve the student's spatial skills. Fifth, computer microworlds help the student create a link between formalism and experience.

RedShift is an interactive computer microworld with some multimedia features. The simulations used in this experiment included still photographs, graphic images, and animations, all of which were accessed by the student through the clicking of icons. The program has no audio capability (RedShift 2 & 3, more recent versions, do utilize audio).

RedShift allows the user to experiment with and modify dynamic computer-generated models which exhibit both the concrete and the abstract features of real physical systems. The program can take the student through a series of "Guided Tours." These are pre-selected program settings designed to showcase some of the more familiar views in the solar system. The student has the freedom to adjust program settings such as magnification and viewing location to create a simulated view of any object in the real sky. The universal time clock can also be adjusted forward or backward. By manipulating the models and simulations in RedShift, students may be able to refine their mental models so that they become more like those of the experts.

RedShift has the scope and flexibility which enable it to meet a variety of changing needs in the classroom. For example, it allows students to engage in the processes of science. Students can research a variety of topics in astronomy through hypertext links to diagrams, text, animations, and video. It also has features which facilitate the scientific processes of observation and exploration. Students can turn their "telescope" on any region of the sky and zoom in on virtually any object they see. They can gain immediate access to information about what they are viewing.

This study is a logical extension of previous research focusing on microworlds. First, while most previous research has been done with elementary or high school age subjects, the participants in our study are undergraduate college students. Secondly, in previous studies, microworlds developed to meet very specific instructional goals were tested. RedShift was not developed to meet specific instructional goals. Rather, it was developed as a tool to help the user learn about astronomy by “exploring” the visible universe. This gives it the flexibility to be incorporated into a variety of instructional settings. Finally, this study relates to previous research into misconceptions by applying computer intervention strategies to learning in the domain of astronomy, a domain which is a problem area for many students.

CHAPTER 3

METHODOLOGY

In the first section of this chapter, a complete description of the experiment is presented. This description includes the preparation and implementation of the treatments, a description of the treatments, the selection of participants, and the details of how the experiment was conducted. Section two provides a description of the testing instruments and the strategy for analysis.

Experiment Design

Overview

The participants in this study were students enrolled in three science classes at two different colleges. All classes had just completed a unit of study which included Moon phases and eclipses. The experiment was performed on each class separately, utilizing a two-group, pretest/posttest design. The participants in each class were randomly assigned to one of two treatment groups. The two treatment groups each received a different form of the experimental treatment being investigated.

The independent variable in this experiment was the specific presentation mode for a sequence of computer-generated astronomy simulations involving the Moon's phases and eclipses. The simulations were created using the computer program RedShift. An instructional narration was written to accompany the simulations. Participants in the computer users group encountered the simulations while working through a computer lab activity designed for groups consisting of three members each. Each member of the group played a functional role in the activity. Participants in the video viewers group were collectively shown a video-recording of the simulations.

Three dependent variables were examined in this experiment. The first dependent variable was the participant's understanding of Moon phases and eclipses, measured by a multiple-choice test administered both before and after the treatment. The other two variables, measured using a questionnaire, were each group's perceptions of the effectiveness of the treatment and their level of satisfaction with the experience.

Development of Treatments

Description of RedShift. Produced by Maris Multimedia of London, RedShift is marketed as a "multimedia" astronomy computer program. It is a CD-ROM-based computer planetarium whose central feature is its ability to generate graphic simulations of sky objects. Its huge database contains information on over 300,000 stars, galaxies, and other deep space objects. RedShift has a dictionary of astronomy terms, with over 2,000 entries, which the user can access from any screen. Also available with the click of the mouse are over 700 full screen photographs (most in color) of the sun, moon, planets, nebulae, and many other space phenomena.

RedShift's simulations of the sky and planets is the feature of greatest interest in this study. The program allows the user to put the sky into motion and track the paths of planets, moons, and other objects. It can simulate conjunctions, eclipses, occultations, and other astronomical events occurring over a 15,000 year period. The program is very flexible, enabling the user to control such variables as viewing location, distance from object, magnification, and time of observation. This versatility makes it particularly suitable for astronomy students to explore moon phases and eclipses in great detail.

Computer lab activity description. This experiment was originally conceived in the Spring of 1995. At that time, a computer lab activity was developed by the investigator. In this activity, students used the computer program RedShift to learn about Moon phases and eclipses. The computer activity was intended to be used as a supplement to regular classroom instruction on Moon phases and eclipses. In May of 1995, a pilot study was conducted using seventeen participants. Each participant was personally interviewed by the investigator to determine their understanding of Moon phases and eclipses. Immediately following the interview, each participant performed the lab activity with the investigator reading the instructions aloud and the participant operating the computer controls. Immediately following the activity, the participant was again interviewed to determine whether their understanding had been affected as a result of using the RedShift program.

As a result of this pilot study, several revisions to the lab activity were made. These revisions were completed in December of 1996. It was revised to include a wider variety of simulations. The instructions were made more specific and user friendly so that students with minimal computer skills could successfully use RedShift on their first try. The structure of the activity was redesigned to accommodate small groups rather than individual users. The chosen group size was three, with one student in each group operating the mouse and keyboard, one student reading the instructions to the mouse operator, and one student reading the narration (see Appendix B for a complete script).

Video production. In January of 1997, the simulations from the computer activity were recorded onto a VHS videocassette with the audio narration dubbed in simultaneously. This video was made using RedShift 2 running on a Macintosh platform because only Macintosh equipment was available for making the video. The resulting video had a playing time of 21 minutes. RedShift 2 was also used in the experiment. Since it will run on either IBM or Macintosh platforms, this version was used whenever only Macintosh computers were available to participants. Although RedShift 2 has some additional features, it is identical to RedShift with respect to the features used in this study.

Description of RedShift Instruction

In order to help the participants understand all aspects of Moon phases and eclipses, they needed to be able to see the movements of the Sun, Earth and Moon relative to one another. To provide for this, the RedShift instruction delivered in the treatments included full-motion simulated views of the three bodies from many different angles, at different speeds, and from different distances. To help them see the importance of the illuminated portion of the Moon to its phase, the "phases" mode was switched off (both hemispheres of a planet or moon are shown fully illuminated all the time), then back on (only the hemisphere facing the sun is illuminated) several times during the simulations. This was explained to the participants in the narration.

The RedShift instruction placed heavy emphasis on the Moon's appearance as seen from Earth. The different phases were named and then reviewed several times throughout the instructional sequence. Simulations of both lunar and solar eclipses were played forward and backward and with phases turned on, then off. Throughout the simulation, the accompanying narration explained what was being shown on the screen. Emphasis was placed on the importance of the positions of all three bodies relative to one another as being the cause of Moon phases and eclipses (for a more complete description of the RedShift treatment including graphics, see Appendix D).

Selection of Participants

Description of populations. The college classroom provides the most practical setting in which to carry out the present study. This is true for several reasons. The first reason is that the purpose of this study was to determine whether astronomy instructors at the college level might be able to utilize the computer planetarium program RedShift to help astronomy students improve their understanding of the Sun-Earth-Moon system. A second reason is that thousands of undergraduate college students enroll in astronomy courses each year at colleges and universities in this country. For most of these students, their knowledge of astronomy is very limited. They possess incomplete or incorrect mental models of celestial motion and have developed various misconceptions about astronomy. The majority of them enroll in the course because it satisfies a science requirement in their respective degree programs (Bruning, 1992).

For practical considerations, the researcher did not attempt to sample the population of students in the U.S. who enroll in astronomy courses. Instead, two smaller populations were chosen for this study. Population 1 consists of students at small private colleges. With smaller enrollments, students at small private colleges generally have better access to computer technology than students at larger universities. Many of these colleges offer astronomy courses which fulfill basic science requirements. As an instructor at a small college in central Kansas, the researcher is particularly interested in this population. Population 2 consists of preservice elementary teachers. This group, among others, has been identified in several studies as having misconceptions in astronomy (Dai and Cape, 1990). This population of preservice teachers is a very important group to reach. If their misconceptions in astronomy can be addressed while they are still in training, it might help make them more effective teachers. This population is also very large and difficult to randomly sample. For the purpose of this study, the population has been narrowed to include preservice elementary teachers at state universities having total student population less than ten thousand.

Sample 1. The sample from Population 1 was taken from the investigator's own introductory astronomy course and was designated as Sample 1. The students in this class were primarily freshmen and sophomores at a small, church-affiliated, 2-year college in central Kansas. The class size was 31 students, of whom 24 completed all phases of the experiment. Of the 24 participants, 18 were male and 6 female.

Sample 2. The sample from Population 2 was designated Sample 2. The participants in this sample consisted of preservice elementary teachers. They were enrolled in two sections of a physical science course at a state university in Kansas with a total student enrollment of about five thousand. Each section was taught by a different instructor, so the students in each received similar but not identical instruction. Total enrollment in the two sections was approximately 60, of which 45 completed all phases of the experiment. This smaller number was due to absences either on the day of the pretest/treatment or on the day the posttest was given. Of the 45 participants, 5 were male and 40 female.

Conducting the Experiment

Group assignment. The astronomy class in Sample 1 and both physical science classes in Sample 2 were randomly divided into two experimental groups. The group known as the computer group received the computer activity treatment. Members of this group were randomly assigned to groups of three for performance of the computer lab activity. The other group, known as the video group, remained intact to view the video.

Sample 1. Having completed the instructional unit in which Moon phases and eclipses were taught, the pretest was administered to the entire class (both experimental groups) at one time. Following the pretest, each small group in turn completed the lab activity. Each small group completed the activity in one sitting. The time required for each group was from 40 minutes to one hour. Two days were required for all the groups to complete their computer activity. On the following day, the video viewers group watched the video together in one sitting. The time required was 21 minutes. One week later, the posttest was administered to all participants at one time. The survey was administered to all participants immediately following the posttest.

Sample 1 computer users completed the computer lab activity using the RedShift software running on *Windows 3.1* platform. The groups each took their turn on a single IBM-compatible computer with a pentium processor and 16 megabytes of memory. The computer was equipped with a 15-inch SVGA color monitor, a mouse, and a CD-ROM drive.

Sample 2. As described above, this sample consisted of two sections of a physical science class. Both sections had recently completed an instructional unit in which Moon phases and eclipses were studied. For convenience, the experiment was run on each section during its own regular class time. First, the pretest was administered to all students attending class that day. Immediately following the pretest, the computer groups reported to the computer lab together to work on the activity. Four computers were set up in one room and all four groups completed the activity simultaneously with the investigator standing by to help only with technical problems. Sample 2 computer users completed the computer lab activity using the RedShift 2 software running on Macintosh platform. Time required for the groups to finish ranged from 32 minutes to 43 minutes.

While the computer groups were engaged in their activities, the video group watched the video under the supervision of their course instructor. Following the 21-minute video presentation, participants were given the opportunity to watch all or part of the video again. All participants declined this opportunity but several did ask some questions following the video. These questions related to the Moon's rotation and to the availability of the RedShift computer program, both of which were answered by the instructor. Participants received no additional instruction with respect to Moon phases and eclipses following their respective treatments. The posttest and attitudinal survey were administered to all participants two days later.

Data Collection Methods. All participants recorded their answers to pretest and posttest questions on scantron forms (bubble sheets) for automated scoring. Each answer form was individually checked for completion and erasures. After automated scoring, each answer form was again visually checked for scoring errors. Survey responses were also recorded on scantron forms and tallied automatically. Every effort was made to insure against scoring errors.

Instruments and Analysis

Description of Testing Instruments

Pretest. The pretest (Appendix C) contained 32 multiple choice questions. Some pretest items were developed by the investigator based on problem areas and misconceptions commonly encountered in teaching. Other items were gleaned from various astronomy textbooks. Several items with diagrams were adapted from the testing instrument developed by Dai and Capie (1990) in their investigation of misconceptions about the Moon held by preservice teachers in Taiwan. All items on the pretest had multiple-choice responses.

The test questions can be classified into nine categories based on the specific concept tested. These categories and the pretest questions corresponding to each are listed in Table 1 (for the complete pretest, see Appendix C).

Table 1

Pretest Questions by Category

Category description	Question number
1. The Moon's orbit and its reflection of light	1,4,7,27
2. Distances between the Sun, Earth, Moon and their relative sizes	3,5,6,12,15
3. Relating Moon phases to Sun, Earth and Moon positions	13,14,16-18,22,23
4. Identifying the cause of the Moon's phases	2,21
5. Identifying the different Moon phases in diagrams	8,9,10
6. Identifying Solar and Lunar eclipses in diagrams	30,32
7. Predicting the appearance of the Moon or Earth from different viewing locations	24,25,28,29,31
8. Associating solar or lunar eclipse with a particular Moon phase	19,20
9. Predicting the time elapsed between different Moon phases	11,26

Seventeen of the questions contained computer-generated graphics. It was hoped that, after seeing the computer simulations, participants would be better equipped to answer questions in which the concepts are graphically depicted. An example of a pretest question from category 5 (Identifying the Different Moon Phases in Diagrams) is shown in Figure 1.

(Question 8) Which of the following Moon diagrams is known as "first quarter?"

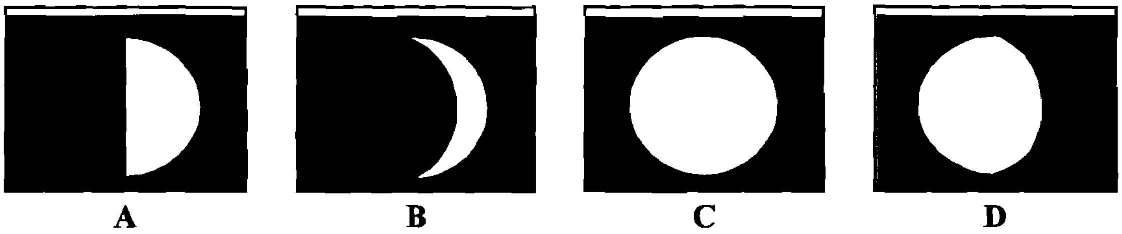
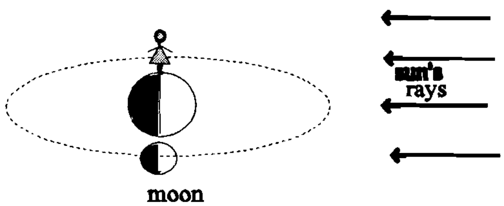


Figure 1. Test question from category 5, Identifying the different Moon phases in diagrams.

Five questions were designed to test each participant's knowledge of the distances between the Sun, Earth, and Moon and the relative sizes of these bodies (category 2). These relationships are partly responsible for causing the Moon phases and eclipses (see question 15 of the Pretest in Appendix C).

Several of the RedShift simulations give the viewer a perspective of the Earth-Moon based outside the Moon's orbit. This helps the viewer understand why the Moon appears as it does when viewed from Earth. With this in mind, several questions were designed to test the student's ability to predict the appearance of the Moon or Earth from different viewing locations (category 7). One such question is shown in Figure 2.

(Question 28) In the following diagram, an observer is standing on the north pole of earth and looking toward the moon. Note the direction of the sun's rays.



Which view will the observer see?

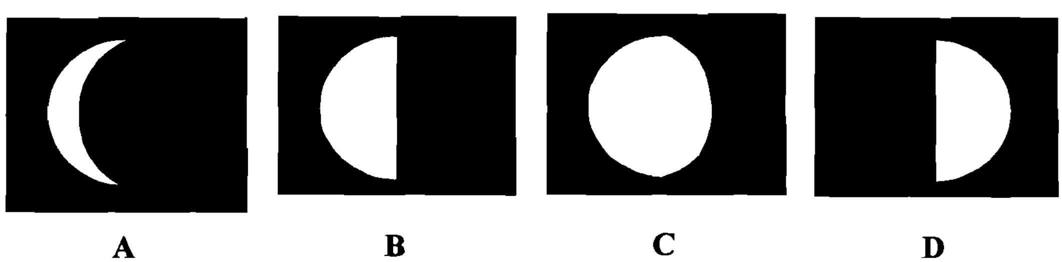


Figure 2. Pretest question from category 7, Predicting the Appearance of the Moon or Earth from Different Viewing Locations.

Posttest. The posttest contained the same questions as the pretest, but the orders of both the questions and answer choices were rearranged. This was done to help reduce recognition of the questions and answers by the participants and to prevent them from giving the same answers as on the pretest without at least thinking about the question first.

Attitude Questionnaire. The questions given to participants in the attitude questionnaire are given in Table 2. They have been abbreviated from those in the original survey to save space (see Appendices E and F for surveys in their original forms). Participants were instructed to respond to each question by selecting one of the following terms: strongly agree, agree, not sure, disagree, or strongly disagree.

Analysis

Pretest and posttest performance. Two standard *t*-test procedures were used to analyze student test performance. This strategy is supported by the findings of Boneau (1960) who showed that the *t*-test is "extremely accurate despite the fact that the assumption of homogeneity of variances and normality of the underlying distributions are untenable" (as cited in Downie, 1970, p.182).

To answer research question 1, pretest and posttest scores of each experimental group were subjected to a standard *t*-test for correlated data. The computer and video groups in Sample 1 were each tested in this manner. The two classes of preservice teachers in Sample 2 were lumped together to form a single computer group and a single video group which were each tested.

To answer research question 2, gain scores of the two experimental groups were compared using the *t*-test for independent samples. For each *t*-test, an α level of 0.05 was selected for rejection of the null hypothesis. All t-tests were performed using KWIKSTAT 4.1 produced by Texasoft in Cedar Hills, Texas. When testing the means of independent groups, automatic corrections are made for non-equality of variance. All t values are given for the appropriate degrees of freedom.

Table 2

Items from Attitude Questionnaire

Items from Attitude Questionnaire
My experience was enjoyable.
I was happy with my role in the computer group.
I would like to use the RedShift program.
I would prefer using RedShift alone rather than with a group.
I would prefer a group size of two rather than three.
I now have better understanding of Moon phases/eclipses.
I had some questions about Moon phases/eclipses which were answered during the treatment.
I now have a better mental picture of what happens as the Moon goes through its phases/eclipses.
I better learned the names of the Moon's phases.
Moon phases and eclipses are interesting and I enjoy learning about them.

Only the scores of those participants who finished all phases of the experiment were included in the analysis. Since all participants were instructed to write their student I.D. number on each of their test forms, this determination was easily made.

Attitude survey. In order to simplify the analysis of the survey as well as the reporting of results, the questionnaires of computer group participants from both samples were lumped together, as were those of the video group participants. In doing this, the assumption was made that even though some differences existed between the two samples, these differences would not significantly affect their attitudes regarding the treatment.

The total number of responses to each choice (strongly agree, agree, etc..) was tabulated for each experimental group. Then the number of "strongly agree" and "agree" responses were lumped together and taken generally as "agree." The same was done with "disagree" and "strongly disagree." This too was done to simplify the analysis and the reporting of results. These numbers were then converted to percentages. The percentages of participants who gave a "not sure" response were omitted from the analysis.

Item analysis. In order to identify those specific concepts on which either experimental treatment was particularly effective, a before-and-after analysis of each test item was performed using the chi square test for correlated proportions. This was done by using a computer spreadsheet to tally all participant responses and to calculate two quantities for each experimental group. Quantity “a” was the number of participants responding correctly to an item on the pretest and then responding incorrectly to the same item on the post-test (negative change). Quantity “b” was the number of participants responding incorrectly to an item on the pretest and then responding correctly to the same item on the post-test (positive change). The spreadsheet was then used to calculate the quantity $(a - b)^2$ divided by $(a + b)$ for each item. According to Downie (1970), this quantity is equal to χ^2. It is also equal to z^2 in tests involving only one degree of freedom. A z-score of 1.96 ($\alpha = .05$) was selected as the minimum value indicating significant change.

Participants' responses to selected distractors were also examined. A distractor is an incorrect answer choice designed to distract attention from the correct answer. When one distractor is chosen by a disproportionate number of participants, it may be an indication of a misconception held by the participants. Lightman and Sadler (1993) used a similar but more complex statistical criterion to identify misconceptions from distractor responses. For each question on which posttest performance improved significantly, a spreadsheet was used to tally the number of responses to each distractor item on the pretest and the posttest. Those distractors chosen a disproportionate number of times were identified. A chi square analysis was then performed on pretest and posttest responses for each distractor to determine whether any significant reduction in the selection of that distractor had occurred on the posttest ($\alpha = .05$).

CHAPTER 4

ANALYSIS AND PRESENTATION OF RESULTS

This chapter has three main sections. In section one, the pretest and posttest scores are reported and analyzed in order to answer the two research questions. First, the results of the *t*-tests for repeated measures are used to answer Research Question #1: "Will either method of using *RedShift* result in significant test gains?" Then the gain scores of the two experimental groups in each sample are statistically compared in order to answer Research Question #2: "Which of the two methods will result in the greater test gains?" In section two, the results of the attitude surveys are reported. The survey provides information about the attitudes of the participants toward their experience and their perceptions of the treatment's effectiveness. In section three, results of the item analysis are reported. Test items on which either of the experimental groups made significant gains are presented. This analysis complements the *t*-test analysis by showing more precisely the types of concepts affected most by the RedShift treatment. It also leads to certain conclusions about the characteristics of RedShift which contribute to its effectiveness.

Results of Test Score Analysis

Pretest Score Distributions

The distributions of pretest scores are shown in Figure 3. It is readily apparent that the scores of Sample 2 participants are more normally distributed while the scores of Sample 2 participants are negatively skewed. This is most likely due to the fact that

Sample 1 participants were enrolled in an astronomy course and received more classroom instruction on Moon phases and eclipses than did Sample 2 participants. The astronomy course was also more intensive, meeting 4 hours per day. Also, the scores for Sample 1 are so high as to leave little room for improvement, indicating that the difficulty of the pretest may not be sufficient to allow for appropriate gains on the posttest.

Another noticeable difference appears between the computer and video group pretest scores in both samples. The variability of these scores, as indicated by the standard deviation, is smaller for both video groups. Since the posttest scores (see Figure 4) exhibit the same type of difference, it is probably due to random differences between the two groups.

Examination of Pretest and Posttest Scores by Sample

Pretest and posttest score statistics for all groups are shown in Table 3.

Table 3

Pretest and Posttest Score Statistics by Group

group	*N*	*M* (Pre)	*SD*	*M* (Post)	*SD*
Sample 1 (computer)	13	23.5	5.6	24.4	6.0
Sample 1 (video)	11	25.7	5.0	27.0	4.5
Sample 2 (computer)	24	19.8	5.3	22.1	5.6
Sample 2 (video)	21	21.3	3.4	23.7	4.2

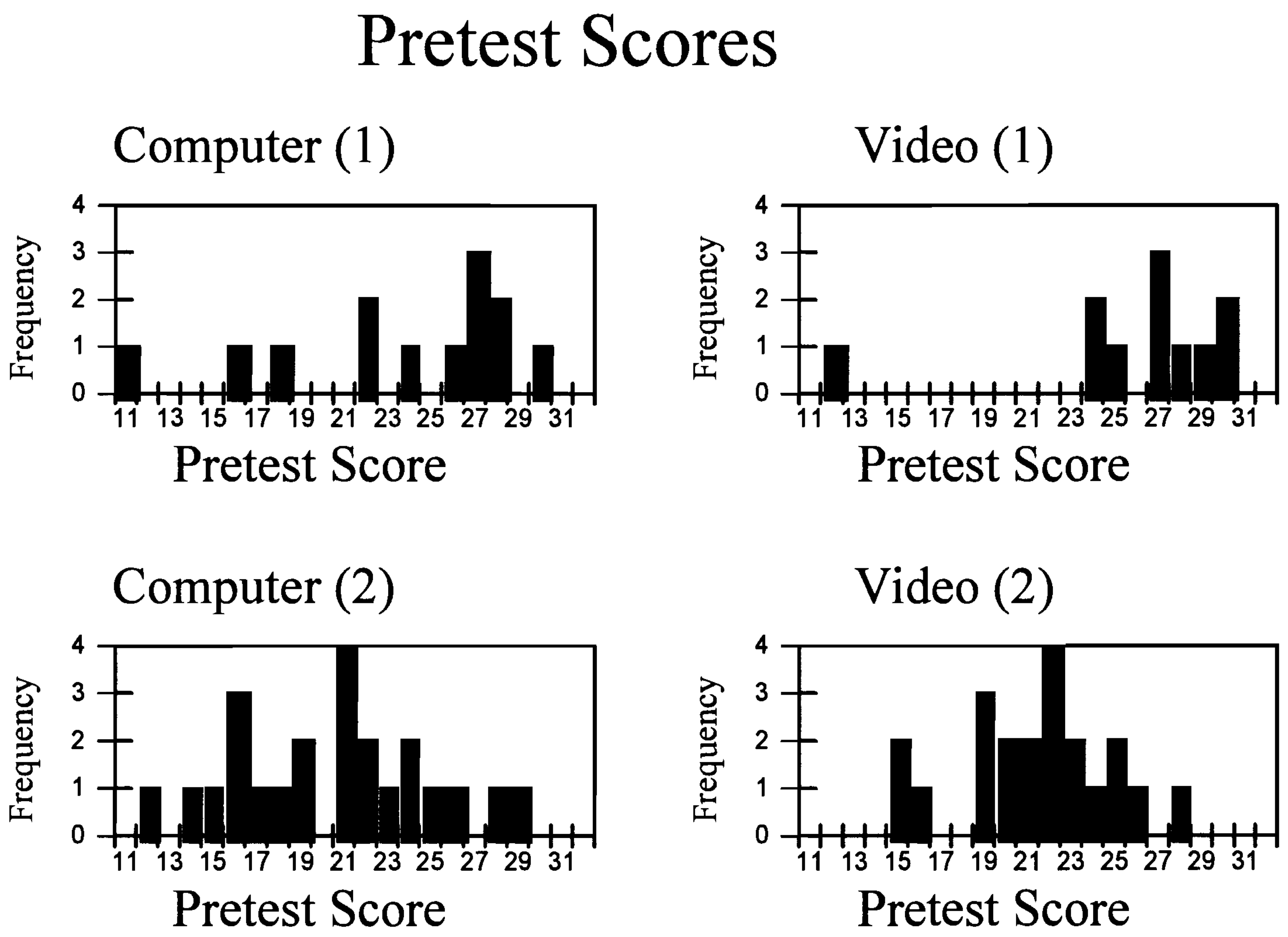


Figure 3. Pretest score distributions for all groups.

In null hypothesis form, the first research question can be stated "There will be no difference in the pretest and posttest performance of the participants." As shown in Table 3, each group showed an increase in its mean raw posttest score. A paired *t*-test was used to compare the pretest and posttest scores of each participant by group. In Sample 1, the increase of 0.9 exhibited by the computer group was not significant ($t(12) = 1.02, p<0.33$). For the video group however, the difference in mean scores of 1.3 was significant ($t(10) = 3.82, p<0.003$). In Sample 2, both the computer group and the video group exhibited significant improvement on the posttest ($t(23) = 2.89, p<0.008$) and $t(20)=4.91, p<0.001$ respectively). Therefore, both forms of the RedShift treatment resulted in significant posttest gains and the null hypothesis is rejected. It should be noted, however, that in none of groups do the posttest scores exceed the pretest scores by a very large amount. The largest gain was 2.4, exhibited by the video group in Sample 2. Though it was a significant improvement, it represents an increase of only about 11%.

The posttest score distributions for the four groups are shown in Figure 4. One can readily see that in both samples, the video group scores are more negatively skewed than those of the computer group. This difference is more pronounced in Sample 1, where the video group gained significantly on the posttest but the computer group did not.

Group Differences in Mean Gain Scores

In null hypothesis form, the second research question can be stated "There will be no difference in the gain scores of the computer and video groups." To test this hypothesis, each participant's gain score was calculated. The resulting sets of gain scores for the computer and video groups were compared using a *t*-test for independent groups.

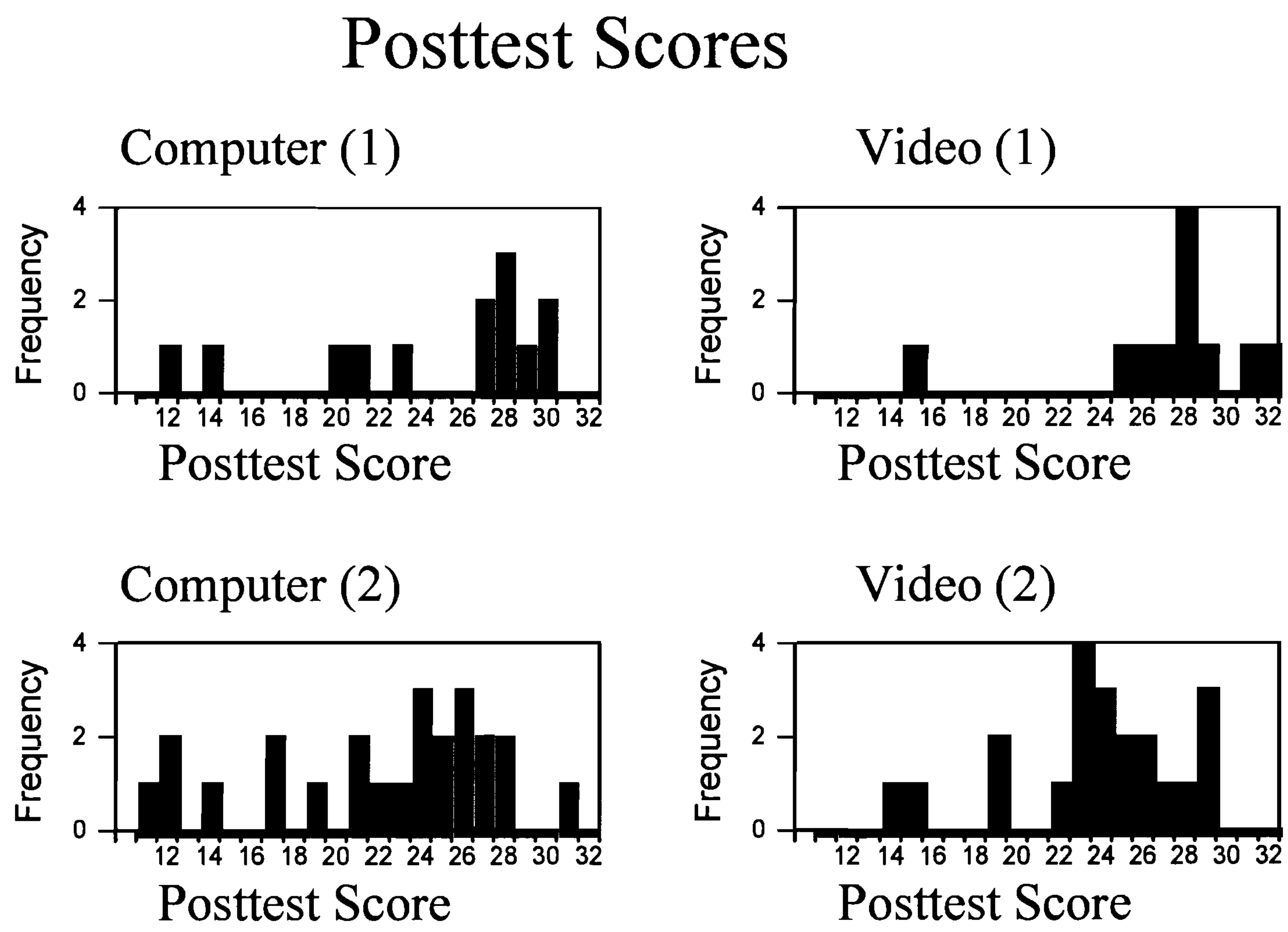


Figure 4. Posttest score distributions for all groups.

In Sample 1, the difference in mean gain scores of 0.4 was not significant ($t(16) = 0.48$, $p = 0.64$). In Sample 2, the difference in mean gain scores was an even smaller 0.1, also not significant ($t(37) = 0.10$, $p = 0.92$). Based on these results, the null hypothesis cannot be rejected. The conclusion can then be drawn that neither form of the RedShift treatment used in this study was better than the other in helping participants improve their posttest scores. However, as will be shown subsequently, the two treatments did differ in the type of test questions impacted. Gain score statistics for each of the four treatment groups are summarized in Table 4.

Table 4

Gain Score Statistics by Group

group	*N*	*M*	*SD*
Computer (Sample 1)	13	0.9	3.00
Video (Sample 1)	11	1.3	1.10
Computer (Sample 2)	24	2.3	3.88
Video (Sample 2)	21	2.4	2.22

Results of the Attitudes Survey

Results of the survey are reported in Table 5. The questions in the table have been abbreviated from those in the original survey to save space (see Appendices E and F for surveys in their original forms). For simplification, the percentages given in the table represent the sum of the "strongly agree" and "agree" responses for each group. When a question did not apply to one group, no response data is given for that group.

There are some striking differences between the two groups. The participants in the computer group enjoyed the experience more than did those in the video group (91% vs. 38%). Computer users, more than the video viewers, reported that using RedShift helped them to learn the names of the Moon phases (74% vs. 44%). More computer users than video viewers claimed to have a better understanding of Moon phases (82% vs. 60%) and eclipses (88% vs. 66%).

There were also some similarities in the responses of the two groups. A large percentage of the computer and video participants reported having a better mental picture of what happens during Moon phases (97% and 88%) and eclipses (94% and 84%). More than half of both groups said they found the topics interesting and enjoyable to learn about (79% and 66%). In addition, most of the video viewers said they would like the opportunity to actually use the program.

Analysis of Test Items

In this analysis, test questions were identified on which there was significant improvement on the posttest by either of the treatment groups ($\alpha = .05$). The analysis was accomplished by performing the chi square test for correlated proportions. To simplify the handling of the data, the data from the computer groups from both samples were combined, as was the data for the two video groups. In the analysis, eight test items were identified. The numbers of correct responses to each of the eight items on pretest vs. posttest are shown in Table 6 by group (see complete pretest in Appendix C). These numbers are shown only as indicators of the magnitude of the participant responses before and after treatment. Chi square calculations were performed using individual participant data not shown (see Methodology, Chapter 3).

Table 5

Attitude Questionnaire Response Summary

Survey Questions (in abbreviated form)	Computer	Video
My experience was enjoyable.	91%	38%
I was happy with my role in the computer group	85%	
I would like to use the RedShift program		69%
I would prefer using RedShift alone rather than with a group	32%	
I would prefer a group size of two rather than three	50%	
I now have a better understanding of Moon phases	82%	60%
I now have a better understanding of eclipses	88%	66%
I had some questions about Moon phases which were answered during the treatment	68%	44%
I had some questions about eclipses which were answered during the treatment	76%	59%
I now have a better mental picture of what happens as the Moon goes through its phases	97%	88%
I now have a better mental picture of what happens during an eclipse.	94%	84%
I better learned the names of the Moon's phases	74%	44%
Moon phases and eclipses are interesting and I enjoy learning about them	79%	66%

Table 6

Participant Responses to Selected Test Items

	Total number of correct responses			
	Computer ($N = 37$)		Video ($N = 32$)	
Item Number	Pre	Post	Pre	Post
1	**24**	**31**	24	27
4	**24**	**31**	23	27
6	31	28	**25**	**30**
16	28	30	**26**	**30**
17	28	29	**26**	**31**
19	25	30	**20**	**27**
29	**24**	**32**	27	27
32	16	17	**10**	**17**

Note. Numbers in bold indicate the group for which the change was significant.

One interesting thing about these results is that on none of the eight questions did both groups exhibit significant improvement. To understand this disparity, it is helpful to examine the types of questions in Table 6 (see Appendix C for the complete pretest). Questions 1 and 4, composed strictly of text, required participants to recall the correct value for the Moon's orbital period (about one month). Only the computer group participants improved on these two questions. Question 6 was also composed of text and required students to recall the relative sizes of the Sun, Moon, and Earth and rank them in order of increasing size. The video group improved on question 6. Questions 16 and 17 included a graphic diagram of the Moon's orbit around Earth and participants were asked to match a given Moon phase with the Moon's correct orbital position. Only the video group showed improvement on these two questions. In question 19, the lunar eclipse is defined and participants are asked to match it with the correct lunar phase (full phase). The computer group was the only group to improve significantly on question 19. Question 29 included a distant view of the Earth and Moon with the direction of the Sun's rays indicated. Participants were asked to determine the Moon's appearance for an Earth-based observer. Answer choices were also of a graphic nature. Only the video group improved on question 29. On question 32, participants were required to identify the correct diagram of the Moon during a lunar eclipse from a set of four choices. Only the video group improved on question 32.

From this analysis, it seems that the computer group performed better on questions involving basic recall of facts while the video group performed better on questions involving visual and spatial skills. The exception to this trend is that the computer group did perform better on question 29 which involved visualization and spatial skills. Possible reasons for these differences are discussed subsequently in chapter 5.

Five of the eight questions in Table 6 each had one distractor which was chosen disproportionately more than the others on the pretest. These distractors, along with the total number of participants choosing each one, are shown in Table 7. Chi square analysis was then performed on the number of pretest and posttest responses for each of the five distractors. This was done to determine whether a significant reduction in the selection of any distractor had occurred on the posttest ($\alpha = .05$).

Table 7

Responses to Distractor Items on Test

	Total responses to distractor			
	Computer (N = 37)		Video (N = 32)	
Distractor no.	Pre	Post	Pre	Post
1(d)	11	6	8	5
4(a)	9	5	8	5
6(c)	2	5	6	2
19(d)	**7**	**1**	**5**	**0**
32(c)	**4**	**0**	3	0

Note. Numbers in bold indicate the group for which the change was significant.

Analysis of distractor responses showed that about 28% of participants initially thought that the Moon orbits the Earth once each day (questions 1 and 4). Following treatment, the number of participants giving this response was reduced by about half. On the basis of this data, it seems quite possible that the participants initially held the mistaken notion that the Moon orbits the Earth once each day, perhaps confusing the daily motion of the Moon (due to Earth's rotation) with its orbital motion. The treatments each contained a very clear simulation of the Moon orbiting Earth. The fact that this orbit requires 29.5 days was also stated very clearly in the narration portion of each treatment.

When answering question 6, participants in general had no trouble ranking the Sun as the largest body, but there was some initial uncertainty about whether the Earth or Moon was larger. On the pretest, 18% of the video group thought the Earth was the smallest of the three bodies, choosing the order "Earth-Moon-Sun" (choice "c"). On the posttest, only 6% of the video group gave that response. The relative sizes of the three objects was addressed in the simulations where the Moon is clearly shown as being smaller than Earth. It is therefore surprising that in the computer group, there was actually a decrease in the number of correct responses from 84% on the pretest to 76% on the posttest.

The change in pretest and posttest performance on question 19 indicates that the treatment helped many participants see the relationship between a lunar eclipse and a full Moon. The distractor chosen most frequently on the pretest was "a lunar eclipse can happen during any one of the Moon's phases." The percentage of computer group participants giving this response dropped from 19% to 3%. For the video group, the decrease was from 16% to 0%. These reductions were both significant at the .05 level, strongly indicating that the simulations helped participants in both groups realize that lunar eclipses can happen only during the full Moon phase of the lunar cycle.

The RedShift simulations helped students to identify a lunar eclipse. Before seeing the simulations, most participants could not distinguish the lunar eclipse diagram from the distractor diagrams (question 32). Following the simulations, the percentage of video viewers who chose the correct diagram rose from 31% to 53%, significant at the .05 level. For the computer users, the percentage rose from 43% to 46% (not significant). The distractor diagram most resembling a lunar eclipse was choice “c”, depicting a waxing crescent Moon. On the pretest, 11% of computer users and 9% of video viewers chose this distractor. On the posttest however, it was not chosen at all. This reduction was significant at the .05 level for the computer group only, but it is clear that following treatment, this distractor was abandoned by both groups.

CHAPTER 5

DISCUSSION

Overview

The efficacy of computer-based instruction and its effects on attitude, the effects of simulations on spatial ability, misconceptions in astronomy, and cooperative learning have all been investigated in recent years. The present study intersects all of these issues and raises interesting questions. In this chapter, the results of the study are discussed within the context of some of this related research. An effort is made to identify those attributes of RedShift which contributed to its effectiveness. Implications for practical implementation of RedShift in the instruction process are also discussed. Suggestions are given for the improvement of the present study as well as for continued research in this field. Finally, the author gives his views, along with the views of others, on the future of computers in education.

Impact of Treatment on Student Test Scores

The first research question was "Will either method of using RedShift result in significant test gains?" In three of the four groups involved in the study, the treatment resulted in significant gains ($\alpha = .05$). The gains observed were small from a practical standpoint, but were nevertheless statistically significant. Considering the duration of the treatment and the fact that students entered the study already having considerable knowledge about the topics being investigated (as indicated by high pretest scores), these results can be used to strengthen the assertion that the computer planetarium RedShift can be used as a viable supplement to astronomy instruction at the college level.

The second research question was "Which of the two methods will result in the greater test gains?" When test performance alone is considered, the RedShift instruction was effective at increasing posttest scores in both the computer activity and in the videotape method. Neither method was superior to the other. However, as noted in chapter 4, the two groups were different in the types of questions on which they improved. The computer group improved on questions involving basic recall of facts while the video group did better on questions involving visual and spatial skills. It is possible that while participants in the computer group were busy working the controls and reading the script, they caught most of the factual information in the script but were not able to concentrate on the RedShift simulations. On the other hand, the video group participants were assigned no tasks other than to watch the simulations. Perhaps because of the limited length of the video and their concentration on the visual aspects, the factual information in the narration may not have been as well retained by them.

The common attributes of both treatments were the graphic simulations of the Sun, Earth and Moon and their motions and the instructional narration. Both treatments gave approximately the same level of benefit. It would seem that the simulations along with the accompanying instructional narration, rather than the format in which they were received (computer vs. video), constitute the key elements of each treatment. These results are important for at least three reasons. First, they have important implications for the instructor who may have limited time and resources. With the additional time, hardware, and supervision required for the group activity, the most efficient use of computer planetarium programs may be in creating simulations which to be recorded for later viewing. Second, the simulations can be delivered in a variety of settings and by a variety of technologies. They can be used both during class and outside of class to supplement instruction. They can be recorded either on videocassette or as computer data and viewed using either a TV or a computer. With access to the Internet becoming more available to students, video clips showing RedShift simulations could be incorporated into an instructor's web page and viewed when convenient for the individual student. Third, other astronomy topics such as planetary configurations or Kepler's laws of planetary motion are demonstrated well with RedShift. Though this study was limited to concepts surrounding Moon phases and eclipses, it is possible that the effectiveness of RedShift would extend to these other topics as well.

Student Attitudes Toward Treatment and Subject Matter

The computer lab activity treatment was generally a more positive experience for the participants than was the video treatment. The two groups also displayed different attitudes toward the subject matter. The computer users reported a greater interest in Moon phases and eclipses and found them more enjoyable to learn about.

These findings regarding student attitudes toward the computer and the subject matter are consistent with results from previous studies. In their analysis of 51 independent studies, Kulik, Bangert, and Williams (1983) found that students taught on computers developed more positive attitudes toward using the computer as well as toward the subject matter than the students who did not use computers. Similar results with regard to computer based instruction were obtained by Kinzie, Sullivan, and Berdel (1988).

The attitudes of students toward the instructional medium presumably affects their level of motivation to use that medium. This in turn would be expected to affect such variables as frequency and duration of use. From this standpoint, the computer lab activity may have an advantage over the videotape method. If students enjoy using the program, they may be willing to spend more time using the computer to learn about astronomy (assuming that students have access to computers and ample time to perform the activities). This issue is important and any efforts to monitor the effects of attitude toward computer-based learning on long-term academic success would almost certainly be worthwhile.

Attitude toward the subject matter is also a critical element in the learning process. The fact that using the RedShift program seemed to promote a better attitude toward the topics being studied is certainly a benefit that is hard to ignore. This association is an interesting one and worthy of further study.

The contribution of RedShift to student attitudes is difficult to explain. Today's students are accustomed to the involvement of computer technology in many aspects of their lives. Even though there are still many students who are not comfortable using computers, for many others, using computers in the learning process seems the natural thing to do.

Impact on Spatial Skills

One of the keys to understanding Moon phases and eclipses is being able to adequately visualize the Solar System from different perspectives. One assumption that motivated this study was that the RedShift simulations could be used to help students improve their visualization and spatial skills. Significant posttest gains are one indication that this may have occurred. However, as the analysis of test items indicated, the video group seemed to benefit more from the visual and spatial aspects of the RedShift instruction. One suggested explanation for this is that the design of the computer activity may have limited the ability of the participants to concentrate on the simulations.

Another possible indication of spatial skills benefit is that participants believed that it did happen. The attitude survey showed that both experimental groups overwhelmingly reported that seeing the simulations helped them to form better mental pictures of what happens as the Moon goes through its phases and of what happens during eclipses (see Table 5).

Impact on Misconceptions

The present study confirmed earlier findings by Dai and Capie (1990) with regard to certain misconceptions about the Moon held by “non-science” education (presumably elementary education) majors. For example, in their survey, they found that many pre-service teachers were unable to correctly predict the lunar phase from a specified lunar day. Similarly, more than one quarter of preservice teachers in the present study were initially unable to associate a specified lunar phase with the correct orbital position of the

Moon (see pretest questions 16-18, Appendix C). Following treatment with RedShift, this number was reduced by half.

The relationship between orbital position and lunar phase was specifically addressed in the RedShift instruction. One of the simulations shows the Moon from two different perspectives simultaneously as the Moon progresses through its orbit (see Description of RedShift Instruction, Appendix D). Participants watched this animation for over five minutes in the video and computer users spent considerably more time on this section of the activity.

Another misconception was revealed in the present study by responses to test questions related to the Moon's orbital period. More than one quarter of the participants initially thought that the Moon orbits Earth once each day. Following treatment, that number was reduced by nearly one half. Lightman and Sadler (1993) also found this misconception to be prevalent among the 1400 high school astronomy students in their study. Participants in the study by Dai and Capie (1990) exhibited a similar idea with the response that the time between two consecutive mornings on the Moon was 24 hours (p.12). In Dai and Capie's study, no treatment was given to reduce the misconception. In Lightman and Sadler's study, the misconception was diagnosed prior to taking a high school astronomy course. Following the course, the misconception still persisted. Since misconceptions are noted for their resistance to permanent change, a possible extension of the present study might involve testing the students again after several months to determine whether misconceptions had returned.

Both Dai and Capie (1990) and Lightman Sadler (1993) identified the common misconception that Moon phases are caused by the Earth's shadow on the Moon in a large portion of their participants. Likewise, in this study, a similar response was given by one quarter of the participants both before and after treatment. This idea is apparently quite resilient to instruction. Perhaps this notion should have been challenged directly in the narration portion of the treatments. This might have caused students to examine their explanation of Moon phases more closely. As more knowledge about misconceptions is collected, perhaps the most effective instruction will be that which causes students to examine their concepts and test them.

Limitations of the Study and Suggestions for Further Research

In considering these findings, it is important to note several things. First, one must consider the low frequency (one episode) and the short duration of the treatments. In other studies involving computer-based instruction, participants received multiple exposures, ranging over weeks and months, and with more dramatic results (e.g., White and Horwitz, 1987). Second, the specific group design of the computer activity may present some cause for concern. Due to the distinct role assigned to each, the three members of each group had a different experience. The duties required of each group member in operating the mouse, giving the instructions, or reading the script may have been distracting. Participants who watched the videotape, on the other hand, were given no additional duties to perform and may have been better able to concentrate.

While logistical and other considerations placed certain limits on the experimental procedures that could be used in this study, future studies of this nature might be enhanced by some additional procedures. First, drawing the sample from a single, large astronomy course section would help to ensure that all participants receive the same classroom instruction prior to treatment. Sample 2 was actually a combination of two different course sections taught by two different instructors. Second, the issue of unequal variance in the two experimental groups should be addressed. Since random group assignment does not insure equal variance in factors such as reasoning ability, this possible threat could be identified by administering a test of reasoning ability prior to the experiment, as others have done (e.g., Williamson and Abraham, 1995). Third, the duration of the treatment (20 minutes for the video viewers group and 45 minutes for the computer activity group) in the present study limits the claims that can be made in favor of RedShift. Applying multiple treatments of various duration over the course of a semester might provide a more realistic view of its potential to stimulate change in students' concepts.

The question of how much freedom to give the student when using the computer should also be of interest to teachers when using computer lab activities. In this study, participants were told exactly what to do when using the RedShift program. A more engaging activity might be one in which students are given only the learning objectives and then required to accomplish the objectives by navigating the RedShift program on their own with little or no guidance. In this kind of activity, students might have the freedom to explore the assigned topics (or topics chosen by them) from a variety of angles and to utilize more of the program's features. Collecting data on the amount of time spent by the students on each topic might also provide useful information.

Another issue which might be explored is the role of each person in a computer group learning activity. It would be helpful to know such things as whether the person running the mouse learns more than the person reading the script or the person reading the instructions. It might also be interesting to experiment with groups of different sizes, say two members per group verses three or four. These are all questions which could be explored within the context of this type of study.

Summary and Outlook

The ever-growing influence of computer technology in students' lives may be part of the reason why participants in the computer group seemed to have a higher level of confidence in the treatment they received than did the video viewers. They more frequently reported having a better understanding of Moon phases and eclipses as a result of using the program. However, as already shown, both methods provided about the same amount of help to the students. It seems that many computer group participants, and perhaps the video participants as well, placed an unwarranted amount of trust in the learning experience provided by RedShift.

This should not be surprising given the increasingly elevated status of the computer in education. Many leaders in the education community have noticed this tendency to expect so much from computers and are concerned about it. One example is Alfred Bork, professor emeritus of Information and Computer Science at the University of California at Irvine. In his view, "a major problem with learning today is the increasing tendency to confuse information with learning" (Bork, 1997, p.70). When using the computer for instruction, Bork and others (e.g. Kozma and Johnston, 1991) maintain that careful distinction must be made between the role of the computer as a conveyor of information and it's role as a powerful tool for facilitating better learning.

So how should computers be used to more effectively facilitate learning? In Bork's view, far too little emphasis has been placed on the computer's potential to provide a highly interactive learning environment, that is, one capable of determining the learning needs of each student and responding with the appropriate help and direction.

While many conservative viewpoints (e.g. Clark, 1994) tend to downplay the uniqueness of the computer as an instructional medium, many others (e.g. Bork, 1997; Cartwright, 1994) see the computer as dominating the future of education. Despite the concerns related to the use of computers in learning, the fact is that computer technology will continue to play an important role in the classrooms of our schools and colleges. All instructors and administrators are going to have to face this issue head on. To insure a future for computer technology that is more productive than the past, educators must work together to explore ways to maximize the contribution of the available computer technology.

While computer-based instruction may not be the solution to all of the problems facing education, it's true potential has hardly been tapped. All educators must become acquainted with the vast body of research related to computer-based instruction. They must work together to identify effective and appropriate software which meets their instructional goals and they must work to secure funding for that software.

Educators must continue the efforts of pioneers like Alfred Bork who have begun to develop the next generation of educational software which is truly interactive. This software, while taking years to develop, will be capable of continuously monitoring students' progress and constantly adapting to the needs of the individual learner. Because of meticulous programming, it will anticipate possible responses by the student and be able to respond accordingly. Through global networks, it will be able to track an individual student's learning over time and distance. Students will communicate with the computer by voice because this is their most natural and efficient language (Bork, 1997).

Though the RedShift simulations did help students gain a better grasp on Moon phases and eclipses, the program itself does not share many of the characteristics of the ideal software of the future. It is not programmed to provide a complete course in astronomy and should not be used as such. It does, however, offer a unique opportunity to investigate astronomy for those willing to learn to use it. In terms of its wide variety of graphic images and accurate simulations of orbits and positions, it provides a good foundation on which to develop more sophisticated, interactive software. The possibilities for adapting RedShift to the classroom of the future abound.

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APPENDIX A

Interview Questions (May, 1995)

I. Phases of the Moon

I will be tape recording our interview. No one other than me will ever hear the tape. I will make a transcript of the tape and destroy the tape. I will publish a report of my study, but no one will ever be able to link you to my study because your identity will be confidential. I really appreciate you being a part of my study. You are making a valuable contribution to the field of education.

The purpose of this interview is to find out how much you know about several phenomena in astronomy which involve the earth, sun, and moon. Please do not worry about whether or not your answers are correct. I simply want you to answer each question honestly. Tell me what you think. I realize you may have never studied this topic nor really thought about these questions before. That's okay. Just answer to the best of your ability. If at any time you do not understand a question, please tell me and I will try to explain the question so that you do understand it.

1. An important topic in astronomy is the study of the moon and the moon's phases. Tell me what you know about the moon's size and distance from the earth.

2. Would you call the moon a planet, a star, or if neither of these, what would you call it?

3. Why is the moon bright? Does it give off its own light?

4. Please describe for me the movement of the moon relative to the earth:

5. Please describe for me the movement of the moon relative to the sun:

6. If you were to watch the moon on a clear night for several hours, what kind of motion, if any, do you think you would see?

7. If you were to observe the moon for several nights in a row at the same time each night, do you think it would

    a. look the same each night? If not, how would it change?

    b. appear in the same place each night? If not, how would it change?

8. Do you understand what the expression "the phases of the moon" means? If so, please tell me what you know about the moon's phases.

9. Here are some photographs showing the different phases of the moon. How many of these phases can you identify?

10. For each phase you identified, can you tell me what factors cause the moon to appear in that phase?

11. Do you feel you could make a drawing which accurately shows the positions of the sun, earth, and moon during each phase that you identified? If so, please do that now with the paper and pencil provided.

12. One phase not shown in these photographs is the "new" moon. Can you describe the appearance of a new moon and name some factors which cause this phase?

13. Do you feel you could make a drawing which accurately shows the positions of the sun, earth, and moon during a new moon? If so, please do that now with the paper and pencil provided.

14. To sum up, could you give me a general explanation of why the moon goes through its phases?

15. Another important topic in astronomy is the topic of "eclipses." There are two main types: the solar eclipse and the lunar eclipse. Could you describe a solar eclipse for me? A lunar eclipse?

16. What factors cause an eclipse to occur?

17. Do you think there is a correlation between the occurrence of an eclipse and the phase of moon? If so, what is that correlation?

18. About how often do you think eclipses occur?

19. Can eclipses be seen from anywhere on earth? If not, from where can they be seen?

20. Is there anything else you know about moon phases or eclipses that you haven't had a chance to tell me?

Now I'm going to have you work some exercises on a computer program about astronomy. The answers to many of the questions I've asked you will be covered as you work the program. Feel free to ask questions or discuss as we go along. When we're finished with the program, I'm going to ask you these same questions again.

APPENDIX B

MOON PHASES/ECLIPSES ACTIVITY
(For RedShift 2 - IBM or Macintosh)

Instructions: Follow this outline step by step. One person should operate the computer controls. One person should read the instructions in *italics*. The third person (narrator) should read the narration, which is in **bold** and enclosed in quotation marks. It is important for the narrator to see the computer presentation as well as everyone else in the group. The narrator should feel free to watch what's happening on the screen before reading his or her narration lines. All three members of the group should coordinate their parts so that each member gets to see all the action. Communicate with each other.

1. *Load the RedShift 2 program.*

2. **"Today, we will be viewing computer simulations of Moon Phases and Eclipses. We will be using a computer program called "RedShift 2"to generate these simulations. "**

3. *Select "Main Program". From the "Information pull-down menu, select "Tutorials." Scroll down to "The Phases of the Moon" (#3) and select it by clicking.*

4. *Close the "Instructions" window.*

5. **"The Moon is Earth's nearest neighbor in space, having an average distance from Earth of about 384,000 kilometers. The Moon orbits the Earth every 29.5 days. During the course of this 29.5 day orbit, if we watch closely, we can see the Moon's appearance gradually change as it goes through its different phases."**

6. *Click the forward play arrow on the control time panel. After one complete cycle, stop the simulation by clicking the stop button on the control time panel.*

7. **"This sequence of phases has been observed and recorded since man first began watching the sky. We call it the "Lunar Cycle" and today we are going to study it from several different reference points."**

8. *From the pull-down"Information" menu , select "Photo Gallery."*

9. *From the list of items in the Photo Gallery, select "The Moon" by clicking on the text. You will now see a list of moon photographs from which to choose. Choose the photo "A Gibbous Moon", it should be the first one on the list. You should then see a full-screen photo of the moon.*

10. **"Here we see an enlarged, photographic image of the Moon. You can see that it has the shape of a circle flattened on one side. This is known as the "gibbous" phase. During this presentation, you are going to discover exactly what causes the Moon to appear in the gibbous phase and its other phases as well. You will also discover how the lunar cycle is related to eclipses. Let's see a quick overview of the lunar cycle to refresh your memory of the Moon's appearance."**

11. *Return to the Tutorial by clicking the "return" icon and closing the Photo Gallery window.*

12. *Advance the Moon's phases in steps by repeatedly clicking the forward slow-play arrow on the control time panel (it's the button immediately to the right of the stop button).*

13. **"This is a simulation of the Moon's appearance as it progresses through its phases. Each incremental change represents one Earth day. Notice how the lighted portion seems to begin on the right and gradually spreads to the left. Remember, the purpose of this investigation is to discover exactly what causes the Moon to go through this cycle of phases and how this cycle is related to eclipses."**

14. *Stop the Moon by clicking the stop button, located on the control time panel.*

15. *From the "Information" menu, select "Tutorials."*

16. *Scroll down to find "Moon's Orbit Around Earth" tutorial and select by clicking the icon.*

15. *Close the "Instructions" dialog box.*

16. *Move the "Controls" panel (the long one) to the bottom of the screen so that most of it is hidden out of sight. Also move the "Settings" panel to the bottom of the screen and tuck it mostly out of sight. By keeping these panels mostly hidden when not in use, you provide a larger viewing area on your computer screen.*

17. *Hit the space bar to hide the menu bar at top of screen. This also gives a greater viewing area on the computer . You may keep this menu bar hidden whenever it is not in use.*

18. *Click the forward play button on the control time panel to start the moon in motion.*

19. **"We are seeing a simulation of the moon's orbit around Earth. We are positioned about 794,000 km from Earth, well outside the moon's orbit. Both the moon and Earth are magnified by a factor of 20 so that we can see them from this**

distance."

20. *Click the stop button and hit the space bar to reveal menu bar.*

21. *From the "Display" menu, select "planets." In the "planet filter" dialog box, under the "phases" options, select "dithered" and click "OK."*

22. **"The simulation now shows Earth and the moon as they actually appear in space: one hemisphere is always dark and the other one is always illuminated by the sun."**

23. *Click the forward play button to start the moon in motion.*

24. **"Keep in mind that we are witnessing the Moon's orbit from outside the Earth-Moon system. Try to imagine how the moon would look from the viewpoint of an earth-based observer."**

25. *Stop the moon and bring the control panel up so that it is entirely in view.*

26. **"This simulation allows us to change our viewing location. We can choose to view the Earth-Moon system from virtually any location. Let's go to a point directly above the earth."**

27. *Click the "A" button on the position selector and set the moon in motion again.*

28. **"Notice that the Moon orbits the Earth in a counter-clockwise direction when viewed from above the Earth's north pole. In order to get a better view, we can zoom out a little."**

29. *Stop the moon. Bring up the "settings" panel, change the "zoom" setting from 1 to 0.7, then click "OK." Tuck the panel away and restart the moon.*

30. **"To remind ourselves where the Sun is located, we can enlarge it."**

31. *Stop the moon and from the "Display" menu, choose "Planets". Change the sun's display setting from "Hide" to "Image" by clicking the fourth dot to the right of the word "Sun." Do not click the "HIDE" button. Now change the Sun's magnification to 100 by sliding the blue marker using the mouse. Click "OK." Now start the moon again.*

32. **"Because of magnification, the system is not shown "to scale." In this simulation, the important thing to notice is the manner in which the moon reflects the Sun's light and how it would appear to an Earth-based observer. Notice that the hemisphere facing the sun is always illuminated. Also note that the Sun appears to**

be orbiting the Earth. It appears this way because this computer program "locks" the Earth in the center of our view."

33. *Stop the moon and from the position selector, click on "O" and restart moon.*

34. **"We have changed our viewing location so that we are now positioned outside the Earth's orbit looking in toward the Sun."**

35. **"We should ask ourselves 'Why do the Earth and Moon appear dark?' It is because from our viewing location, we cannot see their illuminated hemispheres. We only see the hemispheres that face away from the sun."**

36. *Stop the Moon. From the position selector choose "I" and restart moon.*

37. **"Now we are positioned inside the earth's orbit, looking outward away from the sun. We see only the illuminated hemispheres of the Earth and Moon."**

38. *Stop the Moon. From the position selector choose "B" and restart the moon.*

39. **"If we move to a point directly below the Earth's south pole, the moon appears to orbit clockwise. Its orbit has not changed, rather our perspective has changed. Let's take a closer look at the Moon's phases."**

40. *From the "File" menu, select "Open Movie." From the "Drives" dialog box, select the drive containing the RedShift CD-ROM, usually the "D" drive. In the "Directories" box, double-click the "D" drive. Double-click the "Movies" directory, then double-click the "illustr" sub-directory. From this subdirectory, open the file "phase.mov" by double-clicking on it.* [IF YOU ARE USING A MACINTOSH, DO THE FOLLOWING INSTEAD: From the "Information" menu, select "Dictionary of Astronomy." Select "index" and type in the word "phase" then press "enter." You will see a diagram of the Earth and Moon with a movie icon on it. Click the icon and proceed to step 41]

41. **"This animation provides two views of the Moons. The larger view is from an earth-based position. The smaller view shows the Moon's orbit around the Earth and the Sun's rays. We see the Moon here appearing in its Last Quarter phase. Note the Moon's position in relation to the Sun and Earth. The three bodies form a right angle. "**

42. *Now click and hold down on the slow play button located in the bottom right corner of the movie window. As soon as the phase changes to "Crescent", release the mouse button.*

43. **"The Moon has moved into the Waning Crescent phase. When the moon is progressing from Full to New, we say it is waning, or growing dimmer from day to day. Notice how the Moon's position has changed. It is now moving into the region between the Earth and Sun."**

44. *Now click and hold down the slow-play button and allow the moon to progress to the New phase then release.*

45. **"The Moon has moved fully into the region between the Sun and Earth. The Moon appears in the same general vicinity of the sky as the Sun during this phase. It is for this reason that we do not actually see the Moon in its New phase. Sometimes the three bodies come into perfect alignment. When this happens, the Moon blocks part of the Sun's light, casting a shadow on portions of the earth. Observers within that shadow witness a 'Solar Eclipse.'"**

46. *Now click the slow-play button and allow the moon to progress to the Crescent phase then stop the movie.*

47. **"As the Moon moves out of the region between the Earth and Sun, we begin to see its thin crescent. This phase is called "Waxing Crescent." When the Moon is progressing from New to Full, we say it is waxing, or growing brighter from day to day."**

48. *Now click the slow-play button and allow the moon to progress to the First Quarter phase then stop the movie.*

49. **"We call this phase First Quarter because we can see one quarter of the Moon's surface. It is the shape of a half-circle and is often called a 'half moon.' Notice the position of the Moon in relation to the Sun and Earth. The three bodies again form a right angle."**

50. *Now click the slow-play button and allow the moon to progress to the Gibbous phase then stop the movie.*

51. **"As the Moon continues to orbit, it moves into the region opposite the Sun from Earth. It takes on a 'lop-sided' appearance known as the Gibbous phase. Since it has not yet reached its Full phase, it is called Waxing Gibbous."**

52. *Now click the slow-play button and allow the moon to progress to the Full phase then stop the movie.*

53. **"When the Moon has moved into a position directly opposite the Sun from Earth, we can see its entire illuminated hemisphere. The Moon is at its brightest and we call it a Full Moon. Sometimes, the three bodies come into perfect alignment. When this happens, the Moon actually enters the Earth's shadow and we call that a 'Lunar Eclipse.'"**

54. *Now click the slow-play button and allow the moon to progress to the Gibbous phase then stop the movie.*

55. **"As the Moon moves out of the Full phase, it again takes on the irregularly shaped 'Gibbous' phase. This time, however, the Moon is decreasing in brightness and we say it is in the 'Waning Gibbous' phase. Notice its position in relation to the Sun and Earth."**

56. *Now click the slow-play button and allow the moon to progress to the Last Quarter phase then stop the movie.*

57. **"As the Moon completes its orbit, it again enters the 'Last Quarter' phase. The entire cycle took about twenty-nine and one-half days. Let's watch the cycle again."**

58. *Using the slow-play button, allow the movie to play through one complete cycle of phases. Then stop the movie and close the movie window.*

59. *From the "Information" menu, select "Guided Tours" and then choose the Guided tour titled "The Phases of the Moon."*

60. *Close the "Instructions" window.*

61. **"Now we're seeing the Moon just as it would appear to the casual observer on Earth. Let's watch it again as it goes through its phases. See if you can identify each different phase. Remember that each incremental change represents one Earth day"**

62. *After one complete cycle, begin naming the phases throughout the second cycle. Stop the moon.*

63. *On the "Settings" panel, change the "zoom" setting to "1" and click "OK."*

64. *From the "Display" menu, select "Planets." Magnify the Moon and Sun each by a factor of 10 by sliding the blue marker as before. Click "OK."*

65. *Now start the Moon by clicking the play button on the controls panel.*

66. **"We have zoomed out to get a wider field of view. We can see the sun as it passes**

behind the Moon during the New Moon phase. Notice that the Sun and Moon appear to pass very close to one another at New Moon. They may even overlap slightly. This is due to the fact that in this simulation, the Moon and Sun have both been enlarged by a factor of 10 to enhance visibility. In reality, sometimes the Moon does pass directly in front of the Sun, blocking a portion of its light. We call this a Solar eclipse. This program can also simulate a Solar eclipse. Let's take a look at one."

67. *Stop the Moon. From the "Information" menu, select "Guided Tours." Scroll down to find Guided Tour #15, "Annular Eclipse of the Sun" and select it. Close the "Instructions" window.*

68. *From the "Settings" panel, change zoom to 35 and click OK.*

69. *On the "Controls" panel, change "time step" to 10 minutes. Start the eclipse.*

70. **"This simulation shows the Solar eclipse of May 10, 1994. The view is from the Midwestern United States. This eclipse was visible from most parts of the United States."**

71. *As soon as the eclipse is over, stop the moon.*

72. *From the "Display" menu, choose "Planets" and select "No Phase" from the "Phases" box. Click "OK."*

73. **"Now we'll view the eclipse in reverse. We will also run the simulation with the entire Moon illuminated, though in reality the hemisphere facing earth is dark."**

74. *Click the "reverse play" button to run the eclipse in reverse. When the eclipse is finished, stop the moon.*

75. *From the "Information" menu, select "Guided Tours". Scroll down to find Guided Tour #17, "Total Eclipse of the Moon" and select it.*

76. **"As mentioned earlier, the Earth, Sun, and Moon may also come into alignment during the Full Moon phase. When this happens, earth-based observers see a Lunar eclipse. This simulation shows the total Lunar eclipse of November 29, 1993 as seen from the United States. While Solar eclipses can only be seen from certain locations on Earth, Lunar eclipses can be seen from any location where the sun has set and the skies are clear. Let's watch this eclipse."**

77. *Start the eclipse by clicking the play button.*

78. **"The lighter portion of Earth's shadow is called the "penumbra." While in the penumbra, the Moon is slightly darkened but still visible." The darker portion of the Earth's shadow is known as the "umbra." While in the umbra, the moon is much darker yet still visible. It may even take on a golden hue, as light filtered by Earth's atmosphere reaches the moon and reflects back to Earth."**

79. *When the eclipse is finished, stop the Moon.*

80. **"We will now travel to the Moon and watch the same eclipse again. Keep in mind that during a Lunar eclipse, the Earth is between the Sun and Moon. What would an observer on the Moon see? You're about to find out."**

81. *From the "Information" menu, choose "Guided Tours" Scroll down to find Guided Tour #18, "Total Eclipse of the Sun, observed from the Moon" and select it.*

82. *Close the "Instructions" window. Start the eclipse by clicking the play button.*

83**"While Earth-based observers see the Moon slip into the Earth's shadow, a Moon-based observer sees the Earth covering the Sun's disk. This is a "solar eclipse." The Phases option is turned off so that you can see the relative sizes of the Earth and Sun. Though the Earth is much smaller than the Sun, it appears much bigger. This is because the Earth is so much closer to the Moon than is the Sun."**

84. *When the eclipse is completed, stop the moon. From the "Display" menu, choose "Planets." In the "Phases" box, select "dithered" and click "OK."*

85. **"Let's watch that eclipse in reverse, this time with phases turned on."**

86. *Click the reverse play button. When the eclipse is finished, click the "stop" button.*

87. **"Let's review the Solar and Lunar eclipses. "**

88. *From the "File" menu, choose "Open Movie. " Select the CD-ROM drive. Go to the "Movies" directory. Go to the "illustr" sub-directory and double-click on the file "eclipse.mov"* [IF YOU ARE USING A MACINTOSH, DO THE FOLLOWING INSTEAD: From the "Information" menu, select "Dictionary of Astronomy." Select "index" and type in the word "eclipse." You will see a diagram of the Sun, Earth, and Moon with a movie icon on it. Click the icon and proceed to step 89]

89. **"This animation shows the locations in the Moon's orbit where eclipses occur. As it plays, notice the moon's location during each eclipse."**

90. *Play the movie by clicking and holding down the slow-play button. Pause when the Moon reaches "Lunar Eclipse"*

91. **"We see that the Lunar Eclipse occurs at the Full Moon position. That is the only place in its orbit where it can pass into the Earth's shadow"**

92. *Now play the movie to the end. It will end at the Solar Eclipse*

93. **"We see that the Solar Eclipse occurs at the New Moon position. That is the only place in its orbit where it can pass directly between the Earth and the Sun."**

94. *Play the movie completely through again using the slow-play button.*

95. **"You probably wonder why eclipses don't occur at each Full and New Moon. Eclipses require precise alignment of the Sun, Earth, and Moon. Because the Moon's orbital plane is slightly tilted in relation to the Earth's orbital plane, that precise alignment rarely occurs"**

96. *Play the movie completely through again using the slow play button.*

97. **"This concludes today's simulations of the Moon Phases and Eclipses. "**

APPENDIX C

MOON PHASES QUESTIONNAIRE

Directions: After reading each question, circle the letter of the answer that you agree with the most. Mark the corresponding letter on your green scantron form. If you are not completely certain which answer to mark, just mark the one that seems most right to you. After you have marked an answer, please DO NOT change that answer.

1. Which statement is true about the Moon's orbit?
   a. the Moon orbits the Earth once each week
   b. the Moon orbits the Earth once each year
   c. the Moon orbits the Earth about once each month
   d. the Moon orbits the Earth once each day

2. Suppose that one evening the Moon appeared as in Figure 1. Then, a few days later, it appeared as in Figure 2.

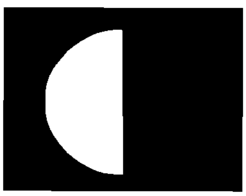


Figure 1

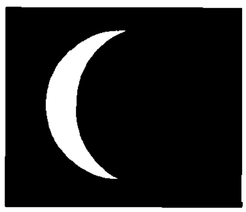


Figure 2

What is the most likely explanation for this change in appearance?
   a. a cloud is blocking the light
   b. a planet is blocking the light
   c. the Earth is blocking the light
   d. the moon's position in its orbit has changed, revealing more of its dark side

3. How many "Suns" would fit in a straight line between the Earth and the Sun ? (In other words, what is the distance from the Earth to the Sun in Sun diameters?)
   a. less than ten
   b. about one hundred
   c. about one thousand
   d. much more than any of these

4. About how long does it take the Moon to orbit the Earth?

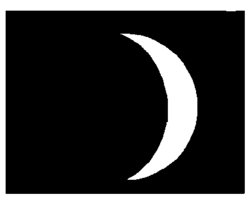
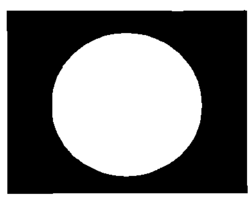
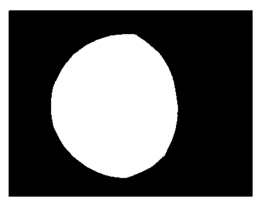
a. a day
b. a week
c. a month
d. a year

5. About how far is the Moon from Earth?
   a. 40 km (25 miles)
   b. 400 km (250 miles)
   c. 4000 km (2,500 miles)
   d. 400,000 km (250,000 miles)

6. Which correctly lists the Earth, Moon, and Sun in order from **smallest to largest**?
   a. Moon, Sun, Earth
   b. Moon, Earth, Sun
   c. Earth, Moon, Sun
   d. Earth, Sun, Moon

7. What is the main source of the light we see coming from the Moon?
   a. it is produced by the Moon
   b. the Moon reflects light from the Sun
   c. the Moon reflects light from the Earth
   d. the Moon reflects light from the stars

8. Which of the following Moon diagrams is known as "first quarter?"

A B C D

9. Which of the following Moon diagrams is known as "waxing crescent?"

A B C D

10. Which of the following Moon diagrams is known as "waning gibbous?"

A B C D

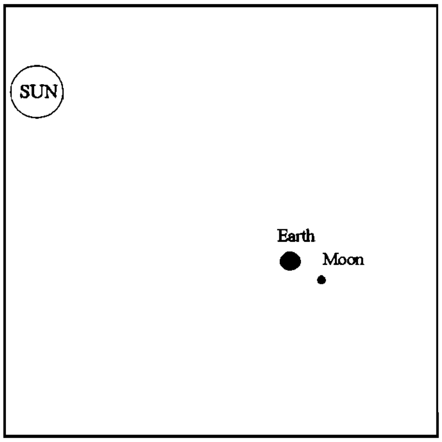
11. Suppose that on Saturday night, the moon appears as in figure A. How much time will elapse before it next appears as in figure B?

A B

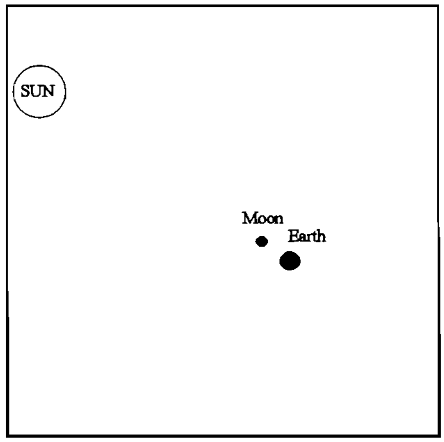
a. a few hours
b. about one day
c. about one week
d. much longer than one week

12. Which is closer to the Earth?
a. the Sun
b. the Moon
c. both the Sun and the Moon are about the same distance
d. sometimes the Sun is closer and sometimes the Moon is closer

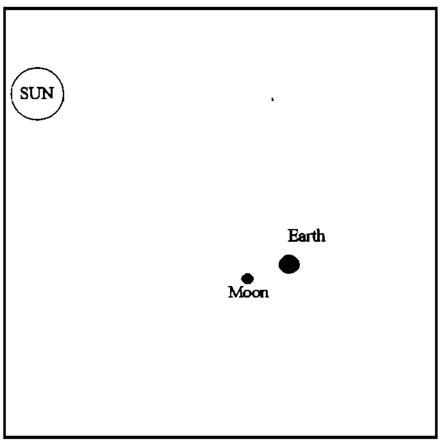
13. Which of the following diagrams shows the correct positions of the Sun, Earth, and Moon during a full Moon? The view is from above the plane of the solar system (above Earth's north pole).



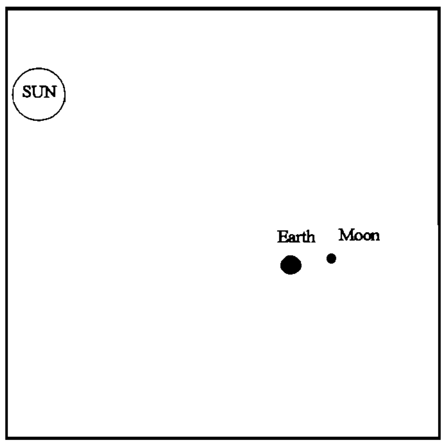
A



B

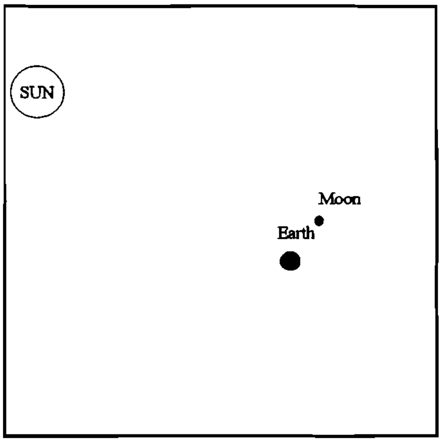


C

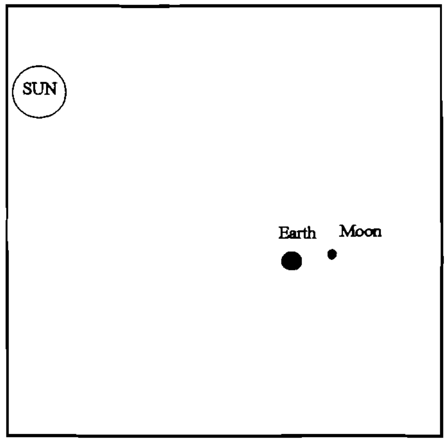


D

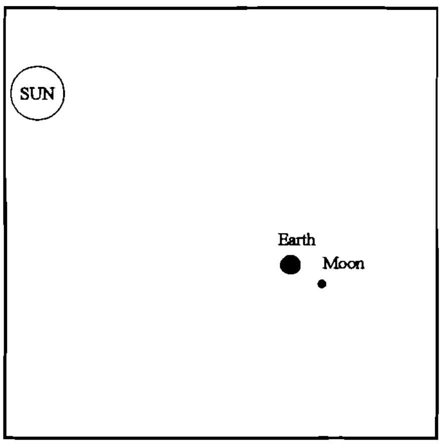
14. Which of the following diagrams shows the correct positions of the Sun, Earth, and Moon during the last quarter phase? The view is from above the plane of the solar system (above Earth's north pole).



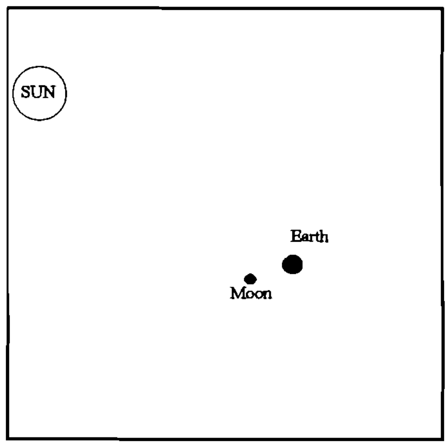
A



B

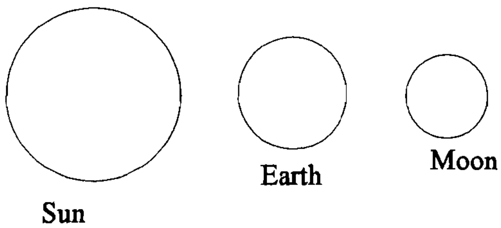


C

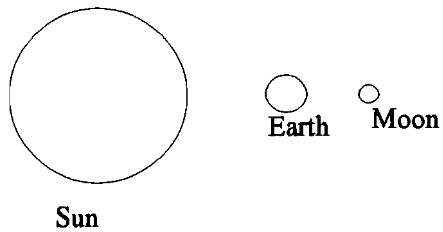


D

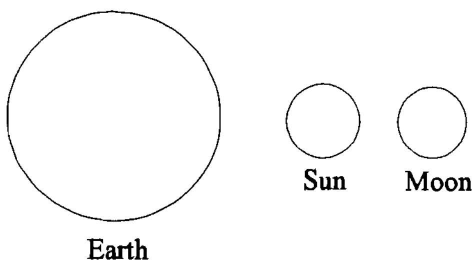
15. Which of the following diagrams **most** correctly shows the relative sizes of the Sun, Earth, and Moon?



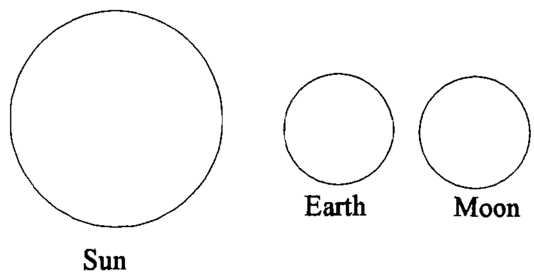
A



B

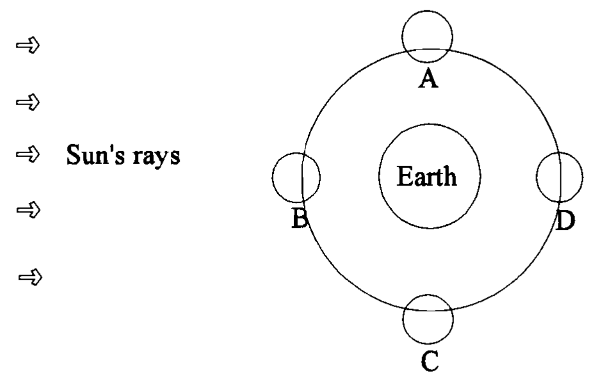


C



D

Please refer to the following diagram when answering questions 16, 17, and 18. (Sizes are not to scale)



16. In the above diagram, which Moon position (A,B,C,or D) corresponds to the full Moon phase?

17. In the above diagram, which Moon position (A,B,C,or D) corresponds to the new Moon phase?

18. In the above diagram, which Moon position (A,B,C,or D) corresponds to the first quarter phase?

19. A "lunar eclipse" occurs when the Moon passes through the shadow cast by Earth. During which phase of the Moon, if any, is a lunar eclipse most likely to happen?

a. first quarter
b. full Moon
c. new Moon
d. a lunar eclipse can happen during any one of the Moon's phases

20. A "solar eclipse" occurs when the Moon passes directly between the Sun and the Earth. During which phase of the Moon, if any, is a solar eclipse most likely to happen?

a. first quarter
b. full Moon
c. new Moon
d. last quarter
e. a solar eclipse can happen during any one of the Moon's phases

21. Which is the best explanation for the cause of the Moon's phases?

a. The rotation of the Moon on its axis causes it to go through its phases.

b. The Moon's orbit causes the relative positions of the Sun, Earth, and Moon to constantly change, producing the different phases

c. Sometimes, an object such as a planet or a cloud passes between the Earth and the Moon, blocking out some of that reflected light and causing the Moon to appear in different phases.

d. During each revolution, the Moon passes into the Earth's shadow. It is the Earth's shadow on the Moon that causes it to appear in the different phases.

22. If you observe the Moon rising in the east as the Sun is setting in the west, then you know that the phase of the Moon must be:

a. new
b. first quarter
c. full
d. third quarter

23. In which phase or phases do the Earth, Sun, and Moon come closest to being in a straight line?

a. Full Moon only
b. First quarter and Last quarter
c. New Moon only
d. Both full Moon and new Moon

24. Paris is about 90° east (one-fourth of the way around the world) of Chicago. On a night when people from Chicago see a first-quarter Moon, what would the people in Paris see (assuming clear skies)?

a. a new Moon
b. a first-quarter Moon
c. a full Moon
d. a last-quarter Moon

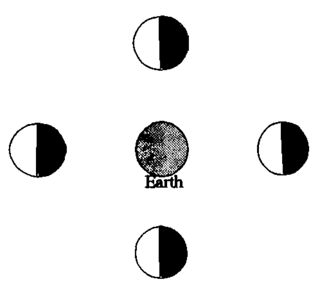
25. Suppose that during the Moon's new phase, astronauts landed on the side of the Moon facing the Earth. Which of the following would be true?

a. Earth would appear full to the astronauts
b. Earth would appear in the first quarter phase
c. Earth would appear in the last quarter phase
d. Earth would not be visible to the astronauts

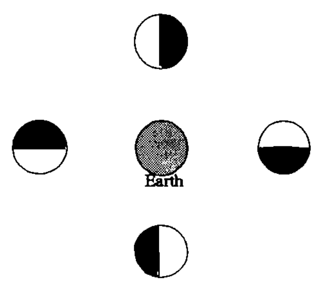
26. If the Moon was full last Saturday, what phase will it be in this Saturday?

a. new
b. first-quarter
c. last-quarter
d. any of the above, depending on other factors
e. none of the above

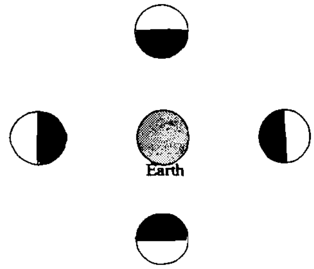
27. Which of the diagrams below correctly shows the way in which the moon reflects light during the course of its orbit?(Assume the sun is shining from the left on each diagram)



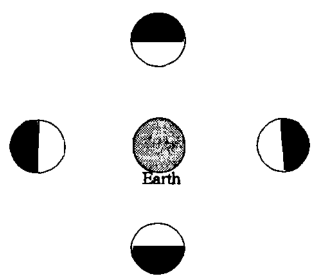
A



B

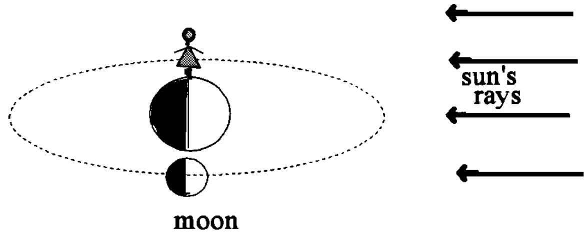


C



D

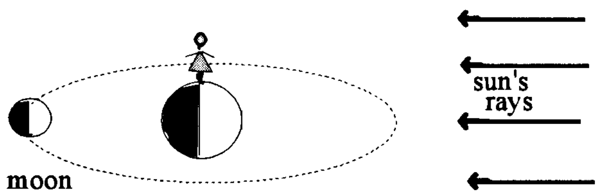
28. In the following diagram, an observer is standing on the north pole of earth and looking toward the moon. Note the direction of the sun's rays.



Which view will the observer see?

A B C D

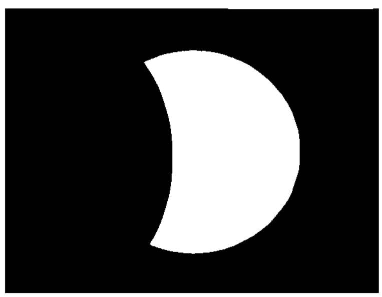
29. In the following diagram, an observer is standing on the north pole of earth and looking toward the moon. Note the direction of the sun's rays.



Which view will the observer see?

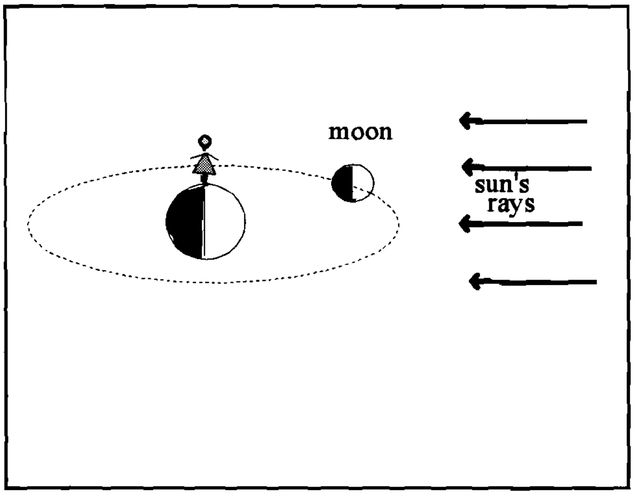
A B C D

30. Suppose that you go outside late one evening, look up at the moon, and it appears as in the following diagram. What is the best explanation for its appearance?

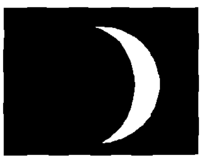


a. the sun is shining on the moon from an unusual angle
b. the moon is being eclipsed by Mars
c. the moon is entering the waxing gibbous phase, just as it does each month
d. the moon is being eclipsed by earth's shadow

31.In the following diagram, an observer is standing on the north pole of earth and looking toward the moon.
Note the direction of the sun's rays.

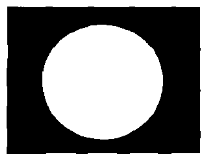


Which view will the observer see?



A

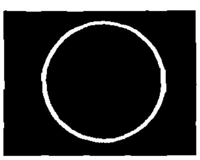
B



C

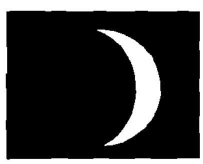
D

32. Which diagram depicts the Moon during a lunar eclipse?

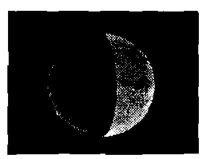


A

B



C



D

APPENDIX D

Description of RedShift Instruction

Following is a scene-by-scene description of the simulations seen by participants in both treatment groups. As described earlier, the difference in the treatments was that the computer groups used the actual computer program while the video groups were shown a video of the simulations.

Scene 1. (63 seconds) The simulations begin with a full-screen view of the Moon's image going through its cycle of phases in fast motion. The narration emphasizes the changing appearance and the length of time required for one complete lunar cycle, 29.5 days. Figure 5 shows three of the simulated images encountered in this portion of the activity.

Figure 5. RedShift simulation of the Moon in three phases: waning gibbous (left), last quarter (center), and waning crescent (right).

Scene 2. (37 seconds) A full-screen black and white photograph (from RedShift's "photo gallery") of Moon in gibbous phase is shown. The narration calls attention to the Moon's shape and tells the viewer that the purpose of the video is to help him discover the cause of the Moon's phases and how the lunar cycle is related to eclipses.

Scene 3. (52 seconds) As in scene 1, the viewer is shown a simulated Moon image going through its cycle of phases, this time a little slower. The narration calls attention to the general direction of light movement across the Moon's surface from right to left. Incremental motions take place at the rate of one each second and each represents one Earth day.

Scene 4. (26 seconds) This scene, captured in Figure 6, shows a simulated view of the Moon orbiting Earth as if seen from a distance of 794,000 km and from within the plane of revolution. Each incremental motion lasts one second and equals several Earth days. Phases are not shown (both bodies are shown fully illuminated).

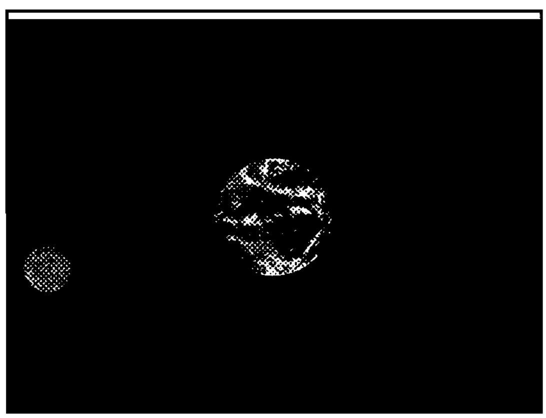


Figure 6. The Moon orbiting Earth in the plane perpendicular to the page.

Scene 5. (47 seconds) This is a repeat of the simulation in scene 4, except now the phases option is turned on (see Figure 7). This option allows the viewer to see that only half of each sphere is illuminated by the Sun at any given moment. The narration emphasizes that each body always has one hemisphere illuminated.

Figure 7. RedShift simulation of Earth and Moon with phases option turned on.

Scene 6. (39 seconds) In this scene, the viewpoint has been changed so that the observer's location is above Earth's north pole.

Scene 7. (14 seconds) The viewpoint is still from the north pole, as in scene 6, but from a greater distance.

Scene 8. (44 seconds) In this scene (Figure 8), the observer is still above the north pole, but the Sun is shown greatly enlarged so its position in relation to the Earth and Moon can be monitored as the Moon orbits Earth. In this view, one can see the relation between the positions of the three bodies and the illuminated portions of the Moon and Earth. The narration emphasizes that hemispheres facing the Sun are always illuminated.

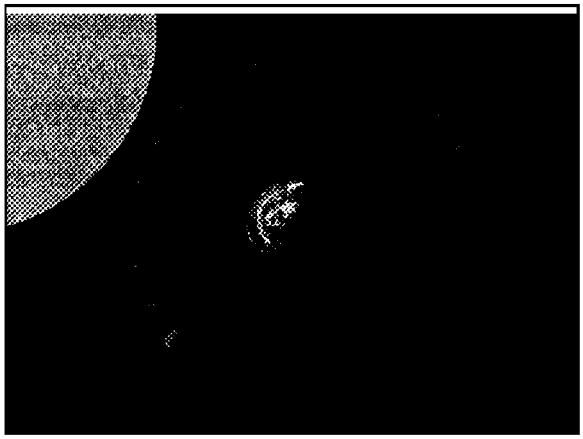


Figure 8. The Moon orbiting Earth. The Sun is enlarged so all three bodies can be seen.

Scene 9. (35 seconds) In this scene, the viewpoint is from outside Earth's orbit looking in toward Sun. The Earth and Moon appear as dark spots in front of the Sun (Figure 9). The narration emphasizes that hemispheres facing away from Sun are always dark.

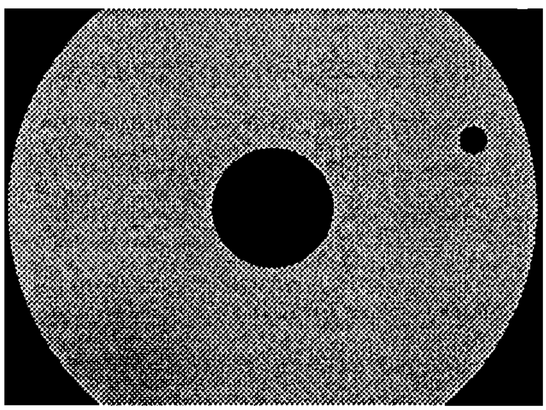


Figure 9. Earth's and Moon's hemispheres facing away from Sun are always dark.

Scene 10. (28 seconds) The viewpoint has been changed so the observer is now inside Earth's orbit looking out toward Earth and Moon. From this viewpoint, only the illuminated hemispheres of the two bodies can be seen.

Scene 11. (33 seconds) In this scene, the view is from above Earth's south pole. Both the Earth and Moon appear to orbit clockwise from this viewpoint.

Scene 12. (5 minutes 20 seconds) In this scene, the user sees an animation from RedShift's "Dictionary of Astronomy." It shows in image of the Moon progressing through its cycle of phases alongside a smaller animation window depicting the Moon's changing orbital position (Figure 10). The narration emphasizes the relationship between Moon's appearance (phase) and its orbital position. All phases are shown in sequence and named. Students in the computer group can stop, start, or replay the animation as they desire.

Scene 13. (70 seconds) This scene is essentially a repeat of Scene 3, showing a full-screen view of the Moon's image going through the cycle of phases. The narration encourages the viewer to name each phase in sequence.

Scene 14. (44 seconds) In this more distant view of the Moon (Figure 11), the Sun's image is shown passing "behind" the Moon's image during the new phase. The narration emphasizes that when solar eclipses occur, it is during this phase.

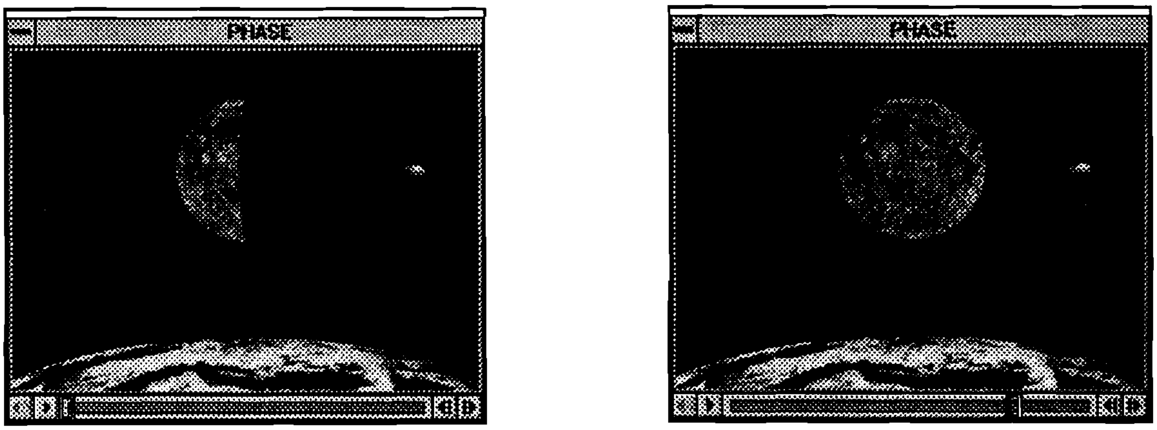


Figure 10. RedShift animation showing Moon's appearance and orbital position during last quarter (left) and full (right) phases.

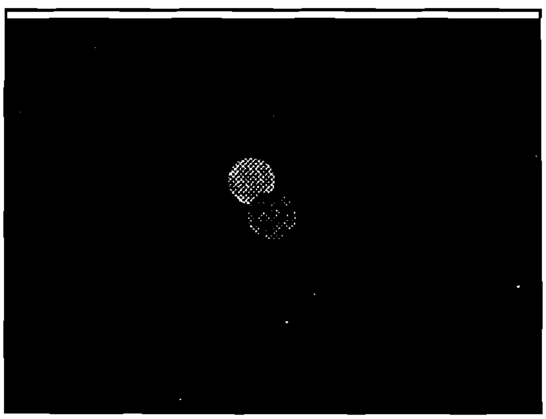


Figure 11. Distant view of Sun and Moon during the Moon's "new" phase.

Scene 15. (34 seconds) In this simulation of the May 10, 1994 solar eclipse, the Moon appears as a black disk passing in front of Sun (Figure 12).

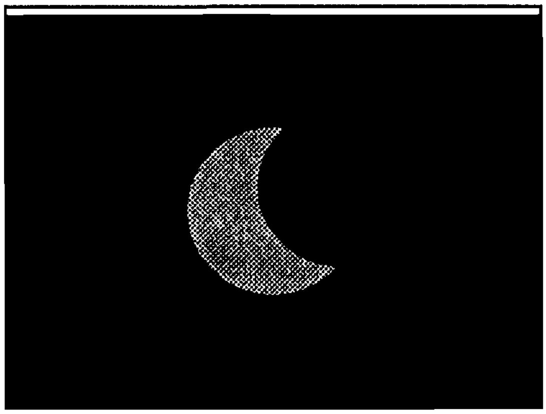


Figure 12. A simulation of the solar eclipse of May 10, 1994.

Scene 16. (33 seconds) In this scene, the solar eclipse of Scene 15 is played in reverse and with phases option turned off (showing earthward side of Moon illuminated).

Scene 17. (93 seconds) The lunar eclipse of Nov. 29, 1993 is simulated here (Figure 13). The narration calls attention to the umbra and penumbra.

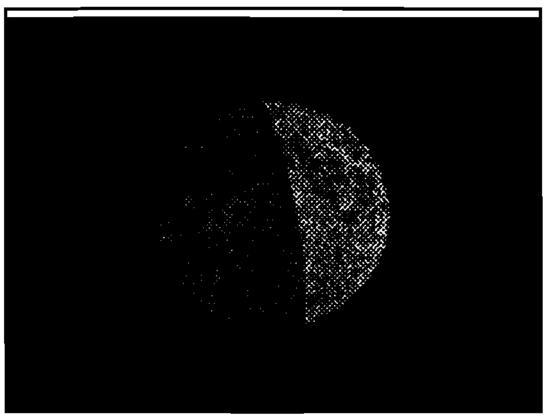


Figure 13. A lunar eclipse view showing the lighter part of Earth's shadow, the penumbra.

Scene 18. (58 seconds) In this scene, the viewer can see how the lunar eclipse in Scene 17 would appear from the viewpoint of a Moon-based observer. The Earth is shown passing in front of the Sun with phases option turned off (Figure 14).

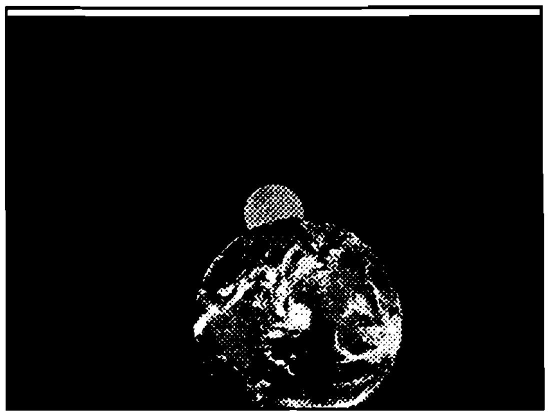


Figure 14. A lunar eclipse as viewed by a moon-based observer. Earth actually eclipses the Sun for this observer.

Scene 19. (32 seconds) The previous scene is played in reverse and with phases option turned on. Earth appears as a black disk passing in front of Sun.

Scene 20. (108 seconds) This animation from RedShift's "Dictionary of Astronomy" shows the Moon orbiting Earth. The viewpoint is from above the ecliptic plane (Figure 15). The narration emphasizes the relative positions of Sun, Earth, and Moon during solar and lunar eclipses: eclipses can only happen during the new and full phases. Also emphasized is that eclipses don't happen during every lunar cycle, but require a precise alignment of the three bodies.

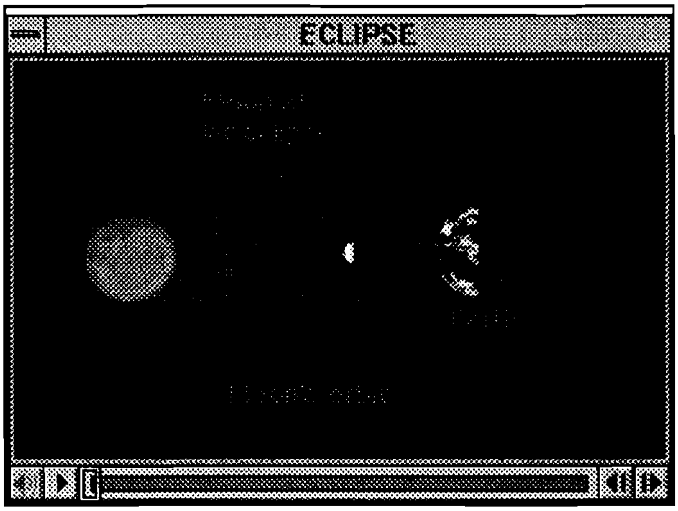


Figure 15. RedShift animation showing Moon's orbital position during eclipses.

APPENDIX E

ATTITUDINAL SURVEY FOR RedShift USERS

Instructions: Following each statement, choose A, B, C, D, or E and darken the corresponding oval on your scantron form. A = strongly agree B = agree C = not sure whether or not I agree D = disagree E = strongly disagree

1. My experience using the RedShift program with my group was an enjoyable one.

2. I was happy with my role in the group (reader, computer operator, or both)

3. I would prefer working with RedShift alone, rather than with a group.

4. I would prefer working with RedShift in a group of two, rather than three people.

5. As a result of using RedShift, I have a better understanding of the Moon's phases.

6. As a result of using RedShift, I have a better understanding of eclipses.

7. There were some questions I had about the Moon's phases which were answered during our group learning experience using RedShift.

8. There were some questions I had about eclipses which were answered during our group learning experience using RedShift.

9. Seeing the computer simulations of the Moon's phases helped me to form a better mental picture of what actually happens as the Moon goes through its phases.

10 Seeing the computer simulations of eclipses helped me to form a better mental picture of what actually happens during eclipses.

11 Using RedShift helped me to better learn the names of the Moon's phases.

12 Using RedShift helped me improve my understanding of what causes the Moon's phases.

13 Using RedShift helped me to better understand eclipses.

14 When using RedShift, I sometimes did not understand what I was seeing.

15 I find the Moon's phases and eclipses interesting and I enjoy learning about them.

APPENDIX F

ATTITUDINAL SURVEY FOR RedShift VIDEO VIEWERS

Instructions: Following each statement, choose A, B, C, D, or E and darken the corresponding oval on your scantron form.

A = strongly agree B = agree C = not sure whether or not I agree
D = disagree E = strongly disagree

1. Watching the RedShift video was an enjoyable experience.

2. I would like the opportunity to actually use RedShift computer program on my own to study the Moon's phases and eclipses.

3. As a result of seeing the RedShift video, I have a better understanding of the Moon's phases.

4. As a result of seeing the RedShift video, I have a better understanding of eclipses.

5. There were some questions I had about the Moon's phases which were answered as I watched the RedShift video.

6. There were some questions I had about eclipses which were answered as I watched the RedShift video.

7. Seeing the computer simulations of the Moon's phases helped me to form a better mental picture of what actually happens as the Moon goes through its phases.

8. Seeing the computer simulations of eclipses helped me to form a better mental picture of what actually happens during eclipses.

9. Seeing the RedShift video helped me to better learn the names of the Moon's phases.

10 Seeing the RedShift video helped me improve my understanding of what causes the Moon's phases.

11 Seeing the RedShift video helped me to better understand eclipses.

12 I find the Moon's phases and eclipses interesting and I enjoy learning about them.

13 While watching the RedShift video, I sometimes did not understand what I was seeing.

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Wesley Detrick
Signature of Author

5-15-98
Date

Effective Use of a Computer Planetarium to Improve Students' Understanding of Moon Phases and Eclipses

Title of Thesis

Signature of Graduate Office Staff

May 17, 1999
Date Received