To the Graduate Council:

I am submitting herewith a thesis written by Roberta Gomes de Souza Ayres entitled " Increased Learning of a Physical Science Concept, Simple Machines, Via an Interactive Multimedia Exhibit Compared to a Hands-on Exhibit in a Science Museum Setting." I have examined the final copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the Master of Science degree, with a major in Education.

Claudia T. Melear

Dr. Claudia T. Melear,
Major Professor

We have read this thesis and
recommend its acceptance:

Accepted for the Council:

Associate Vice Chancellor
and Dean of The Graduate School

INCREASED LEARNING OF A PHYSICAL SCIENCE CONCEPT, SIMPLE MACHINES, VIA AN INTERACTIVE MULTIMEDIA EXHIBIT COMPARED TO A HANDS-ON EXHIBIT IN A SCIENCE MUSEUM SETTING

A Thesis
Presented for the
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Roberta Gomes de Souza Ayres
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DEDICATION

This thesis is dedicated to my parents,
Roberto de Souza Ayres
and
Ana Lucia Gomes de Souza Ayres,
who have given me invaluable educational opportunities, guidance, and support.

To Christian Kasper and our Boston Victor Hugo,
without their friendship, love, and continued encouragement, I would never have reached for this moment.

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ABSTRACT

The purpose of this study was to determine whether the use of an interactive multimedia exhibit was more effective than a traditional hands-on exhibit in teaching physical science concepts in a museum setting. The Simple Machines exhibit, a permanent display at the East Tennessee Discovery Center, was used as a comparison with an interactive computer exhibit designed by the author. All elementary age students (n=104) took a multiple choice quiz before entry in the museum and again after interacting with the exhibits. A random sample was selected using numbers on tags that designated whether they would explore the traditional hands-on exhibit or the interactive multimedia exhibit. The purpose of giving visitors a quiz on the content of the selected museum exhibits was to verify how much exhibit information was learned during museum visit. The results of the study demonstrated increased learning when students interacted with a multimedia exhibit ($t = 4.976$, $p = .063$) in comparison with a hands-on exhibit ($t = 1.866$, $p = .000$). There was no significant difference in holding power between both exhibits. Moreover, both exhibits were very efficient in attracting and engaging students. The ANOVA test verified no gender differences in learning ($p = .486$) or in holding power ($p = .046$). However with a larger sample the results might exhibit a gender difference in holding power, as previous studies have suggested (Koran, Koran, & Longino, 1986; and Greenfield 1995).

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GLOSSARY

Attracting Power - the number of subjects from the target population who stop and look at an exhibit, expressed in percentages. Also explained as the ability of an exhibit to attract attention of visitors.

Cognitive Gain - the retention of a new material and the ability to grasp the meaning of that material as measured by comprehensive assessments, either written or verbal.

Demographics - the characteristics of the audience such as age, sex, race, socio-economic status, etc.

Holding Power - a measure of time spend viewing an exhibit. May be a ratio of average viewing time by uncued visitors as a fraction average viewing time by visitors who are cued (asked to study aspects of the exhibit). On other words, holding power is the average time visitors devote to exhibits.

Interaction - any movement associated with gaining better comprehension of an exhibit - stepping closer, touching, discussing and the use of senses.

Interactive Exhibit - an exhibit where the visitor controls the feedback according to their own interests and per their own responses by the hands-on exhibit and computer's program.

Mechanical Advantage - is a physics terminology that means the multiplication of force.

Minimum Viewing Time - the number of seconds necessary to look at an object, read each label, physically cover the exhibit area.

Quiz - paper-and-pencil self-reported multiple choice evaluation.

Random Sampling - is the process of selecting a sample in such a way that all individuals in the defined population have an equal and independent chance of being selected for the sample.

Validity - refers to the degree to which a test measure what is suppose to measure, consequently, permits appropriate interpretation of results.

CHAPTER I

INTRODUCTION

After the successful flight of the Soviet Sputnik in 1957, critics of the US educational system demanded a shift in the goals of education, particularly in the areas of mathematics and science (Klopfer & Champagne, 1990). In response to this shift, science curriculum development boomed during the next 20 years (Kyle, Shymansky, & Alport, 1982). Many new programs, referred to as "alphabet" science programs, thrived with funding from private foundations and federal agencies, primarily the National Science Foundations. Although these programs differed in their organization and style, each placed a great deal of emphasis on and value in hands-on activities oriented towards discovery learning in schools and informal settings (Kyle, Shymansky, & Alport, 1982; and Klopfer & Champagne, 1990).

A growing concern over the importance of science education has been a major factor for the popularity of informal education in recent years (Rennie & McClafferty, 1995; and Jones, 1997). Education is not limited to the physical boundaries of school; students learn throughout the year in and out of school in various settings. Learning outside of school plays a vital role in the development of competence in language, reading, science, and other school-related disciplines (Stevenson, Lee, Chen, Stigler, Hsu, & Kitamura, 1990; Morrison, Smith, & Dow-Ehrensberger, 1995; and Korpan, Bisanz, Bisanz, Boehme, & Lynch, 1997). Teachers are extending instruction beyond the classroom to help students become familiar with the history, science, and culture around them. Field trips to museums, libraries, historical sites, zoos, botanical gardens, aquariums, and local business and government offices teach students about relevant events in their lives and communities. Such visits can be exciting ways for students to connect information acquired from books and classroom activities with the people, places, and events in their hometowns (Finson & Enoch, 1987; Paris, Troop, Henderlong, & Sulfaro, 1994; and Rennie & McClafferty, 1995). Now researchers are beginning to investigate how children and their families learn about science in museums and other informal settings (Dierking & Falk, 1994; Soren, Weiss, & DeDivitiis, 1994; and Crowley & Callanan, 1997).

Informal education, particularly museum education, is different from traditional schooling. It is noncompulsory, and does not rely on the controls of grades, tests, and legal restrictions that characterize learning in schools. Visitors are free to come and go at will and explore the exhibits at their own speed and according to their interests (Paris, Troop, Henderlong, & Sulfaro, 1994; and Jones, 1997).

What is unique about a museum compared to a classroom setting? The instructional stimuli differ markedly. For example, in informal learning settings exposure time to the instructional stimuli tends to be much shorter than in the formal classroom setting. In addition, the learner can have direct contact with objects rather than symbolic exposure (e.g., textbook description) (Bitgood, 1988).

The informal setting holds tremendous possibility as a mechanism for enhancing the appeal of science lessons. There are multidimensional opportunities for learning that cater to the tastes and preferences of a greater number of the individual students. The flexibility leaves students room to investigate and attend to what interests them (Jones, 1997). It is especially helpful to students coping with the social incongruity of an educational system based on a second language or an unfamiliar value system. It provides the freedom to learn in more comfortable ways (Lee, Fraad, & Sutman 1995). However, until very recently, the value of field trips in learning science rested solely upon the personal testimony of those individuals who actually visited museums. In addition, the budget cuts experienced by many schools have caused administrators and others to question the time and expense required to visit museums, particularly when the value of the visits has been primarily supported only by intangible evidence such as personal testimony (Wright, 1980).

In a effort to enhance their value and to keep up with the demands of the society, many science museums have attempted to exhibit technological artifacts, and explain technological processes used in today's world through the use diagrams, models, and manipulative displays. These museums recognize and attempt to relate the impact that the technological revolution has had on society and science. The swift changes modern science and technology brings with it rapid changes in the society itself (Finson & Enochs, 1987).

Informal science centers provide new environments of self-motivating learning experiences through exhibits that appeal to the senses, emotions, and intellect. They are among the most rapidly developing institutions of learning in contemporary society, and these centers respond to a growing public demand for knowledge and information (Kimche, 1978). Visitors go to science centers to satisfy their curiosity about branches of science that are having more and more impact on their daily lives. The public demands timely access to information on subjects such as the saccharin debate, genetic engineering, nuclear reactors, solar energy, air and noise pollution, food supply, and many other issues critical to their daily lives (Kimche, 1978; and Finson & Enochs, 1987).

The learning opportunities available at science-technology centers comprise a resource that can be best understood in the context of a change in public attitudes towards formal and informal education and leisure time. A survey of high school graduates' satisfaction with their educational achievements during the past 10 years since their high school graduation showed that 46 percent were dissatisfied with their intellectual accomplishments (Hodgkinson, 1976). This would partially explain the findings of Hyman (1976) indicating that 50 million adults are currently engaged in pursuing some form of continuing education and that only 9.6 million of those adults are enrolled in programs that lead to a degree or other certification from an educational institution. The remaining 40.4 million are involved in courses, classes, symposia, and discussion groups provided by other institutions such as museums, libraries, businesses, community groups, religious organizations, and science-technology centers.

People visit science centers for many reasons, such as to socialize with friends and family, to experience something worthwhile, to relax, etc. (Bitgood, 1988). Bitgood (1988) identified six major leisure-activity goals of visitors:

(1) being with people, or social interaction;

(2) doing something worthwhile;

(3) feeling comfortable and at ease in one's surroundings;

(4) having a challenge of new experiences;

(5) having an opportunity to learn; and

(6) participating actively.

Because their goal is to present enough facts to enable people to make intelligent decisions, science centers decide on the information to be presented based on current issues. In fact, special constituencies such as the deaf, the blind, senior citizens, inner-city youth, non-English speaking immigrants, and tourists believe that science centers are among the institutions most responsive to their needs (Kimche, 1978).

The educational potential of science centers is well recognized (Boyd, 1990; Semper, 1990; and Rennie & McClafferty, 1995) although, as some reviewers point out, much of the literature that promotes them is based on little more than anecdotal evidence (Ramey-Gassert, Walberg II, & Walberg, 1990). Relatively little information exists upon which it can be determined whether visitor's experiences in science centers actually result in measurable advances in learning. Research to date has concentrated on gathering demographic data about museum audiences and on exhibits' effectiveness in transmitting information (Hyman, 1976). Both cognitive and affective testing of museum experience are limited because the traditional instructional model employed in pedagogical research in a regular classroom is inadequate to measure the effectiveness of museum experiences (Hyman, 1976; and Ramey-Gassert, Walberg II, & Walberg, 1990).

Furthermore, if learning in a museum is a visual kinesthetic experience, which is qualitatively different from lectures or reading printed text in the classroom, then recent theories of brain psychology should also be taken into consideration (Borum, 1977). Current experiments have found that this distinction has a somatic basis; that is, the hemispheres of the brain have distinctive behavioral attributes (for example, visual learning is right-brained, while linguistic-based information-transfer is left-brained). To maximize the potential of learning opportunities in museums, it is crucial that new measurement models need to be developed based on new technologies. These models need to be founded on the uniqueness of the museum and measured in nontraditional ways (Borum, 1977; and Kimche, 1978).

The interaction of science and contemporary society must be a component of science education. Science educators have the dual responsibility of explaining science in its broadest sense to the public as well as interpreting society's influence on science to the scientific and lay communities. Informal science centers provide the settings to, in part, accomplish this goal (Finson & Enochs, 1987).

STATEMENT OF THE PROBLEM

Public access settings such as zoos, parks, shopping centers, and museums have the potential to educate. As such, public access settings can both complement formal education and affect learning. Through the utilization of advanced methodology in behavior analysis and computer technologies, new learning environments may be created and implemented in public museums (Lee, 1968; Screven, 1969; and Screven, 1974).

Museum environments have always had an important role as repositories of knowledge and artifacts, but in the 20th century they have increasingly become active disseminators of knowledge (Donald, 1991). Through the use of new technological tools, such as multimedia and hands-on exhibits, science educators have created unique opportunities to increase science literacy in museum environments. "The problem is, how museums and other informal facilities successfully evaluate the impact of their educational programs and exhibits on visitors?"

RESEARCH QUESTIONS

- Can an interactive multimedia exhibit be used effectively to teach students about simple machines concepts?
- Can visitors learn more with a physical science multimedia exhibit than with the conventional physical science hands-on exhibit?

OBJECTIVE OF THE STUDY

The objective of the study was to verify whether the use of an interactive multimedia exhibit was more effective than a traditional hands-on exhibit to facilitate connections and clarify complex scientific concepts surrounding the use of simple machines in a science museum setting. The results of these visitor studies can be used to modify and enhance exhibit design, and this function of visitor analysis becomes increasingly important as the economic need for scientific literacy increases. If we, as educators, better understand the process by which visitors learn in the informal setting of the museum, we can use this knowledge to ensure that more visitors encounter successful learning situations. Exhibits become not only more effective teaching tools, but also become intrinsically more interesting.

CHAPTER II

REVIEW OF THE LITERATURE

As our society continues to change there is growing concern over the importance of science education. The infusion of new technologies promises improvement in both instruction and assessment techniques. Recent reform projects such as the National Science Education Standards published by the National Council (1996) present new ideas to direct formal and informal science projects. School can collaborate with museums to provide science educators new tools to create unique opportunities to help every learner construct their own learning rather just giving them facts and figures. Science museums hold a wide range of resources relevant to many topics in the school's curriculum, making organized visits very attractive. Unique, unusual, and even ordinary objects, replicas, and models have the potential for great educational value (Gilbert, 1995).

Museum learning, as a complement to school education, has many advantages: the nurture of curiosity, improvement in motivation and attitudes, engagement of the audience through participation and social interaction, and enrichment. By nurturing curiosity, museums enhance the desire to learn (Ramey-Gassert, Walberg III, & Walberg, 1994) and increase motivation. Interactive science centers generate excitement, enthusiasm, activity, and interest, compensating where formal science education has often neglected students (Wellington, 1990). Several authors documented positive attitude changes toward science (Finson & Enochs, 1987) and knowledge increase (Eason & Linn, 1976; Gottfried, 1980;

Balling & Falk, 1981; Balling & Falk, 1982; Feher & Rice, 1985; Kanel & Tamir, 1991; Ramey-Gassert, Walberg III, & Walberg, 1994; and Boisvert & Slez, 1994) among visitors after being exposed to a museum environment.

Learning in a museum environment is not evaluated or assessed according to prescribed standards such as a letter grade or number, and it occurs without planning (Birney, 1988). Most of the visitors (potential learners) decide for themselves what is of interest to them, whether they wish to investigate principles presented by an exhibit, and how much time they want to spend on it. This creates a unique environment to learn about science (Beardsley, 1975; Thier & Linn, 1976; Balling & Falk, 1981; and Boisvert & Slez, 1994).

Educators can list several reasons for taking their class to a field trip. Gottfried (1980) reported that teachers' reasons to visit the Biolab at the Lawrence Hall of Science included: (a) a desire for a change of pace, (b) science enrichment, (c) a social experience for the students, and (d) a chance to increase their exposure to science. However, there is another important reason to visit science centers. Research has shown that visits to science centers are memorable events (Stevenson, 1991; McManus, 1993; Wolins, Jensen, & Ulzheimer, 1993; Greenfield, 1995; and Rennie & McClafferty, 1995). Memories persist in the minds of children and remain with them into adulthood. Falk and Dierking (1994) interviewed middle school children and graduating college students and found that 80% of them could recall three or more specific things linked to a field trip during their first, second, or third grade.

In general, educators are increasing the use of community resources to supplement formal education (Beardsley, 1975). Each school year, millions of children participate in field trips to museums, zoos, aquaria, and nature centers (Balling & Falk, 1981). Informal education has become a very important mechanism to disseminate information to the public about new ideas and technologies (Beardsley, 1975; Balling & Falk, 1981; and Boisvert & Slez, 1994). Although most people do not visit museums specifically to learn, some of both factual and attitudinal learning does take place (Boisvert & Slez, 1994). Gottfried (1979) found that two weeks after their visit to a science museum discovery space, 9- to 12-year-old subjects could discuss a wide range of facts learned there. Currently there are over 200 science museums in North America focusing on exhibits for children. Typically, these exhibits offer a wide variety of interactive activities that can simultaneously entertain and educate visitors as they manipulate the components of the exhibit (Greenfield, 1995).

What happens during a visit to a science center? The behavior of visitors in science centers is well-documented and remarkably consistent. Visitors orient themselves for the first few minutes, attend to the exhibits for a considerable time (approximately 30 minutes or more), and then cruise around for a period (perhaps 15 to 30 minutes) (Diamond, 1986; Falk, Koran, Dierking, & Deblow, 1985; and Stevenson, 1991). From their extensive evaluations, Price and Hein (1991) suggest that a two-hour visit is appropriate because shorter visits can lead to lack of involvement and longer visits result in lack of interest. When visiting a particular science center for the first time, exploration-and setting-orientated learning is a high priority for students, and in a new and unfamiliar setting, this behavior takes precedence over the teacher's plans for the visit (Falk, 1983; and Falk, Martin, & Balling 1978). Children who are already familiar with the setting tend to learn more than those who are not (Balling & Falk, 1980; Wolins et al., 1992); however, if students are very familiar with the setting, they may find the visit boring (Balling & Falk, 1980; Falk & Balling, 1982; and Talisayon & Talisayon, 1987). Orientation programs can facilitate cognitive learning from a zoo visit, especially when conducted by the teacher. Research on the use of novelty reducing interventions, such as slide shows before a visit, indicates that the amount of purposeful exploratory behavior can be increased (Kubota & Olstad, 1991).

According to Oppenheimer (1968), science and technology are becoming increasingly important in modern life, but a large gap exists among their complexities and our daily experiences. The media from which most of the science knowledge and understanding is drawn -- books, newspapers, magazines, films, TV, even school and college courses -- are very valuable but share a major disadvantage: the absence of experience, observation, demonstration, and participation in a scientific phenomena and how and why it works. Explaining science without them is like trying to teach swimming without going near the water.

THEORETICAL FOUNDATION

Computers as an Instructional Tool

Ten years ago the use of computers as an instructional tool was largely limited to environments that supported mainframe computers or minicomputers offering timeshare capabilities. Terminals were generally restricted to text output and were reserved for independent study environments. The introduction of the microcomputer, however, changed the way in which educators viewed the uses of computer technology (Modell, 1989). As we entered the 1980s, most high schools were getting their first micro computer laboratories. For some, the microcomputer replaced the terminal that used a time-sharing mainframe; for others, it was the school's first experience with computers. In most cases, the microcomputers were used by math or business teachers or sometimes by both. Each unit had 64K of memory, one or two disk drives, and a monochromatic screen. A few had printers. Life was simple. But finding a teacher or teachers who knew or wanted to know how to use the computers was often difficult. In most high schools, only one or two teachers used computers regularly. Colleges were just beginning to train computer teachers, and industry was hiring them as fast as they were produced. It was easy to mass produce equipment, but much harder to produce knowledgeable computer teachers (Taitt, 1993).

By 1985, 39 states in the United States still had no certification requirements for computer teachers, although many did encourage teachers to take advantage of stateoperated workshops. Thirty-six states and the District of Columbia had computer coordinators who served as the state's contract for all computer education activities (Taitt, 1993).

As technology was no longer restricted to rooms that provided "hard wired" or modem connections between terminal and computer, microcomputers could be easily moved to where the students were. Further more, these machines could be easily programmed to include graphic displays and animations (Modell, 1990). In addition to pursuing the traditional applications of computer-assisted instructions (Rovick & Jofi, 1984; Jones, Mann, & Aucone, 1985; and Modell, 1989), educators moved the technology to the classroom. Applications ranged from fostering active learning through simulations in small group (Schottelius, 1984) and lecture (Mikitten, 1984) settings using the computer as a "slide projector" to incorporate animation and provide a "building block" approach to developing concepts with students (Levine, 1984; and Heckman et al., 1987). In contrast to slides and a blackboard, the computer is ideally equipped to demonstrate changing phenomena and interactions (Levine, 1984). The technology also provided a communication vehicle in the form of an electronic blackboard that could be used during teleconferencing between instructors and students who were separated geographically (Kastella & Gordon 1987). By introducing video projection devices (Vincenzi, 1984; and Stull & Knoll, 1987), the class and instructor could work together while viewing large screen displays of the computer output (Kastella & Gordon 1987).

The microcomputer has also enhanced the active learning experience in the laboratory (Blakely, 1988). The technology provided a relatively inexpensive tool for acquiring as well as analyzing data within the time frame required for the student laboratory (Blakely, 1988; Amend & Furstenau, 1992; Molitoris, 1992; and Bruning 1992). Using computers in the laboratory allows students to more fully participate in the process of science and to perform any step in the process of science better, faster, or more accurately (Wise & Okey, 1984; Blakely, 1988; Amend & Furstenau, 1992; and Stevens, 1995). Furthermore, by using computer simulations students could perform experiments that were previously not possible due to the cost of necessary equipment, time available, or risk to student safety (Wise & Okey, 1984; Blakely, 1988; Amend & Furstenau, 1992; Molitoris, 1992; and Stevens, 1995). Through the use of computers, students are given the opportunity to ensure their ability to solve problems as well as memorize facts. Dynamic and microscopic events can be enlarged for all to see and can be slowed down so tat each progression can be studied. With the color, motion, stills, and access power of a computer, multimedia can be an effective tool for any science teacher (Couch, Couch, & Peterson, 1993).

The increased availability of computer technology, both in terms of price and ease of use, offers the mechanism for educators to incorporate the principles of discovery learning in the classroom (Modell, 1990; and Callon, 1992). With discovery learning comes a shift in the focus of the classroom from the instructor to the student. Students are guided to discover and explore new concepts and investigate their relationships with concepts they've already encountered, with the instructor serving as a resource in and out of the classroom (Wise & Okey, 1984; Callon, 1992; Amend & Furstenau, 1992; and Molitoris, 1992). A well-written computer lesson challenges students to apply previously learned facts and concepts to the solution of problems, thus showing students what they know and what they need to learn (Schottelius, 1984).

In museum settings computers have become exotic flowers that attract the honeybee visitor. When software's are an integral part of a larger exhibition, they draw a higher proportion of visitors than other exhibit units. Moreover, contrary to the popular belief that computers compete with other exhibits, the presence or use of an interactive unit has been associated with an increase in average visit duration and number of visitors at related exhibits. Computer stations that are part of larger exhibits are used for significantly more time than other exhibit unit types. Although the exotic flowers of computer-based exhibits attract and hold the honeybee visitors, the underlying question is whether visitors are involved enough to absorb, cognitively or affectively, the available nectar. The limited evidence available thus far about computer museum exhibits suggests that they can be successful learning tools. Electronic exhibits can attract visitors, hold their attention, and yield a variety of cognitive and affective outcomes (Flagg, 1991).

As Borum's (1983) research suggests, computer technology provides museums with the opportunity to create a range of experiences for visitors that will enrich and expand the learning that takes place in exhibits. Computers have three capabilities that make them especially attractive as a medium for museum education:

- *Information retrieval and storage.* They have the ability for a large data base to be stored in a manner that facilitates convenient and rapid recovery.
- *Graphics and sound.* The computer can present to the visitor a wide variety of sounds, color graphics, and animations in addition to the text.
- *Interaction through random access.* Computers can respond differently to varied input from visitors. This interactive capability is responsible for the tremendous attracting power of computers.

The widespread use of microcomputers is now a fact of life in research and education (Vincenzi, 1984). This technology has the potential to revolutionize learning and to help establish a pattern of life-long learning for the citizens of tomorrow. In the next century, students will be able to "experience" a walk in the jungle, a desert caravan on a camel, or a space flight to Mars. The early stages of this technology can be found at Disney World, where movement, sight, sound, and smell add to the feeling of reality at some of the attractions (Taitt, 1993).

Computer competency will be vital. Computers may run computers, but students will need to know how to program the computers in order to understand what computers can and cannot do. Communication will be the most important skill -- communication with other people, with computers and technology, with other cultures, with related processes and techniques. Information may come from anywhere in the world, in any language, and at any time. Understanding that information, being able to act on it, and then being able to communicate with others will be a valuable asset (Taitt, 1993).

The Impact of Integrated Multimedia-Oriented Instruction on Learning

The careful coordination of a student's entering knowledge and the new information presented in a lesson is one of the most important cognitive factors associated with student achievement (Okey, 1985; and Narita,1995). Integrated multimedia-oriented instruction (IMOI) allows students to manipulate and interact with information in ways traditional tools do not allow. They learn to analyze, synthesize, and solve problems with information that they have taken control of as active learners. IMOI helps students who have difficulty with traditional learning methods to tap their strengths so that they can find ways to communicate and represent the knowledge and understanding they have of their world (Waugh, 1986; Hasselbring, Goin, & Bransford, 1991; Fifield & Peifer, 1994; and Narita, 1995). Several studies suggest a positive influence of IMOI on student performance in the classroom (Waugh, 1986; Hasselbring, Goin, & Wissick, 1989; Fifield & Peifer, 1994; and Narita, 1995). Furthermore, IMOI is considered to be a method to explain, elaborate, clarify, and visualize aspects of a lesson that cannot be explained as well on paper or through a lecture (Browning, 1988; and Hoover & Abhaya, 1995).

How does IMOI facilitate the process of learning? Pictorial representations of structure, processes, and relationships play a central role in both science and science education. In their efforts to understand the world, scientists have given us familiar images such as the Bohr atom, DNA's double helix, and food webs. The most challenging task of science educators is to help students understand complex topics that are far removed from familiar contexts. In studies of learners ranging from grade school to college, the effects of illustrations include increased recall and comprehension of material, increased motivation and interest, and the cultivation of cognitive or thinking skills. Illustrations include photographs, drawings, charts, graphs, diagrams, motion video, and computer animation (Levie & Lentz, 1982; Fifield & Peifer, 1994; and Levie, 1987).

Interactions with computers involve touching, manipulating events on the screen, solving problems, accepting challenges, asking or answering questions, exploring ideas, and making predictions. These activities are likely to be intrinsically rewarding to people of all ages and play an important role in attracting power (number and kinds of visitors who approach a particular exhibit) and holding power (total number of seconds a visitor remains at the exhibit divided by the minimum number of seconds "S" necessary to read and see the exhibit) as well in learning. For visitors, access not only means that an immense variety of information becomes available, but also that visitors can receive information in a wide variety of text formats, visuals, animation, and interactive modes that accommodate different ages, vocabularies, knowledge, interests, and learning styles. Thus computers can combine text, sounds, and visuals; can animate and simulate complex processes; and allow an almost unlimited branching (Screven, 1992). Children expect hands-on exhibits to be lively, flashy, and fun. They expect an exhibit to "do something," and their goal is simply to "make it happen." When they manipulate and experiment, they discover and extend prior learning in a personally meaningful and motivating way (Paris, Troop, & Henderlog, 1994).

Students' recall and comprehension of material increase when relevant pictures are included in instruction (Levie & Lentz, 1982; Levie, 1987; and Fifield & Peifer, 1994). Explanation for this effect suggests that illustrations provide contexts within which students can organize and interpret information, either by activating existing mental schemes or by modeling new schemes that students can internalize. Some illustrations provide concrete contexts for abstract topics, such as a stylized representation of an ion gate in a cell membrane during a discussion of transmission of nerve impulses. The motivational effect of illustrations can increase the time spent interpreting a concept, resulting in greater learning (Levie & Lentz, 1982).

According to Pavio (1986), the nature of memory itself may also make illustrations beneficial. Pavio's (1986) dual coding theory of memory proposes separate but interacting storage systems for verbal information and nonverbal images. Images are more likely to be tagged with verbal labels by students and stored in both nonverbal and verbal memory systems, which reduces the likelihood that information will be forgotten and produces elaborate, interconnected representations in memory. Strictly verbal input is less likely to be stored in both verbal and nonverbal systems (Pavio, 1986; and Baggett, 1989). The use of illustrations can refine existing cognitive skills or encourage the development of new skills through modeling (Solomon, 1979). For instance, viewing computer animation simulating the three-dimensional rotation of objects has been shown to improve students' abilities to spatially interpret two-dimensional drawings (Zavotka, 1987). In this case technology provides the experience students need to develop mental skills that they may have difficulty developing on their own (Solomon, 1979; and Kumar, 1990). Student surveys (Kumar 1990; Fifield & Peifer, 1992; Bohren, 1993; and O'Connor, 1993) and achievement tests (Waugh, 1986; Browning, 1988; and Sherwood et al., 1990) have shown significant improvement in learning skills when classrooms used instead of traditional instruction.

In conclusion, technology has had an important impact on the teaching/learning process (O'Connor, 1993). Educators already have access to a broad scope of visual, audio, and textual databases with which to encourage active learning experiences within a group or independent study setting. The new user interface modalities (e.g., mouse and touch screen), easier graphics generation (e.g., "draw" and "paint" programs), the ability to incorporate multimedia resources through hypermedia or other applications, and the growing resources available to generate or access visual and audio data have opened new vistas for faculty interested in developing instructional materials. Incorporating these resources with technology designed to foster communication between students and instructor (Kumar, 1990; and Fifield & Peifer, 1994) can result in an active learning classroom environment in which educators can diagnose and address progress.

Measuring Learning in Museums

How is learning measured in the museum? The measures most frequently mentioned are associated with visitor's movements in the museum and are discussed in terms of the success of exhibits, specifically their "attracting power" and "holding power"

(Kool, 1986; and Miles, Alt, Gosling, Lewis, & Tout, 1982). Attracting power is the number and kinds of visitors who approach a particular exhibit (Miles et al., 1982). Holding power is the amount of time visitors spend exploring an exhibit, expressed as the total number of seconds a person remains at the exhibit divided by the minimum number of seconds necessary to read and see an exhibit (Kool, 1986). Several studies have focused on visitor characteristics and their relationship to attraction, holding power, and visitor engagement levels. Munley (1985) reported that attraction power and attention to parts of exhibits were related to visitor gender. During an exhibit on 18th century farm life, he observed that women rarely viewed farm equipment and men rarely viewed items found in the kitchen. In their study, Koran, Koran, and Longino (1986) also described that the attraction and holding power were related to gender but related it to age as well.

Other measures, such as cognitive tests, could also be applied to museum settings and would show the educational value of a museum experience (Borum, 1977; and Alt & Herrick, 1991). In general, studies have shown that some cognitive learning does occur on field trips, and at the very least, field trips are perceived as worthwhile by both students and educators (Gottfried, 1979). A variety of objectives for enrichment of field trips are espoused, from broadening the child's experience to reinforcing classroom lessons and from advancing cognitive abilities to promoting socialization skills. Regardless of the teacher's objectives, most field trips place children in a novel, stimulus-rich setting (Falk, Martin, & Balling, 1978; Balling & Falk, 1981).

Learning in Museum Environments

A science museum and its collections are, in a sense, a vast three-dimensional catalog of learning opportunities (Chase, 1975). Exhibits provide another means of attacking the problem of science illiteracy by educating visitors about science and technology. By engaging visitors in informal learning through experiences, facts, lessons, and impressions, each visitor accumulates knowledge. Unlike a school, a museum setting is voluntary, open-ended, non-linear, hands-on, and entertaining. There are no requirements, no prerequisites, no exams, and no grades. Science museums are places where motivation and curiosity can be explored and are complementary to formal methods of education (Ucko, 1985).

When visiting a museum, children engage in tasks that they define for themselves, without adult views of completion, achievement, failure, and they emerge from these experiences with feelings of success and competence (Sykes, 1992). Although, for a museum experience to be truly effective, the exhibit or experience must attract and hold children's attention and give them time to practice their skills and store new information in their memories. It is also very important for interactive displays to minimize the possibility of embarrassment for children, as that is one of the great ways to break a child's concentration. The moment a child feels self-conscious, the child becomes afraid of looking foolish, and concentration breaks down. When concentration is intense, the person experiences several things. One is loss of the sense of time. When the activity is enjoyable, people forget clock time. Sometimes a few seconds seem to stretch forever, or several hours may disappear without leaving any trace. Falk (1983) found that the time spent at an exhibit affects the amount of learning. A Child's gender may also affect his or her choice of exhibit and interaction with it (Bremer, 1992; Carlisle, 1985; Hidi, Soren, & Weiss, 1994; and Koran, Koran, & Longino, 1986), although there is no evidence that one gender has less positive experiences than the other (Boisvet & Slez, 1994; and Stevenson, 1991).

In general visitors are not attracted to science museums to learn facts; they come to find out about a new and interesting phenomena. When visitors interact with an exhibit, they gather a different kind of evidence than when they just hear or read about the same topic. The interactive learner manipulates objects, explores variables, and utilizes the evidence obtained in reaching a personal conclusion about the situation investigated (Their & Linn, 1976; and Raymond 1997).

Paris et al. (1994) describe the universal set of characteristics that explains why people want to get involved in something. Naturally, people became involved in an activity because is fun and enjoyable, but they also became involved because the activity is a reward in and of itself. Situations become most involving and finally most enjoyable when visitors' opportunities to act in a situation are matched to their capabilities to act -- that is, when they perceive that what they are able to do and what is possible to do in a situation are more or less in balance and they have a 50-50 chance of success. Clear feedback is important for keeping attention focused and avoiding distraction, which are also the conditions required for involvement in learning. The feedback should not come just at the end of an activity, but preferably be embedded throughout the interaction so the participant can check his or her understanding of what is being seen and whether he or she has a good grasp of what is being presented there. In situations where the challenges and skills are matched and goals and feedback are clear, one is able to achieve the concentration needed for learning.

Visitors do not arrive at the museum door with empty minds. Instead they come with preconceptions about the subject matter to be presented. Researchers currently believe that human learning is so complex that a single model may not be adequate and that a better approach would be the development of a comprehensive model (Dierking, 1991). Dierking (1991) proposed 10 generalizations that represent key factors contributing to such a model.

1. *Perception is central to the process.*

To learn something one must perceive it in some way. Individuals have preferred modes of perception, such as touching or hearing (not just reading). Museums and other informal learning institutions try to present information in different modes. Visitors to informal settings must be oriented in such way that they know what to perceive and have an opportunity to perceive in a variety of modes.

2. *Memory is central to the learning process.*

Learning is defined as a measurable change in behavior that persists over time, presumably because it becomes part of our memory. When attempting to determine whether learning has occurred, psychologists traditionally focused on short-term memory because it was easier to measure. More recently, there has been an effort to study long-term learning, also referred as "meaningful" learning and "real world" learning, and to explore innovative ways of measuring learning.

3. *Learning is an active process.*

Learning involves making sense of and organizing the information we perceive. This process can be thought of as constructing and organizing frameworks for the information; Piaget called it "schemata". The new information is linked to prior knowledge, resulting in the reorganization and rearrangement of existing schemata. Learning also involves the retrieval and transfer of information, suggesting the active use and reconstruction of these existing schemata. Therefore, the learner must actively manipulate -- either mentally or physically -- the material to be learned in order to construct his or her own schemata or meaning of the material learned.

4. *Learning is both a cognitive process and a "metacognitive" process.*

Metacognitive refers to the process of reflecting upon how we think and learn -- the "how" and "when" of learning as well as "what" of learning. Museum educators are teaching visitors metacognitive strategies for dealing with museums when they teach them how to look at art, to interpret an object , or to use a museum.

5. *Development influences the learning process.*

The developmental level of the subject influences the learning process. In informal settings, it is important to have some general sense of the visitors' developmental levels while appreciating that there may be a great variability among individuals.

6. *The learning process is not always orderly or sequential.*

It seems that learning occurs in bursts or phases. Long-term memories of informal settings tend to be grouped temporally, but they are also grouped in other ways. For example, a museum visit remembered as "things we did on family vacations" includes a wealth of museum memories as well as seemingly extraneous memories.

7. *The learning process is strongly influenced by prior knowledge, beliefs, and experience.*

Prior knowledge, beliefs, and experiences are considered the most important predictors of how much a person will learn. If it is known what a person knows and how he or she feels about the subject, it can be predicted what he or she is capable of learning. Shettel et al. (1968) found that visitors who learned from a science exhibit had prior knowledge and experience in the scientific content presented.

8. *Learning occurs in a physical and social context.*

Where you are and who you are with have tremendous impacts on what and how much you learn. Falk and Balling (1982) investigated the importance of context by observing children who were taught zoological information in appropriate at the zoo and next to the right animals and inappropriate at the zoo but next to the wrong animals or away from the zoo. They found that children learned most when taught in the appropriate context.

9. *Motivation strongly influences learning.*

"Motivation" refers not only to linking a subject, but strongly correlates with choices the learner makes as to what and how to learn, with persistence in a learning task, and with continuing drive to learn. Because museums are free-choice learning settings for most visitors it is critical to consider and understand the nature of motivation and its influences on learning.

10. *People learn in different ways.*

The learning process differs for each person based on perceptual preferences, social interaction preferences, age, and other factors.

Individual differences among visitors to a museum constitute an important class of variables that can and should be explored in museum research. These differences could be any characteristic of the individual's cognitive, affective, psychomotor, or developmental states that function selectively with respect to a visitor's reaction to an exhibit. Some of these characteristics could facilitate learning, interest, or motivation, while others could interfere with the effectiveness of a given exhibit. Clearly, such differences may be expected to interact with the type of exhibit, the attention given to an exhibit, and the potential outcomes derived from this experience (Koran & Koran, 1983).

Museums are difficult environments for which to develop effective informal learning materials. Their audiences range widely in age and bring a variety of interest and levels of background knowledge that utilize different learning methods. The term generally used to describe the different ways that people learn is “learning style”. Just as there are many theories of learning, there are many schools of thought regarding learning styles.

One model that attempts to explain these different learning patterns is a model proposed by Gardner (1983). Gardner‘s model holds important implications for museum educators when designing programs and exhibits. The model outlines seven intelligences and suggests that each of us has varying degrees of abilities in these areas:

1. *Linguistic intelligence* is exhibited by the highly verbal person who likes to write, read, and has a good memory for places, dates, and trivia.
2. *Logical-mathematical intelligence* is exhibited by the person who can compute math problems quickly in his or her head and often plays and wins chess and other strategy games.
3. People with high *spatial intelligence* have good visual memories; read maps, charts, and diagrams easily; and enjoy looking at movies, slides, or photographs.
4. *Musical intelligence* is exhibited by people who play musical instruments, remember melodies of songs, and say they need music to concentrate.
5. *Bodily-kinesthetic intelligence* is exhibited by people who perform well in competitive sports, like to engage in physical activities, and demonstrate skill in crafts.
6. The person who exhibits high *interpersonal intelligence* often has many friends, like to socialize, and enjoys playing group games.

7. *Intrapersonal intelligence* is exhibited by people who display independence, like to be alone to pursue projects, and have a great deal of initiative in completing projects independently.

Another important consideration in museum studies is the influence of novel environments in learning (Falk, J. H. et al., 1978; Falk, J. H. & Balling, J. D.,1982; and Falk, J. H. 1983). Studies have shown that novel environments stimulate students to direct their attention away from structured learning activities toward other components of the environment. Once the environment becomes "familiar," students can focus more on the conceptual task. As an adjustment or adaptation process, the novelty of the field trip setting is conceptually similar to other psychological processes. Any time a learner encounters a new situation, he or she must make generalizations about this situation by itemizing or naming objects, followed by grouping or clustering the items (Falk, Martin, & Balling, 1978). For example, if the novel situation is a forest, the learner would first need to experience "itemizing" or locating trees, shrubs, vines, etc., before a useful concept of the forest could be compared with Piaget's (Flavell, 1963) proposed concepts of assimilation and equilibrium. If a learner enters a forest, but already possesses some structures for forests, the novel setting is readily assimilated into previously existing structures. However, if the setting is completely new, a greater disequilibrium can occur, requiring a greater accommodation to the new information and the formation of entirely new structures before the learner reaches a state of relative equilibrium (Falk, Martin, & Balling, 1978).

The process of experiencing a new environment has conceptual similarities with classic exploration behavior. Higher animals spend a substantial portion of their time and energy on activities to which terms like curiosity and play seem applicable (Berlyne, 1966). Several studies conducted on lower animals, subhuman primates, and humans provide some insight (Falk, Martin, & Balling, 1978). Exploratory behavior has been described by Weisler and McCall (1976) as a relatively stereotypic perceptual-motor examination of an object, situation, or event in order to reduce subjective uncertainty and to acquire information. Some basic features of exploration have been suggested.

1. Exploratory behavior is pervasive among mammals, and it is obviously adaptive.
2. There seems to be considerable similarity -- even stereotype -- in the general form of this behavior across situations.
3. The organism explores when confronted by a moderate amount of uncertainty; young or inexperienced organisms are especially cautious and reticent to explore in situations of extreme uncertainty.
4. Exploration can be a high-priority behavior in moderate amount of uncertainty situations, frequently superseding eating, drinking, eliminating, and avoiding pain, even under circumstances where these behaviors become very important (e.g., deprivation).
5. Organisms seek out stimulus variation and uncertainty; exploration is not always pleasurable. Organisms may be tense with intense, nervous facial expressions.

Weisler and McCall's (1976) study also mentioned that organisms', including humans', exploration increases linearly with the amount of novelty for a wide variety of stimuli. It is suggested that extreme novelty leads to less exploration and even fear. However, Rice and Feher (1987) contend that novelty can be a very important dimension of learning by attention arousal and may serve to generate interest during the hands-on active phase of learning. Children may learn and remember what happens on an all-day field trip because it is such a novel, unusual event and is clearly delineated from the day-to-day routine.

Starting with infancy and continuing throughout the entire life cycle, curiosity, exploration, and play are important components of the human behavioral repertoire. The human nervous system is organized so that we are inclined to show interest in the novelty of and changes in our environment, and we are equipped with a broad range of exploratory behaviors. However, the exploration of objects, events, and even ideas and feelings does not occur in environments that fail to encourage or provide opportunities for exploration (Chase, 1975).

Maw and Maw (1964) defined curiosity is as a verbal or nonverbal response to a novel, complex, or incongruous stimulus. Curiosity is exhibited when an individual scans the environment for novelty, physically or psychologically approaches a new object or event, interacts with that object or event, and then persists in this behavior. Another common definition of curiosity (Berlyne, 1966) is that curiosity functions as a drive produced by novel or incongruous stimuli that can be reduced only by investigating, either physically or mentally, the condition that generated the uncertainty. In museums, the novel or complex stimulus is the object or event. Curiosity is the response to this stimulus and in turn functions to encourage visitors to use their senses to pay attention to the stimulus and learn about it.

According to Chase (1975), a successful learning experience is based on three important principles. First, learning involves growth and differentiation of an already existing behavioral repertoire and thus requires experiences that are compatible with existing interests, needs, and skills. The designer of an effective learning environment must therefore know a lot about the past history of those who will be using the environment. This allows a design that will from the outset make sense to its users, generate interest, and support exploration. Second, learning must evoke sense of wonder, excitement, and curiosity. When visitors enter a museum and encounter a reconstructed whale or a dinosaur skeleton, most of them feel a sense of wonder. Whether this emotional energy is put to concentrated and focused use that is required for learning depends on how the learning environment is designed and managed. Third and most important, the behavior that is elicited during the learning process must have positive and interesting consequences for the learner.

In conclusion, review of the literature suggests that museums provide real-world connections to science (Ramey-Gassert et al., 1994). Although most of the people do not visit museums specifically to learn, some learning does take place. Museums can enhance children's sense of wonder through direct interactive experiences with real objects. The educational value of museum collections lies in the displays of objects and interactive exhibits that satisfy students' needs for real world connections when exploring and learning science (Burdick, 1979; and Boisvert & Slez, 1994). As Burdick (1979) stated "To have a museum be responsive in real time to the individuals curiosities... requires the museum and the visitor to be able to enter into a conversation."

CHAPTER III

METHODS

The scientific study of learning has been the province of schools of education and psychology departments. We know something about how people learn in schools and a little about learning in the home, but less about learning in museums and other informal settings. Although according to Smith (1990), all methods of educational research and evaluation are readily adaptable to museum settings.

Through experimental designs, interviews, test questions, and behavioral codes, museum researchers continually gather and interpret information given by museum visitors. Meanwhile, the experimental subjects continually react to the presence of the researcher. This complex interaction is set in motion any time a study is conducted to investigate human behavior. As might be expected, the difficulty in human behavior studies is to maximize the ability to document behavior while minimizing the disturbance and distortion of the behavior (Diamond,1980).

To evaluate specific display components, it is necessary to have some objective measure of success. The most commonly used measures are "attracting power" (number of visitors) and "holding power" (average time spent) (Borum, 1977). These are presumed to be indirect measures of interest and understanding. There are obvious problems with such indirect measures. Time spent is not necessarily an indication of interest or of what is learned (Borum, 1977). For this reason, in addition to measuring "attracting power" and "holding power," one must devise a way to test so that the teaching effectiveness, as well as interest stimulation ability, of particular exhibits and the museum as a whole can be measured. The use of cognitive tests have been used extensively with museum visitors. Most efforts at cognitive testing have been conducted to verify visitors' cognitive gain and have focused on school children (Shettel, Butcher, Cotton, Northrup, & Slough, 1968; Screven, 1974; Borum, 1977; Mary-Lynn, 1990; and Raymond 1997).

SETTING

This study was conducted at the East Tennessee Discovery Center, 516 N. Beaman Street, Chilhowee Park, Knoxville, Tennessee 37914. The East Tennessee Discovery Center (approximately 5,000 square feet) was built in 1973 and is an exciting place for students of all ages. The Center features hands-on exhibits divided into two open exhibit areas that are divided by the space bus exhibit. The science center also offers a classroom for special programs and workshops, a library, a gift shop, a planetarium, and an open air picnic area. The exhibits covers five topics:

1. *Life Sciences* -- this exhibit features 10 aquariums with fresh water fish and other creatures, a collection of stuffed animals, easy-view microscopes, an insect collection, and seasonal living insects.

2. *Physical Sciences* -- this is represented by a group of exhibits that demonstrate various aspects of light and visual perception, the Giant Whisper Dish that demonstrates the reflection and transmission of sound waves, simple machines such as pulleys and levers, and a group of exhibits demonstrating various aspects of electricity and magnetism.
3. *Earth Science* -- this topic includes displays of plant and animal fossils, a large display of the three basic types of rocks, and a case of "touchable" specimens.
4. *Kidspace* -- this new exhibit area provides multiple experiences for young children. Features included plastics recycling, an "Imagination Reading Tree," Whose Hat," geoboards, tangrams, the "Magic School Bus" computer, an imagination lab, and building material.
5. *AKIMA Planetarium* -- this exhibit accommodates 50 students at a time and offers different programs such as "The Sky Tonight," and "Planet Talk".

The East Tennessee Discovery Center is committed to innovative approaches to convey science to the public and attempts to create a playful environment where visitors can explore and investigate objects and natural phenomena. One particular physical science exhibit, Simple Machines, is a permanent hands-on display at the Center and was used in a comparison with an interactive computer exhibit designed by the author to be integrated within the physical science exhibits. The interactive computer exhibit was placed in the Kidspace area. This study considered two types of variables:

- *Exhibit Viewer Variables (Independent Variables) or Demographics* (age, sex, race, amount of the particular physical science concept, simple machines) and

- *Exhibit Effectiveness (Dependent Variables)* (holding power, attracting power, multiple choice test results).

DESCRIPTION OF THE EXHIBITS

Hands-on Exhibit

Simple Machines are a group of interactive exhibits, including levers, pulleys, and an engine hoist, that demonstrate how basic types of machines multiply human strength (Appendix A). By reading the labels, visitors are encouraged to interact with the exhibit and answer some proposed questions (Appendix B).

Computer Exhibit

The Simple Machines computer exhibit is an interactive computer display that utilizes a Gateway Pentium computer (17-inch monitor) and HyperStudio software application. HyperStudio is a flexible integrated text and graphic database management system produced by Roger Wagner Publishing, Inc., El Cajon, California. This software is an "authoring tool" that permits users who are not professional programmers to design and create their own systems for the organization and presentation of information. A large amount of complicated data, including images and sound, can be managed to provide greater educational opportunities through the stimulation of many senses. HyperStudio is the computer equivalent to a set of flashcards (Appendix C), with a collection of cards being called a "stack." The "flashcards" are connected by a "button," which is an area of the screen that activates a script to create actions for HyperStudio to execute. Actions are links to other cards, sounds, animation, and other special features.

The content of the computer exhibit was designed to follow exactly the same objectives as the hands-on exhibit. When completed, the software had its content evaluated by an instructional technology professor from the College of Education and a physical science specialist from the Physics Department at the University of Tennessee, Knoxville.

INSTRUCTIONAL OBJECTIVES OF THE EXHIBITS

An exhibit can introduce a subject, simplify a complex subject, give a detailed description of a subject, or provide a teaching tool for museum and/or outside instructors, and the objective of any exhibit should be defined in advance, taking into consideration the expected audience (Bergmann, 1976). The usefulness of a museum exhibit as an educational tool, however, is that it can combine powerful visual experience with thought content. Even if the aim is to convey a general principle, it follows that the more vivid the totality of the concrete experience (visually, emotionally, esthetically), the more substance there will be to the abstract principle that is being taught (Fine, 1963).

According to Screven (1974), determining exhibit objectives involves more than stating the exhibit's purpose in generalized terms. "This exhibit will help visitors to understand the important place of plants in their interpersonal lives" is not an acceptable instructional objective. The term "understand" is not specified in observable terms. Acts that cannot be seen or heard should not be used to define instructional objectives on an exhibit. Terms such as "understand," "discover," "grasp the meaning of," and "know" are too obscure and do not relate to behavior that can be directly observed; therefore, they are inappropriate when defining instructional objectives. In contrast, examples of behavior that can be observed and terms that would be appropriate include: "name," "arrange," "compare," "order," "solve," "list," "reject," "identify," "distinguish," and so on.

An instructional objective will usually include three factors: (1) specification of the learner's (visitor's) behavior, using action verbs (solve, list, order, etc.) expected to be a result of exposure to the exhibit; (2) the conditions (choose between pairs, match pictures with styles, etc.) under which these actions should occur; and (3) a statement of a visitor's minimum acceptable performance (Screven, 1974).

Hands-on Exhibit Instructional Objectives

The goal of the interactive Simple Machines hands-on exhibit, which is composed of levers and pulleys, is to demonstrate how basic types of machines can multiply human strength. The instructional objective of this exhibit is:

(1) By pulling down the ropes of the three different types of *pulleys*, which are one by one attached to a 100 lb. bag, students will be able to:

• *Name* and *distinguish* the different types of pulleys.

•*Compare* and *list* which pulley increases the mechanical advantage and makes it easier to lift the same weight (100 lb.).

(2) By pulling three different lengths of *levers*, which are attached one-by-one to a 100 lb. bag, students will be able to:

• *Distinguish* the different types of levers.

•*Compare* and *list* which lever increases the mechanical advantage and makes it easier to lift the same weight (100 lb.).

Computer Exhibit Instructional Objectives

The goal of the interactive computer exhibit is to demonstrate how basic types of machines, including levers and pulleys, can multiply human strength. The instructional objective of this exhibit is:

(1) By "clicking" the ropes of the three different types of *pulleys*, which are attached one-by-one to a 100-lb bag, students will be able to:

• *Name* and *distinguish* the different types of pulleys.

•*Compare* and *list* which pulley increases the mechanical advantage and makes it easier to lift the same weight (100 lb.).

(2) By “clicking” three different lengths of *levers*, which are attached one-by-one to a 100-lb bag, students will be able to:

• *Distinguish* the different types of levers.

•*Compare* and *list* which lever increases the mechanical advantage and makes it easier to lift the same weight (100 lb.).

INSTRUMENTATION

The following instruments were used to conduct the study.

Review of Related Literature

To determine what was written and published on effects of computer in science museum education, the researcher conducted an extensive database search using the University of Tennessee, Knoxville (UTK) library computer system. The following keywords were used to search in the UTK database system: science education, museum education, computer and science education, computer and museum education, informal education, and informal education and computer.

Observation of Attracting Power and Holding Power of the Exhibit

Learning is very difficult to measure directly in a museum setting without disrupting the informal nature of the learning experience. The attracting power and holding power of exhibits are parameters suggested by Koll (1986) as units of measurement for learning in museums. Attracting power is the number and kinds of visitors who approach a particular exhibit (Miles et al., 1982). Holding power is the amount of time visitors spend exploring an exhibit, expressed as the total number of seconds a person remains at the exhibit divided by the minimum viewing time necessary to read and see an exhibit (Koll, 1986). Because attracting power, holding power, and visitor engagement can be measured using unobtrusive methods, they are often used by museum educators, researchers, and evaluators as indicators of visitor learning (Falk, 1983). The observation of attracting power and holding power was recorded using a form designed by the researcher (Appendix D).

Multiple Choice Cognitive Test

According to Miles et al. (1982), the multiple choice form is considered by many test experts to be the best type of test for measuring learning performance. Multiple choice tests consist of an incomplete statement or question followed by choices that include one correct and several distracters; in addition, multiple choice tests have great versatility. The weakest aspect of multiple choice forms is the difficulty in developing good questions. Often, the correct answer can be guessed easily because the distracters are obviously wrong. To construct an objective test, a large list of items has to be produced and this is reduced by eliminating the items that are ambiguous. This can be done by trying out the initial items on a sample of visitors for whom the test is intended. A good measure of the discriminative power of an item is the variance of the answers given to it by the members of the sample. Usually, an item is scored “”1” for a correct answer and “0” for an incorrect answer. If p is the percentage in a sample that has an item correct, then the variance of the item is given by:

$$pq, \text{ where } q=100\text{-}p$$

The maximum value of the variance is when $p=q$, that is when 50 percent of the sample get the item correct. For values of p in the range of 20 to 80 percent, the variance is still relatively large, but it decreases drastically for values of p outside this range. Notice should be taken of this fact because, at first sight, it might appear that only difficult items should be included in a test if the idea is to differentiate between those individuals who have learned something from those who have not. Thus in the extreme case, where p=0 percent or p=100 percent, no information is given. Miles et al. (1982) suggest that in producing an informal objective test, it is always good practice to place a few easy items at the beginning get everybody started.

In this study, the multiple choice test was composed of three sub-scales, as suggested by Borum (1977). Considered collectively, they yield a score on the exhibit-based quiz that is the general measure of the learning of exhibit content (Appendix E). Individually, the scales measure a hierarchy of learning skills:

1. *Vocabulary* -- Identification of display items based on the content of written labels,

2. *Experience* -- Recall of interactive experience, and

3. *Concept Formation* -- Understanding of the basic science concept.

Questions 1 through 8 were scored 10 if the answer was correct; question 9 was scored "20" if answered correctly and "0" if answered incorrectly.

Statistical Analysis of the Results

The purpose of giving visitors a quiz on the content of the selected museum exhibits was to verify how much exhibit information was learned during the visit to the East Tennessee Discovery Center. The pre-test group (visitors tested before their museum visit) served as a control to tell us how much of this information visitors already knew. Thus, the difference between the mean score of pre-visit and post-visit samples was the measure of museum learning. A paired sample t-test was used to compare whether the mean of pre- and post-values were statistically significant. The analysis of variances test (ANOVA) verified possible gender interactions with learning and holding power.

PROCEDURES

Selection of Sample

The subjects of the study were composed of elementary school students who visited the East Tennessee Discovery Center between April 1 and July 31 of 1997. Ages of the participants varied from 8 to 13 years old. According to the State of Tennessee Curriculum Framework (1995), students learn about simple machines during the third grade. For this reason, the study focused on elementary school students. The study used a large random sample (n=104) so that the possibility of pre-test score influencing the post-test score could be eliminated (Borum, 1977).

In order to participate in the study, according to The University of Tennessee Human Subjects Committee, students needed informed consent from their parents (Appendix F). Because each school visit to the East Tennessee Discovery Center was scheduled far in advance, the researcher contacted the teachers personally. A letter containing a detailed description of the purpose of the study was mailed to the teachers (Appendix G) with the request forms for parental informed consent for each student. This way, students had the signed informed parental consent forms with them signed on the day of the visit to the East Tennessee Discovery Center. Before sending the letters to the teachers and to the subjects' parents, the study was approved by The University of Tennessee Human Subjects Committee (Appendix H).

Data Collection

When arriving at the East Tennessee Discovery Center, each subject received a tag with a designated number. The numbers were computer generated by the UTK Math Department as a table of random numbers (Appendix I). Each school group in the museum entrance hall took a multiple choice pre-test quiz on simple machines before their visit to the museum and a multiple choice post-test after their visit. The purpose of giving visitors a quiz on the content of the selected exhibits was to verify how much exhibit information was learned during the visit. The quiz was designed to cover all areas and levels of content of the exhibit. Following the pre-test, a random sample was selected using the numbers assigned on the tags. The random sample group then explored either the traditional hands-on exhibit or the interactive multimedia computer exhibit. While the subjects were interacting with the exhibits, the researcher completed a data sheet and timed each subject using a stop watch to accurately collect the data (attracting power and holding power).

The only risks to the subjects were those stemming from the possibility that their identities might not be held confidential. However, the researcher tried to keep subjects' identities confidential by not requiring names when collecting the demographic data of the sample. Demographic data consisted only of age, sex, and race. The informed consent forms will be kept for 5 years at the College of Education, The University of Tennessee, Knoxville.

CHAPTER IV

RESULTS

The results of the study showed that the use of an interactive multimedia exhibit was more effective than a traditional hands-on exhibit to teach and clarify a specific science concept in a science museum setting. The physical science concept of simple machines was the subject of the study.

KNOWLEDGE GAIN

The two independent samples paired t-test (Table1) revealed a significant difference (t = 2.239, p = .027) in test score improvement using the multimedia method over the hands-on method.

Table 1. Two Independent Samples T-Test: Difference Between the Amount Learned in the Multimedia and Hands-on Methods.

t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Mean Lower	95% Confidence Interval of the Mean Upper
2.239	102	**.027**	9.4231	4.2090	1.0745	17.7717

The paired sample t-test (Table 2) made it possible to verify that the multimedia score improvement was significantly larger than zero, while the hands-on score

Table 2. Paired Sample T-Test: Amount of Improvement of the Knowledge Gain in Test Score.

Experimental Group	Mean (pos - prescore)	Std. Deviation	Std. Error Mean	t	df	Sig. (2-tailed)
Multimedia	15.0000	21.7382	3.0145	**4.976**	51	**.000**
Hands-on	5.5769	21.1821	2.9374	**1.899**	51	**.063**

improvement was not significantly larger than zero. Students learned more about simple machines when interacting with the multimedia exhibit ($t = 4.976$, $p = .063$) than the hands-on exhibit ($t = 1.866$, $p = .000$). Indicating that the multimedia method was more effective in teaching the physical science concept of simple machines. The pre-test group served as a control sample showing how much information visitors already knew about simple machines (Table 3).

The results supported the study's hypothesis that in a science museum setting, there is increased learning of a physical science concept when students interact with a multimedia exhibit in comparison to a hands-on exhibit. These results therefore sustained Balling's

Table 3. Mean Percentage of Students Pre-Test and Post-Test Correct Answers to the Knowledge Gain Multiple Choice Test.

Experimental Group	N	Pre-Test Mean Percentage of Correct Answers	Post-Test Mean Percentage of Correct Answers	Difference Between Post-Test and Pre-Test
Multimedia	52	50.8	65.8	**15.0**
Hands-on	52	62.1	67.7	**5.6**
Total	**104**	**56.5**	**66.8**	**10.3**

and Falk's (1981) notion that significant cognitive learning does occur through interactive computer experience during museum visits.

Research has shown that knowledge gain is related to exhibit type. As an exhibit becomes more participatory, increases the number of senses, or includes reinforcement, knowledge gain increases. As exhibits become more concrete than abstract, the greater the probability of knowledge gain (Shettel, 1973; and Solomon, 1979). According to Dandridge (1966), changes to the environmental and mentally stimulating conditions can be either conducive or adverse to learning. For example, peaceful surroundings in a school are more conducive to the function of learning than an environment of noise and distractions. The multimedia exhibit was located in a more isolated area of the science center -- Kidspace -- resulting in a setting where the conditions ideal for students to make full use of his or her ability to concentrate and learn.

There appears to be general agreement with the idea that interactive science museums, if properly structured and implemented, constitute a valuable cognitive and effective learning experience for both children and adults by enhancing actual learning and enthusiasm for learning (Shettel, 1973; Solomon, 1979; and Greenfield, 1995). Whether these functions are accomplished equally for females and males is another question, especially in light of studies showing that in general girls and boys do not receive equal experiences in or out of school (Greenfield, 1995).

The study's data (Table 4), although not significant with this number of subjects, exhibited a possible gender difference between the mean score of correct answers to the

Table 4. Mean Percentage of Correct Answers to the Knowledge Gain Multiple Choice Test.

Experimental Group	Gender	N	Pre-Test Mean Percentage of Correct Answers	Post-Test Mean Percentage of Correct Answers	Difference Between Post- and Pre-Test
Multimedia	Female	33	47.9	63.6	15.7
Hands-on	Female	30	61.3	70.3	9.0
Total	**Female**	**63**	**54.6**	**70.0**	**15.4**
Multimedia	Male	19	55.8	69.5	13.7
Hands-on	Male	21	62.4	63.3	0.9
Total	**Male**	**41**	**59.1**	**66.4**	**7.3**

knowledge gain pre- and post-visit tests. The score differences on both exhibits were slightly higher for females ($x_{multimedia} = 15.7$, $x_{hands\text{-}on} = 9.0$) than for males ($x_{multimedia} = 13.7$, $x_{hands\text{-}on} = 0.9$).

According to the ANOVA test (Table 5), this difference wasn't statistically significant ($p = .486$), confirming that there were no gender differences in learning the concept of simple machines.

HOLDING POWER

Holding Power is represented as the total number of seconds a visitor remains at the exhibit divided by the minimum number of seconds "S" necessary to read and see the exhibit (Kool, 1986). There were no significant differences in holding power between both exhibits. Although the results indicated a possible gender difference in holding power; females seemed to spend more time interacting with the hands-on exhibit, and males seemed to spend more time at the multimedia (Table 6).

Table 5. ANOVA Test for Gender and Exhibit Differences in Knowledge Gain.

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	3191.362a	3	1063.787	2.308	.081
Intercept	9574.992	1	9574.992	20.770	.000
Exhibit	2359.141	1	2359.141	5.117	.026
Sex	638.826	1	638.826	1.386	.242
Exhibit* Sex	223.907	1	223.907	.486	**.486**
Error	46099.984	100	461.000		
Total	60300.000	104			

a. R Squared = .065 (Adjusted R Squared = .037)

Table 6. Holding Power for the Experimental Exhibit Types Based on the Mean Length of Stop in Seconds.

Exhibit Type	Gender	N	Mean Length of Stop (seconds)	Holding Power (seconds *)
Multimedia	Male	19	237.9	1.0
Multimedia	Female	33	201.9	0.8
Hands-on	Male	21	116.0	0.8
Hands-on	Female	30	140.4	1.0

*Minimum number of seconds (T) necessary to read and see the exhibit: $S_{Multimedia}$=240 seconds & $S_{Hands\text{-}on}$=140 seconds.

The ANOVA test (Table 7) showed that the gender difference wasn't statistically significant (p = .213). However, there was a possibility of an interaction between gender and holding power (p = .046), but it wasn't strong enough in the sample. Further studies should consider a larger sample in order to verify the occurrence of gender difference in holding power in science museum settings.

ATTRACTING POWER

Attracting Power is the number and kinds of visitors who approach a particular exhibit (Miles et al., 1982). The percentages of attracting power for the multimedia and hands-on exhibit indicated that both exhibits were very effective in attracting observers (Table 8). Although a random sample was selected by using the numbers assigned on the tags to explore either the traditional hands-on exhibit or the interactive

Table 7. ANOVA Test for Experimental Exhibit Types Holding Power.

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	.587 a	3	.196	1.522	**.213**
Intercept	84.720	1	84.720	658.623	.000
Exhibit	7.914E-03	1	7.914E-03	.062	.805
Sex	4.648E-04	1	4.648E-04	.004	.952
Exhibit* Sex	.525	1	.525	4.082	**.046**
Error	12.863	1	.129		
Total	101.613	104			

a. R Squared = .065 (Adjusted R Squared = .037)

Table 8. Percentage Attracting Power for the Experimental Exhibit Types by Gender.

Exhibit Type	**Gender**	**N**	**Attracting Power**
Multimedia	Male	19	**100%**
Multimedia	Female	33	**100%**
Hands-on	Male	21	**100%**
Hands-on	Female	30	**100%**

multimedia computer exhibit, the students had free will in choosing whether to interact with the exhibits. The researcher's goal was to maximize the ability to document behavior while minimizing the disturbance and distortion of the behavior.

Summarizing, the study showed increased learning when students interacted with a multimedia exhibit in comparison with a hands-on exhibit, but both exhibit types were very efficient in attracting and engaging students. The ANOVA test verified no gender differences in learning or in holding power between the two exhibits. Although, a larger sample, might show results indicating a gender difference, as previous studies have suggested (Koran, Koran, & Longino, 1986; and Greenfield 1995).

CHAPTER V

CONCLUSIONS AND IMPLICATIONS FOR FURTHER STUDIES

KNOWLEDGE GAIN

The results of the study led to the conclusion that there was a significant difference in test score improvement (knowledge gain) when students interacted with a multimedia exhibit compared to a traditional hands-on exhibit. Students seemed to be more interested when interacting with a multimedia exhibit. They spent time carefully reading the instructions and information available in each card of the multimedia program. When interacting with the illustrations, animations, and sounds, students clearly expressed excitement, and curiosity. In contrast, students who interacted with the hands-on exhibit cared little about reading the instructions and information available at the labels of the exhibit. Some of them began interacting with the pulleys and levers immediately, exhibiting more "fun-play" behavior rather than trying to find out why it was easier or more difficult to lift bags with the same weight using different pulleys and levers.

The multimedia exhibit was capable of creating an environment more conducive for learning the specific physical science concept, simple machines, than using only a traditional hands-on exhibit. This was because, as previous research has shown, a good interactive multimedia exhibit involves touching (e.g., mouse pad, touch screen), solving problems, accepting challenges, answering questions, exploring ideas, and making predictions, thereby creating a motivating and conducive environment in which learning can take place. Furthermore, a multimedia exhibit offers access to information in a wide variety of text, visuals, sounds, and interactive modes to accommodate different ages, vocabularies, knowledge, interests, and learning styles. The multimedia exhibit provides a range of engaging experiences that are rewarding to visitors, making learning experience more fun, more meaningful, and more relevant (Borum, 1984; Klevans, 1990; Flagg, 1991; Screven, 1992; and Greenfield, 1995).

To carry these findings to a logical conclusion, if the cognitive experience gained by the museum visitor can be linked to the internal and external experiences that occur in everyday living, then the informal kind of learning that is possible in museums is invaluable. It is important to understand how opportunities for learning in museums can be enhanced by appropriate links to other learning environments, as well as ways in which learning in other environments might be enhanced through appropriate links to museums.

HOLDING POWER

There was no difference between the multimedia and hands-on exhibits' holding power (total number of seconds a visitor remains at the exhibit divided by the minimum number of seconds "S" necessary to read and see the exhibit). However, the results revealed a possible gender difference in holding power. The amount of time spent interacting with the hands-on exhibit seemed greater for females and greater for males with the multimedia exhibit. However, the sample may not have been large enough to confirm the gender difference.

One factor that had an important influence on the holding power of both exhibits was the actual time that each school spent in the East Tennessee Discovery Center. The majority of school groups visiting the Center during the research period had a defined amount of time to spend interacting with the exhibits. Each school group spent an average of 60 minutes in the science center as a whole and probably only 30 minutes or less interacting with the exhibits. Students' time to explore all the exhibits and to participate in the research was limited.

ATTRACTING POWER

Students were equally attracted to approach and interact with both simple machines exhibits (multimedia and hands-on). However, the fact that a random sample was selected to explore either the traditional hands-on exhibit or the multimedia computer exhibit may have influenced the attraction power of the exhibits (number and kinds of visitors who approached a particular exhibit). The use of random by assigned numbers probably restricted the students' use of free will to choose the exhibit with which they wanted to interact. Consequently, any difference in the kinds of visitors, such as gender, that interacted with both exhibits is not shown, although research has clearly shown that there are gender differences in attraction power.

Greenfield (1995), in her research on sex differences in science museum exhibit attraction, found that boys were more likely to interact with computers and exhibits illustrating physical science principles while girls would interact more with puzzles and hands-on exhibits focusing on the human body. However, by using randomly assigned numbers, the researcher increased the possibility of obtaining a representative sample to interact with both exhibits because each school group had a limited time in the exhibit halls of the science center.

IMPLICATIONS FOR FURTHER STUDIES

The findings of the study suggest several implications for museum researchers and educators. First, it is very important to continue research on the impact of new technology on learning in informal settings. The development of research techniques, such as the use of larger samples to evaluate the possible influence of gender interaction on holding power, attraction power, and learning, is essential to successfully determine the educational value of exhibits and educational programs. The increasing affordability, reliability, and flexibility of computers and video disks are resulting in their proliferation in public museums, zoos, and visitor centers. Emerging technologies have an immense potential for improving the quality and effectiveness of the museum experience.

Second, the social context of a museum visit has a powerful influence on behavior and learning. Interactions between individuals are at least as important for learning as the interactions between the individual and the exhibit (Diamond, 1986; and Blud, 1990). McManus (1988) extensive research led her to conclude that the social aspect of the visit is a fundamental source of satisfaction in museum visits. Peer teaching frequently occurs, with children taking the role of teachers as they question their companions, read labels aloud, and demonstrate the way an exhibit works (Gottfried, 1980).

A final implication for making a visit to a science center more beneficial to student is the need to know how to integrate a science center as an adjunct to the science classroom so that the interactive center becomes, in effect, a giant classroom. Teacher preparation prior to the museum visit is crucial. A recommendation for this final implication is that teachers need to visit the science center to discover:

- what exhibits are there,
- what concepts or phenomena they demonstrate,
- what level of thought processes are required for them to be understood,
- whether there are worksheets or other cues available,
- how students' movement through the center can be organized, and
- how long the visit should last.

Science museum educators should organize programs for teachers to facilitate these prior visits. With this information, teachers can determine how to make the visit to fit the needs of their current teaching program.

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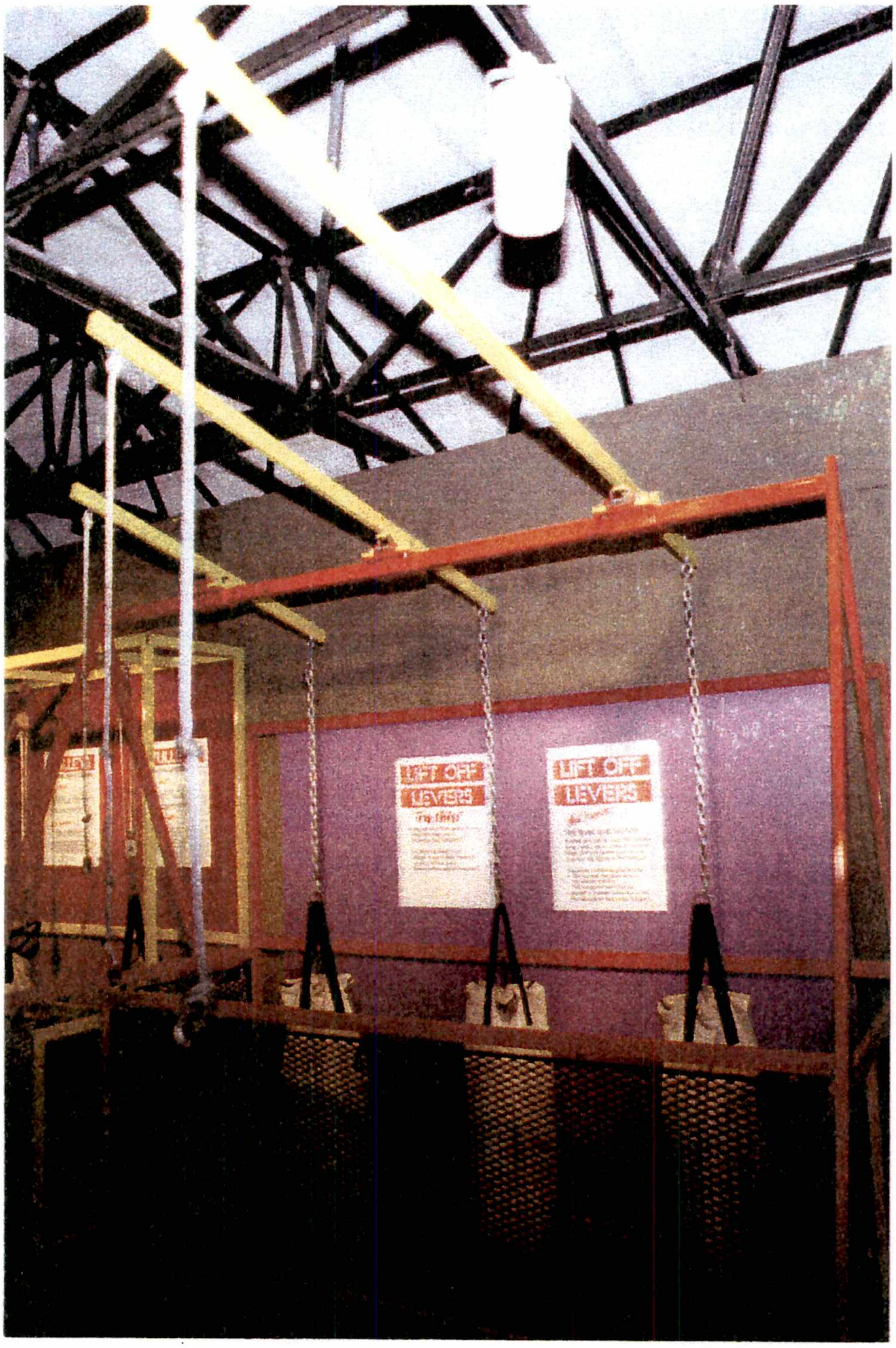
APPENDICES

Appendix A

Hands-on Exhibit: Pulleys

Appendix A

Hands-on Exhibit: Levers



Appendix B

Hands-on Labels

PULLEYS

1X FIXED PULLEY

Try this!

Try to lift the 100 lb. bag by pulling the knotted rope on each pulley assembly. (Each bag weights the same)

Which pulley makes it easiest to lift the weight?

What happens…

A pulley is a simple machine made of a turning wheel and rope. This pulley turns your downward pull into an equal upward force. It does not multiply the force of your pull, it only changes the direction of the force.

2X PULLEY COMBO

Try this!

Try to lift the 100 lb. Bag by pulling the knotted rope on each pulley assembly. (Each bag weights the same)

Which pulley makes it easiest to lift the weight?

What happens…

This pulley is a combination of one fixed pulley and one movable pulley. You can lift the same weight with half the force needed for a single fixed pulley, but you must pull the rope twice as far to lift it to the same height.

3X PULLEY COMBO

Try this!

Try to lift the 100 lb. Bag by pulling the knotted rope on each pulley assembly. (Each bag weights the same)

Which pulley makes it easiest to lift the weight?

What happens…

Each loop around the wheel increases the mechanical advantage (multiplication of force) and makes it easier to lift the weight. This pulley system has a mechanical advantage of 3 - you can lift the same weight with one-third the force needed for a single fixed pulley, but you must pull the rope three times as far.

LIFT OFF LEVERS

Try this!

Compare the three yellow levers.

- How are they alike?
- How are they different?

Pull down on each rope .

- Which lever makes it easiest to lift a 100 lb. Bag?
- Which lever makes it hardest?

What happens…

The lever and fulcrum

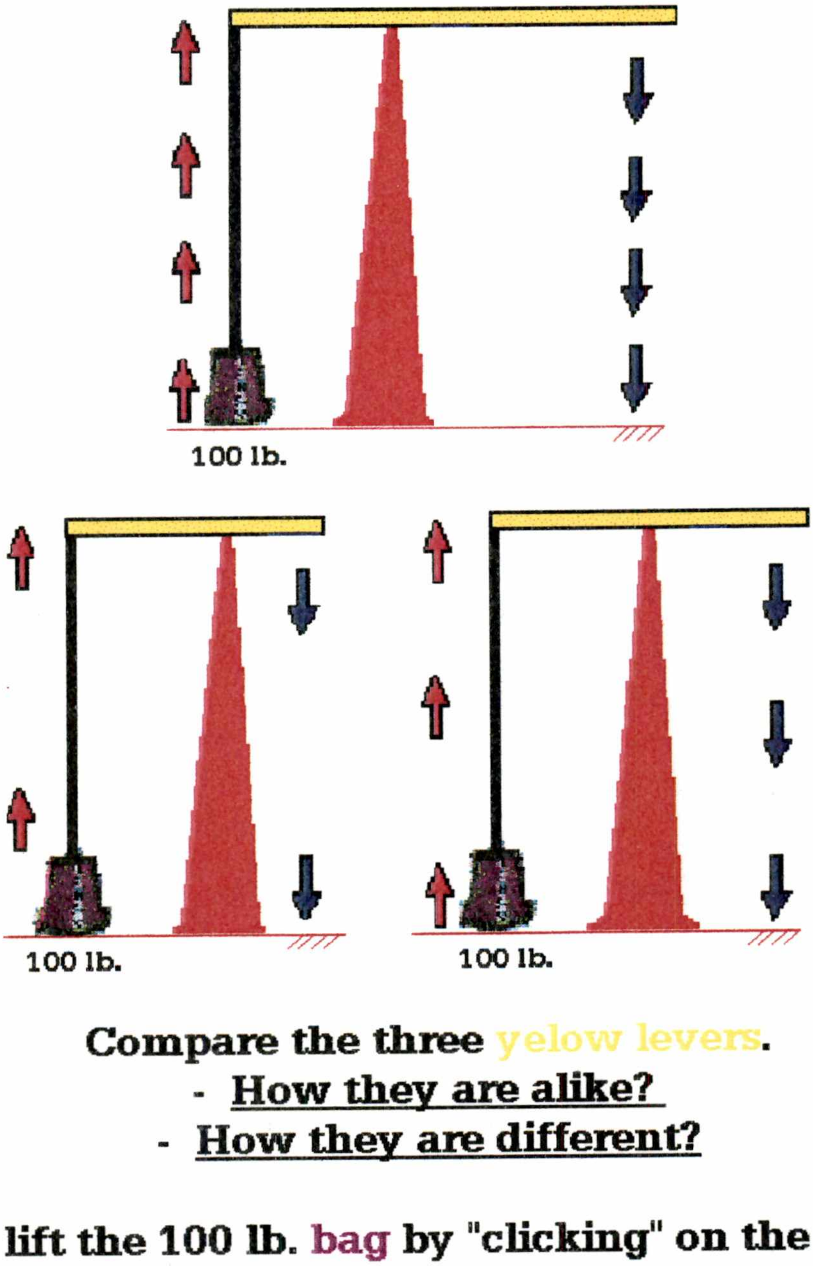
A *lever* is a bar or pole that pivots on a fixed point, called a *fulcrum*. Here, the yellow bars are levers and the red stand is the fulcrum.

You have probably discovered:

- The longer the lever arm, the easier the lift.
- The longer lever must be pulled a greater distance to lift the weight to the same height.

Appendix C

HyperStudio Sample



Compare the three yelow levers.

- **How they are alike?**
- **How they are different?**

Try to lift the 100 lb. bag by "clicking" on the blue arrows. Each bag weights the same.

- **Which lever makes it easiest to lift the weight?**

Appendix D

Attracting Power and Holding Power Data Sheet

Name of the Observer:

Name of the School: **Date:**

Attracting Power

Exhibit Type: Hands-on ( ) Computer ( )

Age:

Sex: Male ( ) Female ( )

Holding Power

Time spent viewing the exhibit **(T=seconds):**

Holding Power **(T/X minimum of seconds necessary to read and see the exhibit):**

Appendix E

Quiz

Name of the School:______________________________________
Date:_______________

Number:_________ **Age:**________ **Sex: ( ) Female ( ) Male**

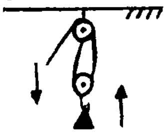
Race: ( ) White/Caucasian ( ) Black ( ) Hispanic ( ) Asian

Grade:____ **Did you study Simple machines at school ? ( ) Yes ( ) No**

INSTRUCTIONS: Please circle the correct answer for each question. There is only one correct answer for each question.

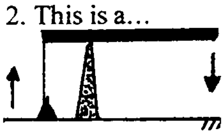
---

1. What is this?



a. **2 X Pulley Combo**
b. **1 X Fixed Pulley**
c. **2 X Pulley Combo**

2. This is a...



a. **2 X Pulley Combo**
b. **Lever**
c. **1 X Fixed Pulley**

3. A Lever and a Pulley are:
Machines
b. **Simple Machines**
c. **Complex Machines**

4. Which Pulley makes it easier to lift the a. **Power** bag?
a. **3 X Pulley Combo**
b. **2 X Pulley Combo**
c. **3 X Pulley Combo**

5. Which Pulley makes it harder to lift the bag?
a. **3 X Pulley Combo.**
b. **1 X Fixed Pulley.**
c. **2 X Fixed Pulley.**

6. The Lever with the longer arm...
a. **Makes it easier to lift the bag.**
b. **Does not make a difference to lift the bag.**
c. **Makes it harder to lift the bag.**

7. What is Fulcrum?
a. **Fixed point on which a lever turns.**
b. **Fixed point on which a Pulley turns.**
c. **Non-Fixed point on which a Lever turns.**

8. Simple Machines are devices that...
a. **Don't help you to lift the weight.**
b. **Makes it difficult to lift the weight.**
c. **Help you to lift the weight.**

9. What is Mechanical Advantage?
a. **Efficiency of the force.**
b. **Multiplication of the force.**
c. **Reduction of the force.**

Appendix F

Parent's Letter

Date

Name of the School
Address

Dear Parent/Guardian:

__________ Elementary School was chosen to participate in a research study during Mr./Mrs. _______ class visit to the East Tennessee Discovery Center on **(date)**. The purpose of the study is to verify if the use of an interactive multimedia exhibit is more effective than a traditional hands-on exhibit to teach scientific concepts. The study will focus on a particular physical science exhibit, Simple Machines, which is a permanent display at the East Tennessee Discovery Center, and an interactive computer exhibit which is being designed to be integrated within the physical science exhibits. Your child will be involved in the study for about 30 minutes. The results of this project will be included in a master's thesis.

In order for your child to participate in the study, a parental consent form needs to be signed. Please send the form back to Mr./Mrs.______ along with the permission slip before the visit to the East Tennessee Discovery Center takes place on **(date)**. This research study is strictly voluntary, and your child's identity will be anonymous. You may withdraw your child from this research project any time.

Thank you very much for your time. If you have any question regarding the study, please call me at (423) 974-4453.

Sincerely,

Roberta Ayres
Graduate Student
University of Tennessee, Knoxville

Parental Consent Form

"Increased Learning of a Physical Science Concept, Simple Machines, Via an Interactive Multimedia Exhibit Compared to a Hands-on Exhibit in a Science Museum Setting"

The purpose of the study is to verify if the use of an interactive multimedia exhibit is more effective than a traditional hands-on exhibit to teach scientific concepts. The study will focus a particular physical science exhibit, Simple Machines, which is a permanent display at the East Tennessee Discovery Center, and an interactive computer exhibit which is being designed to be integrated within the physical science exhibits. The results of this research project will be included in a master's thesis.

Your child will be involved in this study by way of the following:

1. Pretest quiz on simple machines.
2. Posttest quiz on simple machines.
3. The time that each student spent on each exhibit is going to be recorded.

All these activities should not take more than 30 minutes per student. There are no foreseeable risks to the students involved. Specific information about individual student, such as age and sex, will be kept strictly confidential. The results that are published publicly will not refer any individual student's name, since the study will only analyze relationships among groups of data.

The purpose of this form is to allow your child to participate in the study, and to allow the researcher to obtain the necessary information in order to analyze the outcomes of the study. Parental consent for this research study is strictly voluntary without undue influence or penalty. You may withdraw your child from this research project at any time.

If you have any additional questions regarding the study, rights of subjects, or potential problems, please call me up at (423) 974-4453.

______________________	______________________	__________
Student's Name (Printed)	Student's Signature	Date

______________________	______________________	__________
Parent/Guardian's Name (Printed)	Parent/Guardian's Signature	Date

Appendix G

Teacher's Letter

Date

Name of the Elementary School
Address

Dear Mr./Mrs. __________:

Your class has been chosen to participate in a research study during your visit to the East Tennessee Discovery Center on **(date)**. The purpose of the study is to verify if the use of interactive multimedia exhibit is more effective than a traditional hands-on exhibit to teach scientific concepts. The study will focus a particular physical science exhibit, Simple Machines, which is a permanent display at the East Tennessee Discovery Center, and an interactive computer exhibit which is being designed to be integrated within the physical science exhibits. The results of this research project will be included in a master's thesis.

Your class will be involved in this study by way of the following:

1. Pre-test quiz on simple machines.
2. Post-test quiz on simple machines.
3. The time spent on each exhibit is going to be recorded.

In order for your class to participate in the study, a parental consent form needs to be signed. Please send the form to each one of your students together with the permission slip for the museum's trip. That way, on the day of your visit to the East Tennessee Discovery Center, your students will have the parental consent form previously signed.

The results of these visitor studies can be used to modify and enhance exhibit design. This function of visitor analysis becomes increasingly important as the economic need for scientific literacy becomes greater. If we, as educators, come to better understand the process by which visitors learn in the informal setting of the museum, this knowledge can be used to ensure that more visitors encounter successful learning situations. Exhibits become not only more effective teaching tools, but also become intrinsically more interesting.

Thank you very much for your time. If you have any question regarding the study, please call me at (423) 974-4453.

Sincerely,

Roberta Ayres
University of Tennessee, Knoxville
Graduate Student

Appendix H

Form B: Human Subjects in Research

Application for Review by the UTK Institutional Review Board

IRB #________

Date Received in OR________

THE UNIVERSITY OF TENNESSEE, KNOXVILLE

Application for Review of Research Involving

Human Subjects

I. IDENTIFICATION OF PROJECT

A. Principal Investigator

Roberta Gomes de Souza Ayres

401 Gallaher View Rd. Apt. 311
Knoxville, TN 37919
Phone/Fax: (432) 690-4616

Email: rayres@utkux.utcc.utk.edu

B. Faculty Advisor

Claudia T. Melear

Department of EdSMRT
311Claxton Education
Knoxville, TN 37996
Phone: (423) 974-5037

Email: ctmelear@utkux.utcc.utk.edu

C. Project Status

Masters Thesis

D. Tittle of Project

"Increased Learning of a Physical Science Concept, Simple Machines, Via an Interactive Multimedia Exhibit Compared to a Hands-on Exhibit in a Science Museum Setting".

E. Starting Date

Second week of April 1997.

F. Estimation Completion Date

End of July 1997

G. External Funding

N/A

II. PROJECT OBJECTIVES

The objectives of this study are to verify if the use of an interactive multimedia exhibit is more effective than a traditional hands-on exhibit to teach complex physical science concepts, such as simple machines, for museum visitors. **The results of this project will be included in a masters thesis.**

III . DESCRIPTION AND SOURCE OF RESEARCH SUBJECT

The subjects of the study will be composed of elementary school students that will visit the East Tennessee Discovery Center during the period of April through July of 1997. The age range of students enrolled in elementary school is normally from 5 to 10 years old. The study will use a large random sample, Nmin=100 and Nmax=300, so that the possibility of pre-test score influencing the posttest score can be eliminated. According to the State of Tennessee Curriculum Framework (1995), students learn about simple machines during the third grade. For this reason, the study will focus on elementary school students.

Friday, the East Tennessee Discovery Center receives visitors from local schools, and also schools from distant areas. During the week-end the visitors are mainly composed of family groups. According to the East Tennessee Discovery Center schedule, the following groups will be visiting museum during the period of April and May:

Date	Name of the School	Area (County)	Number of students & Grade
April 9,1997	Foot Hill Elementary School	Blount County	N=80 3rd Grade
April 18, 1997	Saint Jude Elementary School	Chattanooga	N=45 3rd Grade
April 23, 1997	Sterchy Elementary School	Knox County	N=38 5th Grade
May 7, 1997	Rich View Elementary School	Roane County	N=55 3rd Grade
May 16, 1997	Jefferson Elementary School	Jefferson Co.	N=39 3rd Grade
May 21, 1997	Rich View Elementary School	Roane County	N=55 3rd Grade

Other schools may be added to the list as more visits are scheduled to the East Tennessee Discovery Center during the period April through July.

IV. METHODS AND PROCEDURES

The following methods and procedures are going to be used to collect data:

When arriving at the East Tennessee Discovery Center, each student will attach tag with a designated number. The entire group is going to take a multiple choice pre-test quiz and a multiple choice post-test quiz at the museum's entrance hall, respectively before and after the visit to the museum. A random sample is going to be selected using the numbers assigned on the name tags to explore either the traditional hands-on exhibit or the interactive computer exhibit . The numbers are going to be selected accordingly to a computer generated table of random numbers created by the UTK Math Department .

The purpose of giving visitors the pre- and post- The purpose of giving visitors the pre- and post-tests quiz on the content of the selected museum exhibits (simple machines), was to verify how much exhibit information was learned in the course of the visit to the East Tennessee Discovery Center. The quiz was designed by the researcher to cover all areas and levels of content of the exhibit. A pre-test group (visitors tested before their museum visit) will server as a control to tell us how much of this information visitors already knew. Thus, the difference between the mean score of pre-visit and post-visit samples is going to be the measure of museum learning. T- test is going to be used to compare if the mean of pre- post-values is statistically significant.

V. SPECIFIC RISKS AND PROTECTION MEASURES

The only risks to the subjects are those stemming from the possibility that their identities might not be held confidential. The researcher **intends** to keep subject's identities confidential by not requiring names when collecting the demographic data of the sample. The demographic data will consist only of age, sex, and race.

VI. BENEFITS VS RISKS

The results of these visitor studies can be used to modify and enhance exhibit design. This function of visitor analysis become increasingly important as the economic need for scientific literacy becomes greater. If we, as educators, come to better understand the process by which visitors learn in the informal setting of the museum, this knowledge can be used to ensure that more visitors encounter successful learning situations. Exhibits become not only more effective teaching tools, but also become intrinsically more interesting.

VII. METHODS FOR OBTAINING "INFORMED CONSENT" FROM SUBJECTS

A letter containing a detailed description of the purpose of the study will be mailed to the teachers together with the informed consent form for each student, since each school visit is scheduled far in advance. That way, on the day of the school visit to the East Tennessee Discovery Center students will have informed consent properly signed.

The signed informed consent forms will be stored at the **Education in the Department of Education in Sciences, Math, Research and Technology Unit for the duration of this research and for three years following the completion of the research.**

VIII. QUALIFICATIONS OF THE INVESTIGATOR

The principal investigator received in 1991 Bachelor and Licentiate Degrees in Biology at the Mackenzie University, Sao Paulo, Brazil. In partial fulfillment of the requirements for the Licentiate Degree in Biology, the researcher had two years of teaching practice in elementary and secondary school level.

On the period of 1993 through 1995, the principal investigator was involved in educational activities and summer camps designed for elementary and secondary school level, conducted at Mote Marine Laboratory Aquarium, Sarasota, Fl.

The principal investigator previous experiences together with the East Tennessee Discovery Center expertise will provide all the requirements to perform the proposed research. The research is supervised by Dr. Claudia T. Melear, Associate Professor and Science Education Coordinator.

IX. FACILITIES AND EQUIPMENT TO SUPPORT THE RESEARCH

This study is going to be conducted in East Tennessee Discovery Center, which is located at 516 N. Beaman Street/Chilhowee Park, Knoxville, TN 37914. The East Tennessee Discovery Center is an exciting science center for students of all ages that features hands-on exhibits. The exhibits are of five topics:

1. **Life Sciences**, featured by ten aquariums with fresh water fish and other creatures, collection of stuffed animals, easy-view microscopes, insect collection, and seasonal live insects.

2. **Physical Sciences**, featured by a group of exhibits that demonstrate various aspects of light and visual perception, the Giant Whisper Dish which demonstrate reflection and transmission of sound waves, simple machines such as pulleys and levers, and a group of exhibits that demonstrate various aspects of electricity and magnetism.

3. **Earth Science**, featured by displays of vegetal and animal fossils, and a large display of minerals, crystals, geodes, the three basic types of rocks. The display also includes a case of "touchable" specimens.

4. **Kidspace**, which is a new exhibit area designed to provide multiple experiences for young children. Features include recycling plastics, imagination reading tree, whose hat, geoboards, tangrams, magic school bus computer, imagination lab., and building material.

5. **AKIMA Planetarium**, which can accommodate 50 students at a time. The planetarium offers different programs such as the sky tonight, and planet talk.

East Tennessee Discovery Center is an institution committed to innovative approaches in conveying science to the public, and attempt to create a playful environment where visitors can explore and investigate objects and natural phenomena. The environments are structured and visitors are encouraged to bring their own learning styles and experiences to the centers.

This study is going to compare the knowledge gain and effectiveness using a particular physical science exhibit, Simple Machines, which is a permanent display at the East Tennessee Discovery Center, with an interactive computer exhibit which is being designed be integrated within the physical science exhibits. The Simple Machines is a group of exhibits that demonstrate how basic types of machines multiply human strength, including levers and pulleys.

X. RESPONSIBILITY OF THE PRINCIPAL INVESTIGATOR

By compliance with the policies established by the Institutional Review Board of The University of Tennessee, Knoxville, the principal investigator subscribe to the principles stated in "The Belmont Report" and standards of professional ethics in all research, development, and related activities involving human subjects under the auspices of The University of Tennessee, Knoxville. The principal investigator further agree that:

a. Approval will be obtained from the Institutional Review Board prior to instituting any change in this research project.

b. Development of any unexpected risks will be immediately reported and submitted to the Compliance's Section.

c. An annual review and progress report (Form R) will be completed and submitted to the Institutional Review Board.

d. Signed informed consent documents will be kept for the duration of the project and for at least three years thereafter at a location approved by Institutional Review Board.

XI. SIGNATURES

Principal Investigator: Roberta Gomes de Souza Ayres

Signature ________________________________ __________
(Date)

Faculty Advisor: Claudia T. Melear

Signature ________________________________ __________
(Date)

Unit Head of Education in the Sciences, Mathematics, Research and Technology:
Marshall E. Meyers Jr.

Signature________________________________ __________
(Date)

Department Faculty Responsible for Human Subject in Research: John R. Ray

Signature________________________________ __________
(Date)

XVII. DEPARTMENTAL REVIEW AND PROPOSAL

The application described above has been reviewed by the IRB department review committee and has been approved. The DRC further recommends that this application be reviewed as:

[ ] Expedited Review-Category(ies):__________________

[ ] Full IRB Review

Chair, DRC________________________________

Signature__________________________________ ____________
(Date)

Department Head__________________________

Signature__________________________________ ____________
(Date)

Appendix I

Table of Random Numbers

92	31	11	22	26	61	40	25	96	84
59	27	53	20	91	72	28	69	33	59
41	45	19	51	8	60	28	47	59	85
57	2	15	67	23	41	78	14	65	25
97	76	51	2	47	42	73	26	10	57
84	2	53	54	4	60	14	32	58	72
68	14	74	83	32	49	75	9	14	91
34	62	18	37	63	16	78	36	42	40
44	25	93	96	31	96	56	44	79	13
68	47	78	93	29	9	93	55	18	6
98	3	20	15	39	82	31	69	69	72
59	13	49	51	8	79	47	15	75	26
27	94	24	5	87	4	65	31	59	34
89	56	36	8	22	26	89	53	46	10
76	5	22	76	56	30	55	54	44	81
31	22	74	6	78	13	9	42	95	68
75	83	75	62	91	97	40	31	1	85
41	77	41	62	53	96	43	59	1	38
91	83	11	17	88	41	29	96	82	75
16	9	58	42	23	99	38	62	30	91
98	22	19	39	35	23	86	77	81	87
66	23	20	76	39	59	68	19	7	2
94	22	10	51	63	84	1	53	97	82
43	95	3	13	33	37	35	19	65	68
57	30	91	76	58	29	35	25	48	93
78	41	14	40	43	29	23	95	32	20
77	27	14	79	39	46	16	74	65	81
41	72	63	31	48	72	60	35	48	59
27	26	52	93	65	46	72	88	40	4
59	17	82	72	96	21	69	63	94	85
95	87	57	58	17	57	80	29	43	28
39	21	5	91	65	70	36	37	9	76
92	18	44	74	41	39	45	10	53	91
46	48	77	55	57	45	11	36	25	5
15	16	25	20	6	90	41	93	78	100
20	21	18	64	45	59	53	90	20	6
32	66	54	60	72	10	56	34	97	81
39	12	97	63	83	54	4	23	98	33
23	18	53	92	32	98	51	85	40	22
43	23	39	96	82	10	57	38	44	54
70	82	66	18	97	49	23	52	23	21
85	46	38	89	89	70	39	40	7	29
13	49	51	51	96	85	61	52	22	56
6	44	90	23	61	38	22	84	89	45
4	25	42	93	66	31	14	55	21	21
84	34	21	86	84	16	70	97	68	44
53	25	87	93	47	48	31	69	83	19
13	87	96	6	80	61	36	45	67	57
65	50	90	85	36	26	1	58	22	20
1	26	44	87	19	42	35	49	10	17

VITA

Roberta Ayres was born in Sao Paulo, Brazil, on September 26, 1968. She attended private elementary and secondary schools in Sao Paulo. She entered Mackenzie University, in January 1988, and in April 1992 she received the Bachelor of Science degree in Biology, with teaching certification in elementary and secondary education. During August of 1993 through June of 1995, Ms. Ayres worked as a research assistant at Mote Marine Laboratory, Sarasota, Florida. She was involved with the Departments of Marine Mammals, Fisheries and Environmental Services. In January 1996, she entered the Masters of Education program at The University of Tennessee, Knoxville. She will receive a Master's degree in May 1998. While at The University of Tennessee, the author was awarded a graduate assistantship by the Center for International Education. Under this assistantship she coordinated and planned programs for students at the International House at The University of Tennessee.

Permanent Address:

Rua Banibas, 660
Alto de Pinheiros
CEP:05460-010
Sao Paulo - S.P.
Brasil