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The effects of computer simulation models on middle school students' understanding of the  
anatomy and morphology of the frog

by

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A dissertation submitted to the graduate faculty  
in partial fulfillment of the requirements for the degree of  
DOCTOR OF PHILOSOPHY

Major: Education (Curriculum and Instructional Technology)

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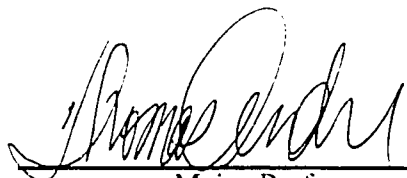
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## GENERAL INTRODUCTION

### Computer Simulations

Computer simulation is the use of a powerful tool, the computer, to imitate or replicate an object in a real or imagined world. Due to an increase in computational power and improvement of software designs, computer systems can imitate situations of great complexity and provide a high level of interactivity. A number of authors have argued that, in science courses, classroom simulations potentially have an important and valid role in creating virtual experiments and problem-based microworlds that allow students to use instruments and monitor experiments, test new models, and improve their intuitive understanding of complex phenomena. Simulations are also potentially useful for simulating experiences that are impossible, impractical, or too dangerous to perform in laboratories. Simulations can also provide students with learning environments in which students search for meaning, appreciate uncertainty, and acquire responsibility.

The use of simulations in science education can make significant contributions by providing appropriate learning opportunities to diverse learners and motivating students to learn science, both inside and outside of the school environment. Computer simulations potentially enable learners to be actively involved in the learning process, to generate and test ideas, and to see and feel things that are not feasible to do with other instructional methods. Simulations allow group cooperation, which is effective in generating new ideas, solving problems, and helping students learn from each other. Learning to work cooperatively is an important goal for children in science and all other subjects. Simulations can motivate students of different learning abilities by enabling them to interact with a given task and work with problems that bring forth meaningful results. Simulations can reduce teachers' teaching times, provide opportunities for student discussion and interaction, and thus, increase communication and reduce both social and learning differences.

### Dissertation Organization

This dissertation reviews the role of simulations in science learning and reports an investigation of the effect of computer simulations in students' understanding of anatomy and morphology of the frogs. This question is explored in two separate papers. This first paper is a review of literature on the topics of videodiscs and simulations in science education and as potential alternatives for traditional methods of dissection. The second paper describes an experimental study that investigates the use of simulations before and after dissection. Following the second paper is a general conclusions section. Additional material that will not be submitted with the papers is found in the appendices. The references cited throughout the dissertation are listed following the appendices.

## COMPUTER SIMULATIONS AND LEARNING SCIENCE: A REVIEW OF THE LITERATURE

A paper to be submitted to the Review of Educational Research

Joseph Paul Akpan

### Abstract

This paper reviewed empirical and theoretical/speculative papers on simulations in science education. Proponents claim advantages for simulations, such as greater experiential learning and higher student motivation. Critics claim simulations subvert scientific understanding because simulated experiences are insufficiently real. One particular focus was the role of simulations as replacement for dissection of animals. This issue is politically controversial because animal rights activists question the morality of dissection, while others argue that science learning is damaged by failure to experience dissection. While suffering numerous methodological defects, the available empirical research on simulations suggests the following: simulated dissection and actual dissections typically lead to equivalent performance on achievement tests, simulations used before actual dissections may enhance dissection performance, and experiential simulations facilitate learning from subsequent didactic instruction. Implications of these conclusions for education practice were discussed.

### Introduction

A number of authors have suggested that simulations can have positive effects on student learning. Zietsman & Hewson (1986) indicated that “simulations are credible representations of reality, capable of producing significant conceptual change in students holding the alternative conception” (p. 28-38). Jerome Bruner (1966) concluded a discussion

of innovative teaching materials of the late 1950s by saying that “the intelligent use of ‘audiovisual’ resources will depend upon how well we are able to integrate the technique of the filmmaker or the program producer with the technique and wisdom of the skillful teacher ” (p. 23). Computer simulations seem to meet the criteria for constructive learning theory and knowledge construction. This new constructivist theory argues that meaningful learning depends on the construction of knowledge by the learner. Constructivists assert that learning is best understood as “a self-regulated process of resolving inner cognitive conflicts that often become apparent through concrete experience, collaborative discourse, and reflection” (Duffy & Jonassen, 1992, p. 40). Duffy and Jonassen claimed that simulations can allow a learner to function at a level that transcends the limitations of his or her cognitive system and therefore, are compatible with a constructive theory about knowledge. Many educators in the current school reform movement argue that the best possible way to learn is to discover information on one’s own (Brooks & Brooks, 1993). Simulations can provide a learning environment for the learner’s construction of new schemata.

Clark (1983) argued that media, in and of themselves, do not affect learning. Rather, it may be certain qualities of media that may affect particular cognitive processes that are relevant for students with specific aptitudes to learn particular knowledge or skills. In contrast, Kozma (1991) argued that when learners are actively working with a medium, they construct meaningful knowledge and that the medium and the methods can cause more or different learning depending on the kind of medium used by the learner. Further, he argued that it is feasible for the medium to provide a theoretical background, especially when the “learner is actively collaborating with the medium to construct his knowledge” (p. 178).

Brant, Hooper and Sugrue (1991) argued that “(a) simulations establish a cognitive framework or structure to accommodate further learning in a related subject area, and (b) simulations provide an opportunity for reinforcing, integrating and extending previously learned material. Therefore, the effectiveness of a given simulation may depend upon when it

is administered within an instructional sequence” (p. 469). Thomas and Hooper (1991) argued that “simulations provide the learner with an environment to focus on without exacting control from the learner, offering unique learning opportunities in all subject areas insofar as simulations permit the attainment of learning goals that are beyond traditional and other computer based instructional methods” (p. 497). Alessi and Trollip (1985) suggested that students are motivated by simulations and also learn by interacting with them in a manner similar to the way they would react in real situations. Carlsen and Andre (1992) argued that one way to develop effective problem-solving schemata is through appropriate experiences to either promote the development of the conditional component of a schema or to develop proper pattern recognition component of a schema. According to Andre and Haselhuhn (1995) “simulations provide a potential means of providing students with experiences that facilitate conceptual development” (p. 2).

Despite these arguments in favor of simulations, previous reviews of research on the use of simulations have not indicated that simulations have a clear cut advantage. This lack of evidence may be due to wrong questions that some researchers have asked or to inappropriate instructional design and unrealistic roles expected of simulations. Cherryholmes (1966) reviewed six studies on educational simulations and concluded that simulations, compared to traditional methods of instruction, offer no significant advantages with regard to learning, retention, critical thinking or attitude change. Pierfy (1977) reviewed twenty-two comparative studies on simulation games and suggested that simulation games are no more effective than traditional classroom methods of instruction. Pierfy did state that simulation games appear to have an advantage when it comes to retention of information and to attitude. A meta-analysis of 93 empirical research studies concerned with simulation (Dekkers and Donatti, 1981) failed to support the contention that use of simulation activities in the classroom resulted in increased cognitive development or retention compared with traditional methods of instruction. On the other hand, Orlansky and String (1979) compared 30 empirical studies on military students’



training achievement when either computer simulation instruction or conventional hands-on instruction was used. Their results showed that simulations not only produced equal or much better achievement gains but required about 30 percent less time than the time required to complete the same course with conventional hands-on instruction.

The inconsistency between the conclusions drawn by various reviewers may be due in part to the poor research design of some studies or the inappropriate use of simulations, as well as poor analysis and interpretation of research data. Salomon (1981), Clark (1983 & 1984) claimed that media research has asked the wrong questions which were based on faulty assumptions, leading to uninterpretable results. The inconsistency could also be due to the different instructional roles expected of simulations in different studies (Jonassen, 1988; Gredler, 1992, Salomon, 1981). Pierfy (1977) noted several design and research flaws in simulation studies. One of these weaknesses was that research studies compared simulations to classroom discussion types of instruction. Such comparison studies are not expected to bring about any meaningful results. And if significant results were found, the differences were often misinterpreted (Clark, 1983, 1984, Salomon, 1981). Sometimes research instruments fail to measure and report what they purport to measure (Dekkers & Donatti, 1981). "Another possible problem is that comparison studies are not very appropriate or sensitive to the students' general characteristics which may interact with instruction to influence learning and achievement" (Gredler, 1992 p. 9). Gredler further, claimed that simulation researchers frequently forget that simulations function well as a problem-solving tool and, as such, simulation is a tool for enhancing decision-making. Another issue is that researchers have not focused on the key question of the conditions under which simulation is most effective or not effective and what are the tradeoffs between encouraging decision making by the students and giving students information.

The pursuit of computer simulations in an educational context is worthwhile for several reasons. Simulations are potentially a powerful learning tools, and they can be applied in many

subject areas. In addition to being safe, convenient and controllable, simulations may encourage students to participate actively in learning activities.

A particularly important issue this review will explore is the issue of the sequence of instruction in which simulations are used. It seems logical that simulations can provide an experiential base in later instruction and enhance motivation. As will be discussed below, there is some evidence that the sequence in which simulations are used relative to other instruction make a difference in their effectiveness. This issue will be explored. More particularly, the issue of using simulations before actual dissection will be examined. However, this issue has not been examined in depth in the literature. Only a few studies, discussed below, involving simulations or simulation-like instructional video disks (IVD) have compared use of the simulation or IVD used prior to another educational experience to an alternative. Because of the limited amount of research, only tentative generalizations are possible.

This paper reviews the literature on the uses of simulations in science domains and the conditions under which simulations influence science instruction. As noted earlier, previous research on simulations have found a fair amount of consistency in the results. My goal is to determine the conditions in which simulations seem to positively influence science instruction and the conditions in which they do not influence science instruction. This paper is different from previous reviews of simulations in that it focuses on science instruction.

The rest of this paper is divided into nine sections and a summary. The first section focuses on a brief review of the literature on the use of simulations and dissection in science instruction. The second section investigates the uses of interactive videodisc in animal dissection. Because interactive videodiscs allow students to manipulate variables or to make decisions, they are similar to computer simulations in some aspects. The third section investigates the effectiveness of simulations as an alternative for conventional methods of dissection. The rest of the sections investigate the following subheadings: significance of dissection in education, controversies over computer simulation for dissection as an alternative

to conventional dissection; the use of simulation in science teaching; advantages of computer simulations; educational and a summary of the literature review.

#### Sources of Data and Inclusive Criteria

This study began by searching three computer databases through Lockheed's DIALOG Online Information Service: ERIC documents, a data base on educational materials from the Educational Resources Information Center, made up of two files, (Research in Education and Current Index to Journals in Education), Comprehensive Dissertation Abstracts, and Psychological Abstracts. Bibliographies cited at the end of each research article provided additional sources. Key words developed for these three data bases yielded over two thousands studies. These were narrowed down by the addition of specific key words to five hundred studies that finally met the three guidelines for inclusion in the study. Since this was too many to review, the addition of the key word 'science' to focus on the science domain further narrowed it down to about two hundred studies. Additional section guidelines used were as follows: The studies had to compare groups that used simulations to groups that did not (for example, simulation versus nonsimulation, video versus nonvideodisc) Second, the studies were performed in actual classrooms in grades 7 and above. Third, the studies reported achievement outcomes for students' performance and cognitive measures for both the simulation and video experimental group and a control group. Excluded from the pools of the studies were those in which the researchers failed to have a comparison group. In addition, papers based purely on the author's opinions, were excluded. Application of these guidelines yielded a set of fifty empirical studies that are reviewed in this paper.

#### The Nature of Simulations

As indicated earlier, simulation is the use of a powerful tool, the computer, to emulate or replicate an object in a real or imagined world. Alessi and Trollip (1985) categorized simulations into the following four different types:

(1) physical simulations, in which a physical object, such as a frog, is displayed on the computer screen, giving the student an opportunity to dissect it and learn about it, or when a student is learning how to operate a piece of laboratory apparatus which might be used in an experiment;

(2) procedural simulations, in which a simulated machine operates so that the student learns the skills and actions needed to operate it; or when the student follows procedures to determine a solution, as when a student is asked to diagnose a patient's disease and prescribe appropriate treatment;

(3) situational simulations, which normally give the student the chance to explore the effects of different methods to a situation, or to play different roles in it. Usually in situational simulations, the student is always part and parcel of the simulation, taking one of the major assigned roles;

(4) process simulations, which are different from other simulations in that the student neither acts as a participant (as in situational simulations) nor constantly manipulates the simulation (as in physical or procedural simulations) but instead, selects values of various parameters at the onset and then watches the process occur without intervention.

Gredler (1992) categorized simulations into two different types. Experiential simulations, the first category, provide students with a psychological reality in which students play roles within that reality by executing their responsibilities and carry out complex problem-solving in that knowledge domain. Experiential simulations are intended to assist students in situations that are either too expensive or too dangerous to experience in a real world. "Four major types of experiential simulations are data management, diagnostic, crisis management, and social-process simulations" (Gredler, 1992). According to Gredler, experiential simulations are assumed to provide opportunities for students to develop their cognitive strategies because the exercises require that students organize and manage their own thinking and learning. A second type of simulation is a symbolic simulation, which is dynamic in

nature and represents the behavior of a system, or phenomena, on a set of interacting processes. The students' role in symbolic simulation is that of principal investigator. Students construct their own learning experiences. Alessi & Trollip (1985); Reigeluth (1987); Bredemeier and Greenblat (1981) argued that when computer simulations are compared to other media such as videotapes or traditional lectures, transfer of learning is greater for the computer simulation group. With transfer of learning, students can apply what was learned from previous instruction to a new situation. But simulations may still be preferred for other reasons, notably cost and safety (Hopkins, 1975). According to Duffy & Jonassen (1992) "simulation is a cognitive tool for accessing information and interpreting and organizing personal knowledge." They claimed that simulation can potentially engage and enhance thinking in learners in science.

#### Controversy about Dissection

There is widespread controversy over the question of whether animal dissection in high school biology classrooms is immoral or unethical. On a religious or ethical basis, some argue against the use of animals for dissection. The animal rights activists group, People for the Ethical Treatment of Animals (PETA), has developed educational awareness outreach programs to stop the use of animals in dissections. This group claims that the experience the students gain in dissection dehumanizes and desensitizes students to the social value of animals. The 1985 amendments to the Animal Welfare Act (AWA) attempted to improve the treatment of animals in laboratories, to improve enforcement, to encourage consideration of alternative research methods that use fewer or no animals, and to minimize duplication in experiments (Baird and Rosenbaum, 1991). Some states have passed laws upholding the students' rights to refuse to perform dissection. For example, in the states of California, Maryland, Florida, and Pennsylvania, laws have been enacted regulating the use of animals in the biology classroom. In New Jersey, a 17-year-old high school student refused to dissect a cat in

biology class. In defense of his stand, the student said, "I think dissection just reinforces the idea that animal life is cheap, I feel it's an inherently objectionable thing to do" (Orlans, 1988, p. 3).

Others, with different moral or ethical views, regard dissection in the classroom as not only legitimate but indispensable to the advancement and improvement of medical knowledge and education. They argue that humans have superior moral status compared to nonhuman animals, and consequently there is no rational or ethical justification to put the same value on animal suffering as on human suffering. For example, Hoskins (1979) and Igelsrud (1986) have argued in support of traditional animal dissection. These individuals reaffirmed, in the strongest terms, the obligation of institutions to carry on the research programs that have expanded knowledge of disease and led to life saving therapies. Thus, Hoskins (1979) and Igelsrud (1986) argued that the use of laboratory animals is totally indispensable. Mackenzie (1988) provided a different argument for simulations. He argued that students who experience science only through the use of computer simulation "may not have the sensitivity to feel compassion toward other life organisms. Real life in the real world is not a computer simulation" (p. 17).

It is important that ways be found to meet the needs of these students who oppose dissection in the classroom and those who may wish to learn about the anatomy and function of organs without sacrificing animals. Science educators, as well as non-science educators, have suggested several alternatives to either substitute or supplement the traditional method of dissection in the science classroom. The alternatives basically provide simulated dissections through the use of various media including interactive videodiscs, videotapes, computer-assisted instruction programs, slides, charts, transparencies, filmstrips and computer simulations.

### Comparison Studies of Simulations and Interactive Videodisc (IVD)

Videodiscs are optical discs that store sound, motion pictures, and still pictures. With a videodisc, the information is not read by the computer. The computer functions only as a controller for the videodisc player, accessing and playing the required frames. "Interactive" refers to the user's ability to react to the computer or videodisc player through a command and have the system respond either negatively or positively. This may be as simple as a user striking the wrong key and having a computer correct the user, or a user telling a videodisc player to go in a certain direction in a simulation. Much of the early investigative research on videodiscs focused on whether or not students could learn from them. This section focuses first on studies that compare IVD to various hands-on procedures and then reviews five empirical studies that compare IVD to hands-on dissections.

Ebner, Danaher, Mohoney, Lippert, and Balson (1984) designed a videodisc lesson on the preparation and administration of an intramuscular injection to train student soldiers for service as combat medics and compared it to a conventional lesson taught by demonstration and the hands-on method. Performance testing consisted of actual preparation and administration of an injection, with pairs of trainees injecting each other alternately. Seventy participants were selected and randomly assigned to experimental and control groups ( $n = 28$  and  $42$ ). The experimental group was introduced to the task in the traditional way, but they used the videodisc lesson to enhance the demonstration, practical exercise, and study hall phases. At the end of the experiment, both groups were tested twice for proficiency and completed a questionnaire designed to assess their attitudes toward the training. The first proficiency posttest was given immediately after training and the second, which was unannounced, at a later time. The results of the study showed that the videodisc group, compared with the control group, completed the lesson on average 125 minutes more quickly (in two hours instead of four) with no difference in degree of satisfaction and achievement. Thus, the experimental group saved time for their learning experience compared with the control group.

Baker (1988) compared the effectiveness of interactive videodiscs and lecture-demonstration instruction in teaching physical therapy students the psychomotor skill of performing a sliding board transfer. A wheelchair with movable armrests and swing-away footrests and a 24-inch long standard sliding board was used to analyze motor performance. The subjects were randomly assigned to a control group (n =15), videodisc group (n =15), or lecture group (n= 15). The videodisc group and the lecture group completed a 10-item multiple choice test on the sliding board transfer before instruction, immediately after instruction, and four weeks after instruction. Learning was assessed with written examinations and performance analyses. The results showed that interactive videodisc instruction was as valuable as lecture-demonstration in teaching this particular psychomotor skill. The results of this study agree with the results of Ebner et al. (1984) which showed that interactive videodisc technology can be a useful educational medium that saves time without loss in achievement and with a high degree of student satisfaction.

Leonard (1985) conducted a series of related studies on learning biological concepts from videodisc versus conventional laboratories. For the study of climate, the traditional hands-on (control) group studied these topics by manipulating graphs, charts, photographs and maps. The experimental group used an interactive videodisc version that contained the same data as that used by the control group but, in addition, contained high-quality video motion sequences of organisms in major biomes of the world. The task for both groups was to infer life types, given climatic condition patterns. For the study of respiration, the experimental group studied the effects of temperature on respiration rate, as measured by the organism's oxygen consumption. Both groups were allowed 3 hours to complete each activity and write a laboratory report, which was subsequently graded. Both groups attended the same lectures and did the same assignments. The videodisc allowed the users to retrieve instant high-quality, "real life" simulated data while they were studying. The videodisc version also allowed students to manipulate the laboratory apparatus on screen. When the hands-on or videodisc



activity was completed, each student completed a 3-page questionnaire. The questionnaire assessed the student's satisfaction with, interest in, and appraisal of the educational value of the activity. The two groups did not differ significantly in general interest, understanding of basic laboratory principles, or scores on laboratory examinations. Nevertheless, the interactive videodisc group spent one-half hour less classroom time to complete the task than did the traditional group. Compared with the control group, the students in the video group expressed a high level of satisfaction with the videodisc lesson with respect to the efficiency it afforded.

In a second study, Leonard (1989) investigated the effectiveness of teaching about respiration and climate by using two videodisc systems in two introductory college biology laboratory sections (twenty students each). Students were randomly assigned to either the interactive videodisc experimental group or the traditional laboratory group. As in the previous study, both groups were allowed three hours to complete each laboratory activity and completed a three-page questionnaire that contained items to assess satisfaction with, interest in, and appraisal of the educational value of the activity. No significant differences were found between the two groups with respect to the content learned. Students who used the interactive videodisc gave significantly more positive responses regarding the efficiency of time spent than did the traditional students. They also rated their understanding of the laboratory experiment significantly higher than did the students in the traditional group. The most frequent comments by students in the traditional laboratory groups were that they preferred to set up, handle, and see the actual apparatus and organisms. Some students felt that the "real" lab provided more opportunity to make and learn from typical mistakes.

Leonard recommended that interactive videodisc instruction be considered for use in teaching situations where "(1) higher-quality video resolution is needed for simulations of laboratory or field experiences, (2) tedious or time-consuming observations or experiments are to be performed, (3) complex and/or expensive instrumentation needs to be accessible to a large number of students, and (4) laboratory or field activities are desirable but not practical because

of space, time, or travel requirements” (p.101). Leonard stated that his study did not support substituting videodisc/computer technology for “wet” laboratory experiences. As he pointed out, he chose the two lessons in his study because they were particularly suited for videodisc instruction. He mentioned however, that interactive videodisc instruction could “substantially enrich the spectrum of educational experiences usually not possible in a typical classroom setting” (p. 102).

Leonard (1992) compared an interactive videodisc to a conventional laboratory for teaching biology concepts and science process skills. Midwestern college students were randomly assigned to two groups for instruction on respiration and biogeography by means of an interactive videodisc or a traditional laboratory investigation. The five dependent measures in the experiment were (1) grades on student reports, (2) grades on a quiz given within two weeks of each investigation, and (3) grades in a laboratory final exam in which questions were asked about all 13 studies done in the semester. Results showed no statistically significant differences between the two approaches with respect to student grades on laboratory quizzes, laboratory reports, and the final exam. However, the interactive videodisc group required approximately one-half as much classroom time as the conventional laboratory group. The two approaches, therefore, appeared equivalent when the groups were evaluated by traditional learning outcomes, but the interactive videodisc method consumed significantly less time than did the traditional laboratory method. These results were consistent with the results of Leonard’s two previous studies.

Fawver, Branch, Trentham, Robertson, and Beckett (1990) compared interactive videodisc-simulated laboratories with two types of traditional laboratories: a traditional (control) lab consisting of a general cardiovascular physiology participation lab and a traditional fibrillation/positive pressure ventilation demonstration lab. The two laboratory sections (consisting of 85 first-year veterinary medical students) were divided into 12 lab groups with 3 to 4 students from each of the two sections. These 12 groups were randomly assigned to either

a traditional live animal laboratory or an interactive videodisc-simulation laboratory to compare the effectiveness and efficiency of these methods of teaching physiology. The IVD laboratory covered the same experimental preparations and the same physiology experiments as the live animal laboratories but also received demonstrations on the use of some drugs not covered in the live-animal laboratory. The videodisc lab presented several versions of most demonstrations to illustrate physiological variations. The students assigned to the live-animal laboratory were expected to review a set of introductory slides before the lab. The students were asked to record the time spent both on reviewing the introductory slides and in the laboratory. The students in the cardiovascular participation laboratory were required to place one venous catheter and one arterial catheter, make recordings from the chambers of the heart, expose and stimulate nerves, and administer vasoactive drugs. A multiple-choice/short answer test was administered to all students after the laboratories. No significant differences were seen between group test scores of the interactive videodisc groups and the live animal laboratory groups, but there were differences in time spent by the two different of groups. The authors concluded that “the interactive videodisc-simulated lab was as effective as the traditional live-animal labs and was more time efficient than the traditional participation lab” (p. 11). The results of this study agree with the results of Leonard’s series of investigations, Ebner et al. (1984) and Baker (1988), which show that interactive videodisc technology can be a useful educational medium for saving time compared with other media.

Student acceptance of videodisc-based learning programs has been well documented by some researchers, such as Leonard (1992, 1989, 1985); Strauss Kinzie (1994). Ebner et al. (1983) prepared a teacher-operated interactive videodisc system on intramuscular injection to supplement conventional lecture and laboratory sessions that taught paramedical and basic nursing skills on how to prepare and administer an injection. Students were randomly assigned to either an experimental or a control group in a way that ensured intergroup similarity for independent variables (age, sex, educational level, and military rank). “Both the

experimental and the control group attended identical subject matter lectures and watched a linearly-played videotape of the tasks to be undertaken. Each group was then divided into practice sub-groups of 14 students per instructor” (p. 3). The experimental group students were taught with instructor-controlled IVD’s, with repeated showings of the nine segments. The traditionally-taught subgroups were given live demonstrations by their instructors. The results showed that the experimental groups not only saved time (three rather than four hours) but also responded more favorably to the teaching experience than did the control groups. The authors asserted that these findings indicate that videodisc-based programs can be effective for training paramedical and basic nursing skills and that their instructors can reduce teaching time with no loss in student achievement and with a high degree of student satisfaction.

Sherwood, Hasselbring, & Marsh (1990) compared chemistry knowledge achievement between ninth-grade students taught with a videodisc lesson called “understanding chemistry and energy.” Tenth and eleventh grade students were taught with standard traditional hands on instruction. The hands-on instruction consisted of standard instructional techniques using printed materials (worksheets and quizzes). The dependent measures were achievement in chemistry. Results on both the pretest and the posttest were used to compare the videodisc experimental group with the control group. Because the differences in the pretest and posttest scores were much larger for the experimental group than for the control group, items were analyzed by teachers to determine whether they had been covered during classroom instruction. Students in the experimental group scored significantly higher than the control group on the posttest items that the control group teachers rated as having been covered “a lot” and “some” in normal classroom instruction.

Tylinski (1994) compared a computer simulation with traditional hands-on dissection on junior high students’ understanding of the physiological systems of an earthworm. The participants were 110 ninth grade students enrolled in the academic biology classes. The control group consisted of 51 participants (25 females, 26 males) and used hands-on

dissection. In the experimental group, 46 students (27 females, 19 males) used the computer simulation. Both the control and experimental groups were to identify the anatomical structures that are a part of the physiological systems of an earthworm and match the structures with their functions. The earthworms were 12 inches long with clitellum. The dependent measures were made up of 40 questions intended to measure students' attitudes and performance. The posttest was administered orally the day after the dissection was completed. No significant differences were found between the control groups and the experimental groups or the genders in either achievement or attitude.

Kinzie, Strauss, and Foss (1993) compared the achievement and attitudes of students who conducted a frog dissection with and without the use of an interactive video-based simulation as a preparatory experience for the actual frog dissection. The participants were 61 high school students enrolled in three general-ability high school biology classes during the 4-day period of the study. The participants in each class were divided into four approximately equal groups. The IVD prep group used the interactive videodisc-based simulation as a preparation for the laboratory dissection, which they then performed. The video prep group viewed a linear videotape containing the same video materials used in the IVD simulation, but without interaction and then performed the dissection. The dissection-only group conducted the dissection without preparation. The IVD-only group used the IVD simulation but did not dissect.

On Day 1 of the study, the students completed the pretest achievement, attitude, and self-efficacy measures. On Day 2, students in the IVD prep group used the simulation; students in the video prep group viewed the videotape; and students in the dissection only and IVD only groups completed library research for a biology assignment unrelated to the dissection. The IVD prep students spent an average of 39.4 minutes on the simulated dissection, and students in the video prep group viewed the videotape for 15 minutes. On Day 3, students in the IVD prep, video prep, and dissection only groups performed the frog

dissection. On the fourth and final day, all groups completed the posttest achievement, attitude, and self-efficacy postmeasures.

The IVD prep and video only prep students, who dissected after using a video preparation tool, scored significantly higher on the posttest achievement measures than those who dissected without a video preparation tool. Achievement measures increased significantly from pretest to posttest (pretest,  $m = 10.05$  posttest,  $m = 21.24$ ). Attitudes toward dissection remained relatively stable from Day 1 ( $m = 50.89$ ) to Day 4 ( $m = 52.50$ ). Self-efficacy with respect to dissection procedures increased from premeasure ( $m = 64.95$ ) to postmeasure ( $m = 72.73$ ). In addition, the results indicated that students in the IVD prep group performed the dissection more effectively than students who received no preparation and more effectively than students whose preparation consisted of viewing a videotape. Those students who dissected after using the video materials as preparation tools learned more about frog anatomy than those who dissected without preparation (Kinzie, Strauss & Foss, p. 995).

Kinzie, Foss and Powers (1993) compared a tutorial computer program to an interactive videodisc simulation; 24 low-achieving college biology students served as subjects. The dependent variable was a test in which students were asked to locate organs on a printed diagram and to name organs shown in videodisc pictures. Observations of the students during learning, interviews, and examination of instructional materials added qualitative data to the study. The "tutorial" computer program allowed the learner to direct or follow the course of study by controlling the content. The videodisc program, called *Rana pipiens*, consisted of a teacher-generated videodisc on frog dissection. Students performed dissection after viewing the videodisc or tutorial. The results showed significant learning from the pretest to the posttest. There were no significant differences between the videodisc or tutorial groups on organ identification.

Strauss and Kinzie (1994) compared the level of learning and retention of knowledge of the frog's internal anatomy in students using an interactive videodisc simulation with those

conducting conventional frog dissection. Two classes (eight and nine students per class) participated. One class consisted of four males and five females, and the other had three males and five females. The students were randomly assigned to either a traditional hands-on method dissection group or a videodisc simulation group. The students in the videodisc simulation group completed the instruction in one class period lasting approximately one hour. The students in the dissection group completed their work in one and one-half class periods. For pretest and posttest achievement measures, students were asked to label 10 major organs on a diagram of a dissected frog, to identify the names of the same organs on a prosected frog, and to answer five multiple-choice questions on dissection procedures. In addition, the students responded to a ten-item attitude test related to how they felt about animal dissection. The pretest was given three weeks before the start of the experiment and the posttest two weeks after the experiment had been completed. The results showed that the two treatment groups did not differ significantly with respect to posttest identification of the frog organs. There were no significant differences in achievement between male and female students on either the pretest or the posttest.

Guy and Frisby (1992) compared interactive videodisc lessons with traditional hands-on instruction with the goal of reducing the number of labor-intensive laboratories in human gross anatomy given to pre-nursing and allied-medical-professions undergraduates at Ohio State University. The subjects were randomly assigned to either a traditional, hands-on cadaver-demonstration lab presented by teaching assistants or an interactive-videodisc computer lab. Both groups covered the same lesson materials. The computer-lab videodisc, composed of a combination of still photos and motion sequences of short demonstrations, depicted everything the students would see in the cadaver demonstration lab. The IVD tutorial provided the kind of student-teacher conversation that usually occurred during the cadaver lab dissection and demonstration practical as well as providing realistic visual material. There were no significant differences between the learning outcomes of students who used interactive-

videodisc lessons and those who participated in the traditional, hands-on cadaver-demonstration lab. The researchers suggested that the computer-based-instruction technique could supplement the traditional cadaver-demonstration method of teaching anatomy.

In summary, research on the effectiveness of videodisc technology in science has produced fairly consistent results, especially when various dependent measures of student achievement are taken into consideration. Of thirteen empirical comparisons, one study found that, on traditional paper and pencil on achievement measures, interactive videodisc led to significantly higher achievement than did traditional dissection instruction; twelve studies showed no significant differences in achievement. Thus, IVD and traditional instruction seem to lead to equivalent learning as measured by typical classroom achievement tests. In addition, six comparisons that examined time showed that IVD dissection was faster than actual dissection. Another major finding of these studies was that students usually develop a more positive attitude toward computers in general. In addition, one study done by (Kinzie, 1994) reported that use of a simulated dissection before an actual dissection improved performance on that actual dissection (Kinzie, 1994).

#### Other Alternatives to Dissection

Because of the political controversy over the use of dissection in education, other alternatives to dissection have been investigated. This section reviews the effectiveness of various dissection alternatives compared to traditional hands-on dissection.

Prentice et al. (1977) developed a stereoscopic slide-based auto-instructional program and compared it with standard human gross anatomical dissection as the nucleus of instruction for medical school students. The study developed as a result of problems in the regular curriculum, including the decreased number of hours students spent in gross anatomy instruction and a shortage of anatomical donors for dissection. The program consisted of 70 units, organized by anatomical region. Eight to ten stereoscopic slides (35 mm) were taken



sequentially of anatomical dissections after important anatomical structures had been labeled with plastic letters placed directly on the body and after all arteries, veins, nerves, and lymphatic vessels had been painted with acrylic paint to conform with the standard anatomical color code (p. 759). Each unit emphasized a student-centered learning approach, encompassing features as self-pacing, self-testing, self-direction, and reinforcement. Three groups of students were selected: physician's assistant students (PAs), physical therapy students (PTs), and graduate students (GSs). For one-half of the course, the PAs (n = 16) used the slide-based auto-instructional program; the PTs (n = 16) and the GSs (n = 7) used dissection. Students were assessed with student laboratory examinations and written examinations. A pretest was administered before the units were given and a posttest three weeks later. There were significant differences between the groups in terms of ability to identify anatomical structures on stereoscopic slides; the auto slide program students (PAs) performed better than the PTs and GSs. The authors indicated that "the predominant complaint of the students who used the SAA program was the difficulty they experienced in attempting to establish an overall anatomical orientation. This finding is not surprising since there is a limit to the amount of material which can be presented on a slide" (p. 762). They further indicated that the SAA program did not provide the student with time to develop a tactile awareness of the structure of the body, which is important to the understanding of three-dimensional human anatomy.

Bernard (1972) compared first-year medical students who learned anatomy from projected demonstration cadavers with students who dissected cadavers. The participants were 154 medical school students in their freshman year divided into three groups. Students were ranked in terms of ability and were assigned to conditions to equalize ability between the groups. The experimental group used student-generated projections. The two control groups did a traditional type of dissection using a standard dissection guide. The experimental group did essentially the same dissections except, that they used a different, specially written, guide.

Within each group, eight medical students were assigned to each cadaver. All three groups took the same examinations. The results showed that the experimental group did as well as, and occasionally significantly better than, the control groups. As stated by the researchers, “the prosection demonstration technique saved time, but it is difficult to assess if the time saving was the result of the learning experience” (p. 725). No significant differences were observed in the mean scores of the three groups. This meant that the two groups learned equally from the two methods and one method was not better than the other.

Welser (1969) compared the effectiveness of single concept film loops in a veterinary basic gross anatomy course to the effectiveness of traditional hands-on dissection. The topic was on the innervation of canine limbs. There were three types of instruction: 1) the traditional method consisting of a dissection guide, a prosected cadaver, and student dissection of a cadaver, 2). the dissection guide and student dissection of a fresh cadaver with films loop and 3). the dissection guide, and films loops as the only primary learning aid. Students rotated among the three types of dissection as they proceeded from one of the five units on canine anatomy to the next. The students recorded the amount of time they spent on each unit and filled out an opinion questionnaire as they completed the units. Pre-quizzes were administered before each unit’s presentation to assess differences in the quality of groups. Significant differences between groups were found in two of three units. The addition of the loop films was found to benefit retention. A savings of time was also seems to be attributed to the treatment group who had loop films as their guide in a technique-oriented exercise. The group that dissected fresh cadaver with films loop did better than two other groups.

Fowler and Brosius (1968) compared the understanding of 165 skills and attitudes of 165 tenth-grade high school biology students who were taught using two methods. Compared were performing actual dissections of certain selected forms (crayfish, frog, earthworm, perch) and viewing of films of similar dissections. Both groups took a pretest prior to the instruction and a posttest after they had finished the instruction. The tests assessed the

following measures: (a) acquisition of factual knowledge, (b) problem solving in biology, (c) understanding the methods and aims of science, (d) attitude toward science and (e) improvement of skill in manipulating certain biology laboratory implements. No significant differences were found in relative effectiveness of all the measures of instruction in improving understanding of the methods and aims of science.

Jones, Olafson and Sutin (1978) studied first-year medical school students who were studying gross anatomy by use of multimedia presentations in place of lectures and use of prosected specimens instead of dissection. No lectures were given, nor was dissection permitted. The multimedia presentations consisted of three basic instructional techniques: 1) slide with presentations audio-tapes, films, and assigned readings, 2) computer demonstrations, and 3) small group discussions around dissected specimens. The experimental group reviewed films or slide-tapes, while the control group watched the teacher's demonstration tutorials. Students met with the instructor around prosected specimens for demonstration tutorials and oral quizzes. The slide-tapes consisted of two-by-two-inch slides of cadaver preparations, models, or graphics with labels and a synchronized narrative on audiocassette. Each slide-tape began with objectives, asked practice questions to reinforce important concepts, and included a pretest and posttest. All instructor prepared examinations contained three parts: practical, written, and reading written instructions. Extramural examinations, the gross anatomy examination of the National Board of Medical Examiners and the Association of Anatomy Chairmen examination were also given. Performance of the experimental groups did not differ significantly from performance of the traditional group on any of the examinations.

Alexander (1970) compared the effectiveness of dissection versus prosection for the teaching of human anatomy to senior physical therapy students at Ithaca College. Students randomly assigned to the control group were required to carry out dissection; students in the experimental group were provided with prepared cadaver specimens. The capacity of students

to demonstrate immediate and delayed recall of human anatomy and to apply anatomical information when called upon to solve clinical problems on immediate and delayed examinations were the criteria selected to compare the effectiveness of the two methods. Students were tested on anatomical relationships of muscles, nerves, blood vessels and skeletal landmarks and were required to locate these structures themselves. The results of an analysis of variance indicated that no significant differences in learning could be attributed to the two methods of instruction. Time was saved with prosection compared with the dissection procedure.

Baggott, Lawrence, Shaw, Galey and Devlin (1977) compared the educational effectiveness of slide-tape presentation versus lecture and discussion in medical school biochemistry. The volunteer subjects were first-year medical school students, randomly assigned to three groups; each group was in turn randomly assigned to instruction by lecture only (control), slide-tape only, or a combination of slide-tape and lecture across three biochemistry units. Cognitive achievement was measured by performance on a multiple-choice examination. No significant differences were found among the lecture slide-tape, and combination groups. Comparison of total learning times revealed that the slide-tape group spent 28 percent less time and the combination group 22 percent less time learning the material than did the lecture group.

McCollum (1988) compared students' knowledge gained by dissection with that gained through a traditional lecture presentation. The 300 students (179 white, 171 nonwhite; 200 female and 150 male) involved in this study were enrolled in biology in five secondary schools of a large metropolitan school district. The students were taught by seven teachers whose experience in teaching biology averaged seventeen years. The classes completed a pretest and were randomly assigned to either the experimental or the control group. The experimental group performed the traditional frog dissection to learn about frog structure, function, and adaptation. The control group received lecture only to learn about the same components of the

frog and then completed multiple choice questions. A posttest was administered after the treatment. Analysis of covariance (ANCOVA) was employed to determine if differences in posttest achievement scores of the dissection and lecture groups were statistically significant. The results of suggested that the lecture method led to higher scores compared to the dissection method.

In summary, the results of other alternatives to dissection empirical research studies indicated that other alternatives to dissection can be as effective as hands-on dissection in promoting student learning of anatomy and morphology of organs. Of eight empirical comparisons, three studies found that, on traditional paper and pencil on achievement measures, alternatives such as film slide and still photos demonstrations led to significantly higher achievement than did traditional dissection instruction; five studies showed no significant differences in achievement. Thus, other alternatives and traditional instruction seem to lead to equivalent learning as measured by typical classroom achievement tests. In addition, four comparison studies that examined time, showed that other alternatives were faster than traditional dissection. Overall these results support the contention that, when learning is measured by typical achievement measures, other alternatives to dissection can be as effective and efficient as traditional hands-on experience.

The achievement measures usually consisted of paper and pencil tests on anatomical body parts and functions. It does not seem completely surprising to see that in the case of simulation of dissection alternatives simulation seem to work at least as well as non-simulation for dissection in teaching recognition of anatomy and morphology presented via diagram as tested in paper and pencil tests. None of the particular advantages of dissections, such as the three dimensional nature of the organs, and how they fit together in the body are assessed in such tests. On the other hand, such tests represented the traditional assessments used in assessing knowledge of anatomy in science classes. As such, these paper and pencils tests are representative of real criteria used to evaluate student progress.

The available research clearly suggests that simulation alternatives can lead to equivalent performance to non-simulation instruction on such tests. In addition, simulation alternatives may save instructional time. These results, combined with the results of the IVD studies described above, support the use of simulation for dissection alternatives when the learning goal is the recognition and basic understanding of anatomical parts and functions in the body.

### Computer Simulations

As indicated in the introduction, simulations are interactive and manipulable representations of real or imaged dynamic systems. Educational simulations present students with problems and allow students to utilize the simulation as a powerful tool to carry out investigations and to solve problems. Educational simulations are designed both to teach content and to enhance higher-order problem-solving skills. Simulations allow learners to explore and manipulate variables and then obtain results from the various manipulations. Those results should provide feedback to their thinking and learning processes in science.

There are, of course, well established arguments that differences in learning between computer and non-computer instruction may be attributed to uncontrolled effects of different instructional methods, content, or novelty (Clark, 1985). This section emphasizes research that compares the results of instruction with and without computer simulations. The organizing question of this section is: under what conditions does the use of instructional technologies such as simulations provide more efficient and effective learning than the learning obtainable without the use of such instructional technology, such as traditional methods of teaching and discussion? The organization of this section is based on subject matter and is limited to the science domain.

Choi and Gennaro (1987) developed a computer simulation model that paralleled traditional hands-on laboratory experiences in the teaching of the concept of volume displacement. They compared learning between junior high school students who used hands-

on experiences and those who used the simulation and assessed students' understanding of volume displacement. Students, 63 males, 65 females, aged 13 and 14 years, were selected from five eighth-grade earth science classes. The dependent variables were achievement scores obtained from a posttest and a retention test. The independent variables were treatment, sex, and time of day. Students were randomly assigned to either the experimental group or the hands-on group (control group). The experimental group (31 males, 32 females) was taught by means of a computer simulated experiment in graphics and animation to help students visualize the concepts they were learning. The traditional, hands-on group (32 males, 33 females) was taught the same concept, volume displacement, but used hands-on laboratory experiences designed by the researchers. Both groups completed five experiments on volume displacement. The control students required two full class periods to complete the learning experience experiment. The experimental group required 25 minutes to complete the simulation. Both groups were asked to determine: (1) the relationship between the volume of an object and the volume of water it displaces, (2) the relationship between the shape of the object and volume of water it displaces, (3) the relationship between the mass of an object and the volume of water it displaces, (4) the relationship between the size of an object and the volume of water it displaces, (5) the relationship between type of liquid and the volume of displacement by an object. No significant differences were found between the computer simulated experimental group and the hands-on laboratory experimental group on either the immediate or the delayed posttests.

In two separate but related studies involving samples of elementary education preservice teachers and eighth-grade students, Baird, Koballa and Thomas (1986) and Baird and Koballa (1988) studied the learning of the science process skill of hypothesis testing. Students who received only computer-presented textual instruction on hypothesis testing were compared with students who used a computer simulation program game that provided practice in testing hypotheses. The dependent measures, which were administered as a pretest and a

posttest, consisted of 22 items taken from the Group Assessment of Logical Thinking (GALT) test developed by Roadrangka, Yeany and Padilla (1983), as well as self reports of satisfaction with the computer simulation or text activities. In both studies, students who completed the simulations did better on the logical thinking items than did students who only completed the text. Also, in both studies, students who used simulations reported higher satisfaction with the instructional materials than did students who used the computer-presented text version.

Mills, Amend, and Sebert (1985) developed a water resource management simulation (WRMS) to serve as a water education training tool for elementary, secondary science, and other secondary teachers. They compared 56 students who used this simulation to 95 nontreatment control students with regard to knowledge and attitude toward water management. The multi-user interactive computer simulation (MICS) was designed to improve the understanding of the major factors in wise water resource management. In this study, the simulation, a model display of hydrologic information, provided opportunity to cooperatively develop and evaluate water management strategies. The results of this study showed that knowledge scores of the teachers who used WRMS were significantly higher than scores of teachers in the nontreatment control group, who did not use WRMS. This result was true for elementary, secondary science and other secondary teaching majors. No significant difference in attitudes were found between the scores of WRMS users and non-users.

Hollen, and Bunderson (1971) compared computer simulation with traditional laboratory exercises in qualitative chemical analysis in introductory college chemistry. In this qualitative analysis computer simulation, stimuli were in the form of telex-typed output; supplemental colored slides were displayed where needed for the students. Students keyed in their answers to questions and the computer responded by displaying the correct answers. If the students were wrong, the computer provided feedback by correcting the answers as well as indicating the next step for the students to perform. In the traditional sections of the qualitative analysis scheme, students were given an outline of the analysis that followed the outline of a



standard text. Schematic analyses were group separations, the silver group, the copper-arsenic group, the aluminum-iron group, the combined alkali metal and alkaline earth groups, and the anion. The dependent measures were performance and achievement and the amount of time it took for the students to complete the task. Pretests and posttests were given to each student. No significant differences were noted between the two groups with respect to performance and achievement. But the experimental group completed the task in less time than did the students in the traditional control group.

In three experiments in a high school chemistry class, Bourque and Carlson (1987) compared the effectiveness of traditional hands-on laboratory exercises and simulations. The effectiveness was assessed in two ways, by testing knowledge of the chemical concepts implicit in the laboratory exercises and by measuring students' attitudes towards the computer-simulation and the hands-on laboratories. Across the three experiments, three computer simulations developed by J. E. Gelder were compared to parallel hands-on laboratories: (1) acid-base titration, (2) equilibrium constant of a weak acid and (3) Avogadro's number. The simulations were presented on the Apple IIe microcomputers. In both the laboratories and simulation exercises, each student prepared a lab notebook, which was to include a statement of purpose, the general procedure, and the construction of a table for collecting data for each activity. In addition, students responded to a list of questions in the affective domain intended to gather information from their personal learning interaction with the computer simulation or with the laboratory format. A 10 item quiz was given as a posttest to evaluate comprehension of the concept involved. The results indicated that, on this posttest, the traditional hands-on laboratory exercise produced significantly higher learning scores in both experiment 1, the acid-base titration and in experiment 2, the ionization constant. No significant difference in performance was observed for experiment 3, the determination of Avogadro's number.

Fortner and Schar(1986) compared effectiveness of computer simulations to effectiveness of non-simulations with respect to computer awareness and perception of

environmental relationships by college students. Undergraduates (n =110) enrolled in an "Introduction to Conservation of Natural Resources" course participated in this study. The experimental treatment group used workbooks and three simulations that were incorporated into the course as individual learning modules; the control group worked with comparable workbook modules, textbooks, and reference materials that covered the same topics as the computer-simulated modules. "Each simulation module consisted of (a) written background information about the topic, (b) instructions for operating the computer program, and (c) a summary worksheet." Content and presentation techniques were assessed on the basis of knowledge the students gained on subtest instruments and an environmental relationship perception survey. Simulation programs utilized a method of demonstrating in a simplified version of real-world conditions, providing learning experiences, and allowing students to manipulate variables that offered them feedback. A computer awareness survey that measured attitudes toward computer enjoyment, anxiety, and user efficiency was also administered. The results showed that, on the knowledge subtest, the experimental group performed significantly higher than the control group, indicating that the simulation was, in fact, more effective for increasing factual recall.

Fennessey (1972) compared the effectiveness of simulation exercises, simulation games, and conventional instruction in elementary and junior high school ecology classes. The subjects were 1,874 students in 60 third, fourth, and eighth grade classes in parochial schools. In this study, the experimental unit was the class and not the students. Classes were randomly assigned to treatment groups. The control group teachers were given a resource booklet containing all the information and materials for Man in His Environment, but all references to the simulation exercises were deleted. The teachers in the simulation exercises group received a resource booklet and a copy of Man in His Environment, referred to as "the Ecology Kit." The teachers in the simulation game group received the resource booklet, the Ecology Kit, and a set of rules for converting "Make Your Own World" into a simulation game. The teachers in

all three groups were told to use the materials provided as the basis for a teaching unit of ten 45-minute class periods, to be taught during a specified two-week period. Teachers in the simulation exercises and simulation game groups were also asked to use each simulation exercise at least once and to use the exercises as much as they could. The teachers in the simulation game group were asked to use only the modified version of "Make Your Own World." The effectiveness of the three experimental treatments was measured by means of an objective test and attitude questionnaire, given on the tenth (final) day of the unit. No significant differences were found between the mean scores across the groups, which indicated that the three treatments were all equally effective.

Munro, Fehling and Towne (1985) studied the effects of student control of feedback messages during interactive dynamic simulations providing skill training in perceptual, motor, and decision-making skills such as piloting vehicles or performing the job of an air traffic controller. Group one, the intrusive feedback group, received an error message. The less-intrusive feedback group received an error message only if the student requested it. These students were assigned to one of the two experimental groups in alternating order as they arrived for the experiment. All students first viewed a six-minute videotape explanation and demonstration of the Air Intercept Controller task. This interactive dynamic simulation consisted of a series of text presentations that were described in the videotaped introduction. It also presented simulation segments that the student was asked to interact with by use of a control keyboard. Number of errors per problem was used as one measure of learning. The mean number of errors was 9.17 for the students in the less-intrusive group and 15.67 for the students in the intrusive treatment group. This difference, which was highly significant, suggested that students in the less-intrusive group learned more than those in the intrusive group and the techniques used for the less-intrusive group had promoted more learning in dynamic skill training.

Rivers and Vockell (1987) compared computer simulations to traditional lecture in teaching middle and lower-middle-class high school biology students to solve problems. The experimental treatment group used a simulation program on Apple computers called "BALANCE: A Predator-Prey Simulation". This simulation allowed students to explore the interrelated variables affecting predator-prey relationships. In groups of three to five, the experimental students prepared for simulations by using laboratory guides, determined what variables to use in the simulation, and planned and conducted experiments using the simulations on the computers. Each computer simulation was integrated with a teacher's guide and a student laboratory guide, which provided additional laboratory and real-life experiences. The control group was taught the equivalent topics in a noncomputerized fashion using textbooks, lectures and traditional laboratories. The same amount of time was spent on each topic in both the control and the experimental treatment classes. The students were to analyze the data collected and draw their conclusions in small groups. The students were given a pretest and posttest for each simulation. The individual unit posttests measured specific problem solving skills directly related to each unit. The groups did not differ significantly in the rate of gain. (However, the experimental simulation students gained more than students in the control group). Rivers and Vockell concluded that "the impact of computer simulations varies, apparently depending on the content of the simulations and the nature of the thinking processes being measured" (p. 22).

Spraggins and Rowsey (1986) compared the effect of simulation games and worksheets on learning in 83 high school biology students (42 males, 41 females) of varying ability. In this study, worksheets consisted of one or two pages that included questions to be answered, tables to be completed, or space for students to make sketches, diagrams, or maps. The experimental group played simulation games that introduced the current lesson and also completed assigned worksheets related to a topic previously covered in class. The control group played simulation games pertaining to a past lesson and were assigned worksheets that

introduced the current lesson. Lessons were the same for both groups. The investigator taught all of the classes. The experimental simulation games used were geologic time charts, the cell game, and a game on blood flow. The control simulation games used were Predator: The food chain game, environmental rummy, and an endangered species game. A mean split the Science Research Progress Test scores were used to classify students into control high and low ability groups for comparisons. An achievement test was developed by the investigators to measure the level of mastery of concepts being taught with simulation games and worksheets. A retention instrument developed by the investigators was used to assess the retention of information by the experimental and control groups. The dependent variables of achievement scores on Geologic Time Table Measure, Cell Biology Measure, and Circulatory System Measure, were analyzed within a factorial design with treatment, ability, and sex as the independent variables. Achievement gains of students who were taught by the simulation game method were the same as achievement gains of the students who were taught by using worksheets. Likewise, there were no significant differences in retention scores between students taught by worksheets and students taught by simulation methods of instruction. Low-ability females who used simulations games scored higher on retention than low-ability female who used worksheets. In contrast, low-ability males who used worksheets scored higher on retention than low ability males who used simulation games. Spraggins and Rowsey commented that they observed a spirit of cooperation among the low-ability females participants of the gaming groups. Because the low-ability girls tended to discuss the situation before responding to the questions, this discussion reflected on their positive learning outcomes. In contrast, the low-ability males were more independent and competitive, therefore, there was less discussion and cooperation among the group members.

Based on the results of computer simulation empirical research studies reviewed in this section, it appears that computer simulation can be as effective and as efficient a medium for delivery of instruction as non-simulation experience. Often empirical research studies, four

studies found that, on traditional paper and pencil on achievement measures, simulations led to higher achievement than non-simulation instruction; six studies showed no significant differences in achievement. Thus, simulation instruction seems to lead to, at least, equivalent learning as measured by typical classroom achievement tests. Although some students may not have liked the simulation, the simulation did at least produce similar achievement results to non-simulation experience. In addition, one study that examined time showed that the simulation was faster than the non-simulation instruction. These results support the contention that when learning is measured by typical achievement measures, simulation instruction can be as effective as non-simulation instruction. While the methodology of any one of the present studies might be questioned, the failure to find any significant advantage for hands-on experience in any of the studies surely cannot be interpreted as support for hands-on experience over simulation instructions.

### Simulations and Conceptual Change

Research on how students learn science indicates that they tend to use their misconceptions about science concepts to comprehend new concepts. The use of computer simulations can assist students in changing their naive misconceptions about science and thereby help improve student learning. This section reviews the use of simulations in helping students overcome misconceptions.

Carlson and Andre (1992) compared simulation to traditional conceptual change text instruction to overcome student preconceptions about electric circuits. The participants (36 males, 47 females) were enrolled in introductory psychology courses and received extra credit points for participating. Two methods were used in this investigation. In the first method, students used traditional text (TT) which combined portions of two commercially available middle school/high school texts that covered basic electrical concepts. The conceptual change text (CCT) consisted of the TT plus sections which challenged students' preconceptions by

presenting diagrams of possible circuits and asked students to predict, in writing, what would happen in the circuit and then presented evidence that countered typical preconceptions. There were two sections of the test; the first dealt with basic electricity and the second with the calculation of current and voltage. The simulation portion was a HyperCard stack which made it possible to design and test circuits. The simulation consisted of a short tutorial on using the mouse and the circuit simulation and simulation itself. Students were presented with the problems in building a circuit. The total posttest contained 66 multiple choice items; 26 of those items asked conceptual questions about series circuits. Students who studied using CCT scored significantly higher than those studying using TT. More importantly, the simulation group also had a higher conceptual model score than the no simulation groups.

Chambers, Haselhuhn, Andre, Mayberry, Wellington, Krafka, Volmer and Berger (1994) compared a simulation experience to hands-on experimentation on acquisition of a scientific understanding of electricity. This study compared reading of three versions of a text to reading combined with simulation or hands-on experience. In the first method, students were directed to use a Macintosh computer simulation in which they constructed simple electrical circuits in order to test their beliefs and predictions. In the hands-on approach, students use kits to physically build the electrical circuits to test their ideas about electricity. The students in this study were in introductory psychology classes and received extra credit for their participation. The data were collected in college classrooms and computer laboratories. There were five conditions of the text: 1) traditional text only; 2) augmented traditional text, consisting of the traditional text with an additional explanatory text, examples, and diagrams; 3) conceptual change text which consisted of the traditional text and conceptual change features that activated and refuted typical misconceptions; 4) conceptual change text with simulation which used the same text, but asked students to test their predictions about circuits by using computer simulation; and 5) conceptual change test with hands on experience, which used the same text, but asked students to test their predictions by building circuits. Students were

expected to write their predictions and observe what happened when they tested those predictions. Prior to the experiment, both groups completed a pretest with a diagram of a flashlight cutaway, and students were asked to explain how it worked. The students also completed a 4-item pretest consisting of slides of circuits and were asked to explain if the circuits would work. The students received an immediate and a delayed posttest that assessed conceptual understanding of electrical circuits. The posttest administered to the students consisted of circuits and noncircuits; and students were to show which circuits would or would not work and why?

Significant differences were found between groups with regard to acquisition of scientific knowledge about electricity. However, a comparison between genders within a condition showed that males scored significantly better than females in the traditional text and augmented traditional text groups. This result suggests that males had more experience and perhaps more interest in electricity than females had. But the performance of males remained the same regardless of whether they had read the conceptual change text, traditional text or augmented traditional text. The researchers reported that the females found the simulation easier and somewhat superior to the hands-on experience and speculated that the lower experience of females with building electrical circuits led to frustration with the hands-on method.

Andre and Haselhuhn (1995) compared students who completed either a Newtonian motion or a non-Newtonian computer simulation either before or after didactic instruction. Participants were students in an introductory psychology classes. The participants received extra credit for their participation. The independent variables were the type of computer activity (simulation or game) and the position of the computer activity (before or after reading the text). The two types of computer activities were: 1) a simulation designed to illustrate Newtonian principles of motion and 2) commercial games with a non-Newtonian motion. The motion simulation allowed the student to explore the effects of applying impulse forces to a body at



rest or moving in a particular direction of space. The computer games were given to students either before or after they read a text dealing with Newtonian motion. The control group was to read the text and then complete the posttest. Students were required to complete a 45-item questionnaire that asked questions regarding their sex, class year, academic major and age. In addition, they completed a vocabulary test and 6 questions concerning their interest and experience in physics. A 4-item multiple-choice motion knowledge pretest was completed by all the students. A 45-item multiple-choice posttest that assessed student understanding of the concepts of rectilinear and curvilinear motion and transfer of the learning of Newtonian principles was also completed by the participants.

There was a significant difference in the posttest means found among the control, simulation-before and simulation-after text conditions. It was also found that male students who engaged in a computer simulation lesson before reading the physics text performed better on a test of transfer knowledge than male students who completed computer games before reading text. This result was consistent with those obtained by Brant, Hooper, and Sugrue (1991) who found that genetics simulation before lecture enhanced learning more than the same simulation after lecture. The results suggested that the use of computer simulations before didactic instruction in physics may be more effective for males than for females students.

Windschitl (1995) compared a constructivist use of a simulation to an objectivist use of the simulation on students' conceptual change in a college human physiology class. The participants were 250 students who were non-biology majors enrolled in a human anatomy and physiology course. The two independent conditions were a confirmatory simulation condition, in which the students used the cardiovascular simulation in a directed step by step manner and an exploratory simulation condition in which the students were given general problems to solve using the cardiovascular simulation. The computer simulation was designed to model the functioning of the human cardiovascular system. Students were assessed based on their epistemological beliefs such as belief in learning, belief in ability to learn, belief in providing an

answer to a problem. The pretest was a 24-item multiple choice instrument in which all questions were based on human physiology. One posttest measure was what the author called a concept pairing test in which students were asked to rate the closeness of the relationship between pairs of terms (22 pair total). A multiple choice posttest was also given. A significant difference was reported favoring the constructivist approach for 2 of 6 commonly held alternative conceptions.

Hargrave & Andre (1993) examined the use of computer simulations, reflective journals, and peer group interactions to facilitate conceptual change about electricity. The participants were 116 undergraduate students (92 females 24 males) enrolled in media course for preservice teachers elementary education. The students were randomly assigned to four treatment groups: 1) the computer-based didactic lesson control group (CP) completed a computer-based instructional lesson concerning simple electrical circuits that used traditional instructional design, 2) the conceptual change computer simulation group (CCCS) who completed a computer-based instructional lesson concerning simple electrical circuits and used a conceptual change approach, 3) the conceptual change computer simulation and reflective writing group (CCCSW) who completed the same lesson as the CCCS treatment group and also recorded their perceptions toward computer lesson in student journal, and 4) the conceptual change computer simulation, writing and peer group interaction group (CCCSWPGI) who completed the same lessons as the CCCSW treatment group and in addition, took part in small group discussions about electrical concepts in the program. Students in the control group completed a didactic HyperCard lesson similar to that found in a typical textbook whereas the experimental group completed a simulation lesson about electrical circuits. The simulation lesson encouraged students to become cognizant about how electrical circuits worked. The students used the computer to built electrical circuits and then test whether the circuit worked. A 29 multiple-choice item posttest, adapted from Carlson & Andre (1989) and Chambers and Andre (1991), which measured students understanding of basic

electrical circuits, was administered to the students. Five posttest subscores were calculated from this posttest. In addition, 4 calculation items tested students' ability to recall and apply Ohm's law to calculate voltage, resistance, and amperage. The posttest was administered twice to the students on different occasions. The results indicated that the CP treatment group scored significantly than the CCCSWPGI treatment group on the BULB subtest score, but that the simulation groups did significantly better than the control group on the SINK subtest score.

Zietman and Hewson (1986) investigated the effects of instruction by using computer simulation to diagnose and remediate alternative conceptions. The microcomputer simulation was used to evaluate the effectiveness of the conceptual change model of learning through the use of a computer simulation facilitating a change in the student's perceptions as cited in Tyliniski (1994). The microcomputer presented two capabilities: 1) a simulation experiment that identified the different conceptions that students hold and 2) a practice test diagnosing the students conceptions in respect to the anatomical functions and identity of the particular organs among other organs in the system. Their results indicated that:

- (1) Simulation is effective and can be credibly represent reality, and
- (2) remediation produced significant conceptual change, particularly in those students holding alternative conceptions.

Students hold a variety of alternative conceptions about natural phenomena that may actively interfere with the development of scientific conceptualizations (Posner, Strike, Hewson, & Gertzog, 1982). In the search for ways to influence the conceptual development of learners, computer simulation has emerged as a possible vehicle for helping students learn and for effecting conceptual change (Zietman & Hewson, 1986). In this section eight empirical research articles were reviewed based on the use of computer simulation to effect conceptual change. On achievement measures, four found that the use of simulations can effect conceptual change and can lead to higher achievement; three found no significant differences in achievement. In one comparison that examined gender, the results indicated that using

simulation before didactic instruction was more effective for males than females. Overall these results support the contention that computer simulations can be helpful in significantly altering students' misconceptions.

### The Controversy Over Computer Simulation and Dissection

As a science teacher who has dissected animals for the sole purpose of studying the anatomical and functional components of organisms, I believe that without dissection in the school biology curriculum, the students' education is threatened, and once education is threatened, the students find themselves in crisis. Some science teachers have asserted that use of simulations as an alternative to traditional hands-on dissection is not a panacea. They claimed that simulations in science education are too abstract, minimize human involvement, cannot promote the learning of biological concepts, or teach interrelationships of the anatomical components of the animal (Mackenzie 1988, p. 7). On the other hand, there are some who endorsed the use of computer simulations to replace the traditional hands-on method of dissection because simulations can allow the dissection to remain "real" while eliminating political controversy, dissection errors and expensive laboratory apparatus (Orlans, 1988; Hopkins, 1975; Murphy, 1986; Winders and Yates, 1990). This section review the arguments made for and against the use of dissections and alternatives to dissection in biology classrooms.

Perhaps the most positive statements that can be made about computer simulations of dissections are that some studies show that use of computer-simulations improves students' learning, reduces students' learning time, and usually fosters development of a more positive attitude toward computers, compared with the traditional instructional approach (Flower & Brosius, 1968; Alexander, 1970; Bernard, 1972; Baggott, 1977; Jones, Olafson & Sutin, 1978; Strauss & Kinzie, 1994). A number of authors have suggested that computer-simulations represent a real-life model in which the student plays a role and interacts with the

computer. Simulations have been used in most high schools and elementary schools throughout the nation to model scientific processes in the classroom. The recent unique advances in the teaching of science have been in the use of computer-simulations. One application of simulation techniques has been as a replacement for the large numbers of animals used for dissection in research.

While an overview of the literature indicates that significant numbers of science and non-science educators express whole-hearted support for using simulations in science education laboratories, there are those who oppose such usage and label it “counterfeit science.” One of the leaders, and perhaps the most eloquent, of the opponents of computer simulations as replacements for hands-on laboratory dissections, Schrock (1984) claimed that computer simulations inserted into the school curricula would not help students in any way to develop positive values from reality, but might function as additional step in isolating students from real-world experience. Schrock went on to say that “Computers do have an important and valid role in instrumenting and monitoring experiments, testing new models and improving our intuitive reach, analyzing real data, and simulating labs that are impossible, impractical, or too dangerous to run. But their use beyond this poses a threat in value education, the so-called ‘affective domain’ in educationese” (Schrock, 1984, p. 254). Schrock added that the sales pitch claiming “installation of computer lab simulations will save large amounts of money consumed by chemicals and lab supplies... money that can go for other curricula needs, etc.” misses the point (p. 4).

Bross (1986) argued that most conclusions drawn from computer-simulations “cannot be scientific” because they are “the imitation of nature with programming and graphics and do not follow directly from natural laws” (p. 13). He believes that the skills acquired through the use of computer simulation activities are perhaps beneficial to students, but if they displace the intended science curriculum, then a serious and negative value shifts occurs. Students may develop computer literacy along with science illiteracy. Similarly, Schrock (1984) added that

“we have sufficient experience indicating that computer-simulations inserted into the current curricula will not help students develop values from reality, but will be an additional step in isolating students from real value-producing experiences” (Schrock 1984, p. 254). “The majority of science teachers are aware that verbal descriptions, theoretically simulated diagrams on the screen, and even audiovisual reproductions are no substitute for the real thing and carry no weight compared with hands-on laboratory demonstrations that are live, captivating, and real” Bross, (1986 p. 28). Wood (1979) suggested that the use of simulations should be limited to biological experiments which, by reason of difficulty of technique, danger to life, or lack of time, would be unavailable to students. Danger to life refers not only to the investigator, but also to the use of simulations to help reduce the number of experimental animals sacrificed in teaching.

Murphy (1986) claimed that most computer advocates believe that computer simulations should function as a supplement, rather than to replace, laboratory or experiences that students gain from field work. Murphy went on to suggest that living organisms should be included in the science curriculum as a part of teaching and learning science. On the other hand, Murphy questioned whether computer simulation instruction was as effective as dissection as a supplementary tool to the instruction. Murphy claimed that any student who experienced dissection only through computer simulation would not only lack experiential skills to handle required laboratory tools, but may not exhibit the compassion toward lower life forms. He suggested that educators should be as explicit as possible and be aware of the nature and limitations of computer simulations. And if computers are to be used in science education, it is imperative educators understand the differences between the terms used like ‘model’ and ‘modeling’ and to use them carefully. If not, there is a real danger of serious confusion in the minds of biology students. In the study of physical phenomena, MacKenzie (1988) stated “that the microcomputer simulation can allow the experiment to remain ‘real’ while eliminating the tedium and errors in gathering and analyzing data and displaying results” (p. 23).

In MacKenzie's opinion, although simulations are capable of imitating or replicating what is 'real' especially in the science laboratory, does not mean that simulations can act as a total replacement to traditional hands-on dissection. He went on to question whether students should really be learning that science is full of amusement, easy, precise and fun as simulation seem to make science appear? In MacKenzie's view computer simulations may be useful in some situations because simulations can be close enough to real laboratory apparatus and instruments that sometimes may be too expensive and hard to find or use, or may require frequent arduous calculations. These useful features do not make simulations compatible to hands-on dissection in his view, however. In support of MacKinzie opinion, I believe that no patient would like to be operated on by a physician who had studied exclusively from computer simulations of human structures, anatomical functions, and locations or had used simulations confirm certain diagnostic tests and conclusions. Winders and Yates (1990) logically compared the traditional science laboratory method to computerized science laboratory simulation without specifically defining these methods. They claimed that traditional hands-on science laboratories provide certain essential skills necessary for the development of a scientifically literate society that are frequently missing from computer simulations. Hands-on labs, therefore, should not be totally replaced with computer simulations and models (p.11-12).

Winders and Yates supported Mackenzie (1988) by saying that "computer simulations suffer by their abstract presentation of real-world phenomena. Students may develop a false sense of reality or security in the simulation of situations which are complex or potentially dangerous, just as with video games" (p. 5). MacKenzie had concluded that the computer simulation-based laboratory was at one extreme (abstract and minimizing human involvement), and the traditional experiment at the other (inaccurate, of limited scope, and labor-intensive). Winders and Yates concluded, "real life in the real world is not a computer simulation! And the use of computer simulations in science education is not a panacea to scientific illiteracy."

Murphy (1986) also warned investigators against the default values of the simulation and basing simulations on mathematical models. He recommended that they use analogues of nature instead, while being “as explicit as possible about the nature and limitations of the simulations” (Murphy, 1986 p. 20). I agree that any student who experienced science only through computer simulations would lack the necessary skills required to properly handle expensive equipment or may lack feelings and human compassion for the fellow humans.

As was noted in the introduction and in opposition to these opponents of dissection, many educators and theorists have argued the advantages of simulations (Alessi and Trollip, 1985; Brant et al., 1991; Duffy and Jonassen, 1992; Greenblat, 1981; Gredler, 1992; Hopkins, 1975; Hoskins, 1979; Igelsrud, 1986; Orlans, 1888, Reigeluth, 1987; Thomas and Hooper, 1991). Research from military and other settings suggests that interactive simulations can be a efficient and effective tool for training psychomotor tasks (Olsen & Bass, 1982; Saettler, 1968). Thousands of military personnel have been trained to rapidly and effectively perform tasks critical to their own survival and to military effectiveness through the use of simulations (Olsen & Bass, 1982). If this is the case, interactive computer simulation may prove to be especially useful in science education and interactive dissection simulations may prove to be an effective vehicle for teaching even the psychomotor skills involved in dissection. It seems clear that the use of simulated frog specimens affords beginning students a firsthand look at a vertebrate that has many body structures in positions and arrangements similar to that of the human. Simulated dissection goes beyond the visual investigation of textbook drawings and photographs and allows students to examine quite real appearing structures and to utilize quite real dissection procedures. Moreover, the applications of simulations to science teaching are nearly unlimited. In visually rich subjects such as life science, simulations can provide a compact library of experiences that could replace bulky and expensive slide collections. Such visual databases in part represent one potentially valuable use of simulation technology. Such



inexpensive simulation databases potentially represent a flexible resource that a science teacher might use in many different ways to promote effective learning.

Thus, in spite of these different opinions on whether or how simulations should be used, in my opinion, the use of simulations in education can be successful in translating imagined situations into something that is very productive and a real learning experience for students. Simulation is neither good nor bad. It depends on its use and the purpose for its use. For example, as supplement to dissection, the use of simulation before dissection may provide experiential based skills in removing specific hidden parts of the anatomical structure which may be difficult to view or remove in the traditional dissection classroom. In my view, computer simulation is an important cognitive tool that can increase students' ability to investigate and understand science. The following section will discuss reasons that justify the use of simulations in the teaching of science.

#### Use of Simulations in Science Teaching

The increasing availability of computer technologies in schools (Becker, 1991) has made it possible for more thorough investigation of their influence on students' learning, achievement, and attitude change. In biological science or physical chemistry, for example, experiments at times can be very expensive, too difficult, or too dangerous for the students to conduct. Through simulations such experiments can be conducted and the intended results actually observed. Simulations make flights through space, man visiting the moon and more complex impossible tasks become possible. In years to come, creatively designed simulations, may make even more impossible events such as humans traveling almost at the same speed of light possible to experience. The unique capacity and ability of simulations to present phenomena in multiple perspectives and to allow the learners to interact with the dynamic imagined worlds, creates a means of making learners the master of their own learning processes.

Computer simulations as instructional tools have gained more popularity and enthusiasm in the past few decades. There is no doubt that computer simulation in science education is a medium of great potential. Like any technological innovation more needs to be learned about its effectiveness in science teaching and learning. Because simulations are readily available commercially at affordable prices, they will be used in schools. Researchers need to pursue research on the effective use of simulation. Such an important studies in part could help to gratify and identify the most appropriate uses of the computer simulation technology as educational tools in science teaching and learning.

In life science dissection, simulations can be helpful because they can reveal frog parts that are hidden and students can see those parts before an actual dissection. When simulations are used before the traditional method of dissection, some evidence suggests that simulations can improve students' performance during actual dissection activities. Simulations are useful for science education because of they have unique characteristics such as repeatability, immediate feedback, and availability at any time allowing students to use without the presence of the instructor. In my opinion, use of computer simulation in science education can help to reduce differences in achievement between majority and minority students. To the extent that the lower achievement of minority group students may be due to inconsistencies between such students and majority group teachers, computer simulations may help to provide minority students with needed learning experiences. In my view, simulation software has the potential to become a second teacher that would allow minority-students to explore the unknown world on their own. Simulations in science education can provide students with first-hand experiences of the thrill of learning by motivating the student as the student witnesses frog dissection for the first time rather than just reading about it in the textbook. Computer simulations can provide students with the opportunity to practice decision making in an environment which is both fairly realistic and safe.

In my view, the primary purpose of computer simulation in biology or life sciences is to provide students with experience before actual dissection activities and to allow fundamental experimentation that would not be otherwise possible. There is some evidence from Kinzie et al. (1993) that simulations can enable students to improve actual dissection. Additionally, evidence as provided by Strauss and Kinzie (1994) suggests that simulation can allow students to observe animals' physiological systems and interrelationships more easily. In some simulations, students can make changes in a dynamic system to learn about the functions of the system. The rest of this section further addresses advantages of computer simulations.

Computer simulation is one resource available for pre-service teachers who are teachers trainees to learn how to integrate technology into their classroom teaching (Becker, 1983). However, teacher training may represent the largest single barrier to computer use in the science classroom. There is growing evidence that computer simulations can help provide an environment for practice of science process skills (Becker, 1983). If it is true that computer simulations in growing numbers are available to science teachers, in what ways can these new tools be most effectively used to teach specific science process skills? Because of simulations' potential, students can understand abstract concepts in a more concrete manner and interact with phenomena normally not accessible in a traditional classroom. Computer simulations can display some distinctive advantages when used as an alternative to the traditional method of dissection. The first is cost-effectiveness and cost-efficiency. Some potential problems exist in medical schools over the lack of cadavers in the laboratory because too few people donate their bodies to science. This problem can make dissection very expensive and, even if money is available, the supply of cadavers may be inadequate. Although most of the alternatives are expensive and require an initial outlay of some money, over time, the money is saved because the purchase of computer simulations is a one-time event, and they can be used repeatedly over long periods of time compared to the cost of purchasing preserved frogs or cadaver specimens every few months. Simulated specimen alternatives have a longer longevity, according to

Hepner (1993), and are non-disposable items in contrast to traditional animal or cadaver specimens. Another advantage is repetitiveness. Students can repeat the given dissection assignment without the restriction of time limits, until they feel they have learned something (Hepner, 1993). Moreover, most of the alternatives that are available are self-directed or self-paced, making them more suitable for students with various disabilities. Most alternatives enhance motivation because students are active participants in the learning situation, as compared to their role in traditional classrooms.

Another important advantage of simulations is that they promote a transfer of learning (Alessi & Trollip 1985). Transfer of learning consists of skills or knowledge learned in one situation being applied in other situations. In my view, simulations potentially can promote good transfer of learning because what is learned in the simulation in one situation or class can usually be transferred to the real-life situation. Use of computer simulations before actual dissection of a frog in order to study internal structures, muscles, and locations as well as functions of organs can result in better transfer of knowledge than dissection after simulation (Strauss and Kinzie, 1994). In addition to saving time, simulations may motivate students. Students may be filled with a high-spirit of excitement when they encounter, for the first time, a sea star or earthworm to dissect via computer simulation. Efficiency in decision-making, by providing a base of previous meaningful experiences, is another way in which a simulation can enhance learning (Gredler 1992). Simulations provide the learner with an environment that is conducive to learning compared to a regular classroom without simulations (Alessi and Trollip 1985; Strauss and Kinzie, 1994; Kinzie, Strauss, and Foss 1993; Kinzie, Foss and Powers, 1993; Rivers & Vockell, 1987; Leonard, 1992, 1985, 1989; & Choi & Gennaro, 1987; & Frisby, 1992).

### Value of Simulations and Instructional Strategies in Science Education

Research studies have indicated that the use of computer simulations of dissection, compared to the traditional hands-on method of dissection, provide comparable results in improving student attitudes and achievement, reduce instructional time (Kinzie, Strauss, & Foss 1993; Kinzie, Foss & Powers, 1993; Guy & Frisby 1992; Fawver, Branch, Trentham, Robertson, & Beckett 1990; Leonard 1992, 1989, and 1985; Choi & Gennaro 1987). Simulations can reduce instructional cost, and provide high-quality, timely, feedback responses to the user. Simulations entice users to manipulate variables and observe their effects in an environment that may be completely impossible, impractical, or inefaceable compared to other methods of instruction ( Rivers & Vockell, 1987). One most unique and powerful aspect of simulations use in science education is interactivity. The key here is that the student must do something. From educational research we come to know that learning involving “doing” is retained longer than learning via listening, reading, or seeing. Simulations in science education provide education which is non-linear and is not teacher-directed. This type of learning offers an inquiry approach in science education. The learner is actively involved in exploring and discovering. In science education simulations can turn over a great deal of power from the lecturer to the learner. Instead of the teacher directly leading students through specific content, the teacher provides an environment in which students can discover and explore. One useful strategy in science education is getting students involved in the best way to motivate them to learn. Simulations seem to hold a natural attraction for students to learn science.

### Summary

This paper has reviewed some major issues on empirical research related to the use of simulations in science education. Among the issues examined were theoretical, logical, and speculative claims made about the advantages of simulations in science education. Many authors have argued that simulations should improve science learning by making learning more

realistic and active and by permitting students to experience situations in simulation that are impossible, impractical, too dangerous, or too expensive to experience in reality. Other authors argue against simulation because they believe simulation reduces the reality of the learning experience in science education.

The research reviewed in this paper suggested that simulations can lead to equivalent learning to hands-on dissection or other hands-on alternatives experiences when learning is measured by paper and pencil tests (Kinzie, Strauss, & Foss 1993; Kinzie, Foss & Powers, 1993; Guy & Frisby, 1992; Fawver, Branch, Trentham, Robertson, & Baeckett, 1990; Leonard, 1992, 1985, 1989; Choi & Gennaro 1987). Further, the research suggested that simulations used before other educational experiences can facilitate learning more than simulations used after other experiences (Andre, et al. 1998; Brandt et al. 1991). One particularly important finding in this review was the Kinzie et al. (1993) study. While several studies noted above have reported positive benefits for the use of simulations prior to didactic instruction, the Kinzie et al. study suggested that a prior interactive videodisc dissection simulation could enhance subsequent actual dissection performance. The present review suggested that simulations can be educationally sound and useful; it also made clear that additional research is needed to more fully understand the educational impact of simulations in science education. One direction for future research is to explore the sequence in which simulations are used relative to other instruction. A second issue to be explored is how individual, group, and cultural differences interact with simulations. Do simulations work equally effectively for the different genders, for students with different personality, metacognitive or cognitive style characteristics, for students from minority groups, or for students from different cultures? Does the use of simulations have to be adapted to such differences in order to be effective? Another issue is the long term use of simulations. Most of the studies reviewed here have involved short term use of simulations. Will simulations have the same educational effects when they are integrated into semester or year long course

sequences and are a typical part of the student's day? These questions can only be answered by additional research.

**THE EFFECTS OF COMPUTER SIMULATION MODEL ON MIDDLE SCHOOL STUDENTS' UNDERSTANDING OF THE ANATOMY AND MORPHOLOGY OF THE FROG**

A paper to be submitted to the Journal of Research in Science Teaching

Joseph Paul Akpan

**Abstract**

Science teachers, school administrators, educators, and the scientific community are faced with controversies over animal dissection in school biology classrooms. For religious or ethical reasons, some argue against the use of animals for dissection. Computer simulation has been proposed as a way of dealing with this issue. One intriguing tentative finding in previous simulation research was that use of an interactive videodisc dissection facilitated performance on a subsequent actual dissection. This study was designed to replicate and extend that finding to computer-based dissection. The purpose of this study was twofold: 1) to examine the effectiveness of a computer simulation model of frog dissection in improving students' actual dissection performance and learning of frog anatomy and morphology and 2) to determine whether the effectiveness of the simulation in improving students' actual dissection performance and learning of anatomy and morphology is dependent upon the sequence in which simulation is presented. Class periods were randomly assigned to three experimental conditions: simulation before dissection, dissection before simulation, or dissection-only. Results of the study indicated that students in the simulation before dissection condition (SBD) performed significantly better than the dissection before simulation (DBS) and dissection-only (DO) conditions on both the actual dissection and on knowledge of the anatomy and



morphology. There were no significant differences between the latter two conditions. Students attitudes toward the use of animals for dissection did not change significantly from pretest to posttest and did not interact with treatment. The genders did not differ in achievement, but males were more favorable towards dissection and computers than were females. Attitudes were not influenced by the experimental treatments.

### **Introduction**

The controversy over traditional dissection

A major controversy exists regarding the traditional hands-on method of dissection in science education. Primarily, the issue is whether the knowledge gained justifies dissection as a primary technique for teaching anatomy and morphology in science classrooms. Some educators argue that dissection is not only a valuable tool that motivates students with sound educational experience but can also help reinforce their knowledge of understanding anatomy and morphology (Berman, 1984; Orlans, 1988; Hoskins & Igelsrud, 1986). Many also contend that animal use in dissection has contributed to the advancement of human medicine, and thus to the alleviation of pain and suffering in human beings and other animals (D'Hooge, 1991). According to Orlans (1988), many educators believe that the knowledge students gain during a traditional hands-on dissection is retained longer and has more impact than the information passed on during a typical classroom lecture using textbooks, charts, or models.

Obviously, dissection provides students with concrete, hands-on learning experiences with anatomy, one of the most basic core sciences. Dissection takes many of the things students have heard or read about and gives them firsthand experience with them. According to Offner (1993), the type of learning that occurs in a traditional hands-on dissection is qualitatively very different from the learning that occurs from any form of instructional media presentation. As an enthusiastic advocate of dissection in high school biology, Offner contends that no model, video, diagram, or movie could duplicate the fascination, the sense of

discovery, wonder and even awe that students feel when they find real structures in their own specimens (p. 149). Offner argued that when students understand that the specimen is real, their attention is elevated, that what they learn is registered in their long-term memory as real, and that such ultimate profound and permanent kind of learning cannot be achieved by using models or videos. Similarly Schrock (1984) states "No computer simulation, whether cookbooked with one result, predetermined with ranges of variation, or loaded with random variation, possesses the spontaneity and truth-in-detail of a real lab." Schrock also believes that computer simulations in the current curricula do not help students develop values from reality, but further isolate students from real value-producing experiences. Murphy (1986) conceded that most computer advocates believe that computer simulations should supplement, not replace, laboratory or field experiences and added that, whenever possible, experiments with living organisms should also be a part of the science curriculum. Mackenzie (1988) supported Murphy in that he said that simulations suffer by their abstract presentation of real world phenomena and maintained that students may develop a false sense of reality or security in the simulation of situations. Bross (1986) questioned whether the student has the intense understanding to comprehensively arrive at the same conclusions drawn from dissecting via simulations in comparison to the level of reasoning and understanding that students arrived at by a conventional hands-on dissecting experiment. Bross believed that any conclusions drawn from the use of computer simulations cannot, in the real sense represent, scientific investigations simply because simulations are imitations of natural phenomena and thus, do not follow scientific laws of nature. Winders and Yates (1990) indicated that, although simulations are manipulable, safe, and less expensive, simulations prevent the development of other skills acquired in real world experiences such as traditional dissection instruction. However, Winder and Yates (1990) did not mention such skills that are more profound and unique in traditional dissection instruction that are not found in a computer simulated instruction.

Others focus on negative aspects of dissection such as the cruel waste of animal life. DeRosa (1986) claimed that “in one year alone, U. S. suppliers shipped approximately 5 million frogs for education and research purposes.” In addition, opponents of dissection claim that dissection creates negative attitudes in students toward animal species as well as creating psychological trauma in students (DeRosa, 1986; Zim, 1940; & Leib, 1985). According to Orlans (1988), when dissection was first introduced, some students lost their interest in biology because of the negative feelings dissection evoked and because of the psychological trauma dissection induced. In addition, because of the ongoing debate over dissection between animal rights activists and public school officials, several states have enacted laws upholding the rights of students in grades kindergarten through 12 to refrain from participation in dissection activities (Orlans, 1988). Many moral and ethical beliefs contribute to the controversy of using animals for dissection. Some groups argue against the use of animals in dissection due to prejudicial behaviors equivalent to racism, sexism, and religious fanaticism (Gilmore, 1991).

A related issue is whether dissection is gender biased. Science educators are becoming increasingly concerned about gender differences with respect to expectations, types of experiences, and participation in science classrooms. Some might argue that males are more likely than females to enjoy dissection. From this viewpoint, requiring dissection in biology classes contributes to a male-oriented dominance in science and contributes to gender inequities in science careers. According to the American Association Union of Women (AAUW) Report (1992) differences between male and female achievement in science, education, and mathematics in secondary school seems to suggest that gender-role socialization mediates intellectual achievement in various ways. Other researchers believe that the differences may be caused by the stereotypically male dominant society since science and math are historically male activities. This research will take a critical look at gender differences to see whether different sequences of simulation use differentially influences male and females.

This study was designed to determine whether the effectiveness of simulations in improving students' actual dissection performance and learning of anatomy and morphology was dependent upon the sequence in which simulation activity is presented. This research also examined male and female differences in the context of simulated or hands-on dissection. Lock (1995) provided some evidence about gender differences in attitudes about dissection. He explored 469 secondary students' knowledge, experience, and attitudes about the use of animals in dissection. Students showed respect for peer objections to dissection when the grounds for objection were moral rather than squeamishness. When the respondent's gender was considered, males were less likely than females to respect a peer's objection on the ground of squeamishness. Females were more likely than males to agree with a peer's refusal on moral grounds if the peer was female. There was lower level of agreement with a peer's refusal to dissect if the peer was a male. Males were more likely than females to offer to do the dissection on the behalf of a peer, giving as a reason, "the animal is dead and it is therefore acceptable to cut it up" (p. 20).

In summary, students varied in their attitudes to using animals in science education. Some gender difference in attitudes toward dissection were absent. Because of this controversy, it is imperative that ways be found to meet the needs of those who oppose animal dissection in the classroom but also help those who may wish to learn about anatomy and morphology of frog. Interactive videodiscs and interactive computer simulations have been suggested as alternatives to either substitute or supplement the conventional method of dissection in the science classroom (Bernard, 1972; Bowd, 1989; Bredemerier, 1981; & Bross, 1986). The National Association of Biology teachers (NABT) supports the use of interactive videodiscs and computer simulation as alternatives to hands-on dissection where ever necessary. National Anti-Vivisection Society (NAVS) claimed that the use of simulations in dissection would create compassion on student attitude toward animal life.

What is simulation?

Simulation is the use of the computer to imitate dynamic systems of objects in a real or imagined world. Computer simulated instruction gives students the opportunity to observe a “real” world experience and interact with it. In science classrooms, some educators argue that simulation can play an important role in creating virtual experiments and problem-based microworlds that allow students to monitor experiments, test new models and improve their intuitive understanding of complex phenomena (Alessi & Trollip, 1985). Simulations are also potentially useful for simulating labs that are impractical, expensive, impossible, or too dangerous to run (Alessi & Trollip, 1985; Wood, 1979; Showalter, 1970; Strauss & Kinzie, 1994). In addition, simulations potentially can provide students with learning environments in which students search for meaning, appreciate uncertainty, and acquire learning responsibility (Andre & Haselhuhn, 1995; Alexander, 1970; Carlsen & Andre, 1992; Brant, Hooper & Sugure, 1991).

Simulation, in general, permits study of a real system without the actual tampering or modification of that specific system. According to Akpan (in preparation 1998), one might apply simulation as a tool in dissecting animals or for analyzing and designing a complex system. Pedagogical simulations can be used in teaching students the anatomy and morphology of complex organisms or understanding complex relations of animal parts and their basic functions without actually dissecting real animals. The field of science education has witnessed an ongoing debate about the use of simulations as an alternative method that does not use live animals in learning anatomy and morphology in science classrooms. Simulations can create on students, spiritual values students can hold, and, with sufficient thought and dedication, simulation can become the guiding light of ongoing debate about animals use in dissection.

### Theoretical simulation effects

Use of simulated instruction seems to satisfy the theoretical requirements for a “good” learning environment advanced by some theorists (Chambers & Sprecher, 1983; Dwyer, 1980). Simulation involves the individual actively in the learning process, which probably facilitates learning (Mckenzie, 1978). Simulation can be used to permit the learner to proceed at his or her own will. The use of computer simulation can reinforce learning in a manner that is immediate and systematized, which should result in more effective learning according to Chambers and Sprecher (1983). Most research studies show that the use of interactive video-simulation as an instructional tool either improves learning or shows no difference when compared to the conventional method of instruction (Andre & Haselhuhn, 1995; Andre & Carlsen, 1992; Baker, 1988; Brant, Hooper & Sugrue, 1991; Ebner et al., 1984; Guy & Frisby, 1992; Harper, 1995; Kinzie, Foss & Power, 1993; Leonard, 1992, 1985, 1989; Munro, Fehling & Towne, 1985; Orlansky & String, 1979; Pierfy, 1977; Thomas & Hooper, 1991 & Tyliniski, 1994). Simulations have typically reduced learning time and led to more positive attitudes.

Lunetta (1981) defined simulation as the process of interacting with a model that represents reality. Lunetta argued that interaction with such a model should enhance scientific understanding of science and facilitate learning. Lunetta added that the potential of computer simulation in science education as a medium of instruction has been inadequately explored, and there are very few research articles reported concerning the effectiveness of simulations. Bross (1986), Clark (1983, 1985), Dekkers & Donatti (1981), Gredler (1992), Orlansky & String (1979), Piefy (1977), and Schrock (1984) criticized research flaws of simulations on methodological grounds. Certainly, there is a need for careful research into the effectiveness of computer simulations in science education.

As noted earlier, previous research has found consistent results regarding the use of computer simulations. Clark (1983, 1985) claimed, that media are “mere vehicles that deliver

instruction but do not influence student learning and achievement any more than the truck that delivers our groceries causes changes in our nutrition” (1983, p. 445). In contrast, Kozma (1991) argued that “when learners are actively working with a medium, they construct meaningful knowledge and that the medium and the methods can cause more or different learning, depending on the type of medium used by the learner”. Moreover, he argued that it is feasible for the medium to provide a theoretical background, especially when the learner is actively collaborating with the medium to construct his science knowledge” (p. 178).

According to research reported by Thomas & Boysen (1989), simulations can fulfill two important instructional roles: 1) setting the stage for future learning and 2) providing an opportunity to apply or integrate newly acquired knowledge. As a stage setting activity, a simulation is used prior to formal instruction; whereas, as an application or integration activity, it is used after the instruction has been given. A particular simulation might serve both functions, or it might be more effective when placed either before or after formal instruction.

Brant, Hooper and Sugrue (1991), Thomas and Hooper (1991), Thomas and Boysen (1989) argue that precise criteria for the optimal use of simulations have yet to be established.

However, when used as a pre-instructional activity, simulations can 1) provide motivation, 2) reveal misconceptions that would inhibit learning, 3) provide an organizing cognitive structure for receiving new material and 4) serve as concrete examples of complex, abstract concepts.

They stimulate the manipulation and activation of relevant knowledge which already exists within the learner’s cognitive structure. The existence of this relevant knowledge has been shown to influence the learning of new material.

Thomas and Hooper (1991) developed a useful taxonomy of uses for simulation and to evaluate the effectiveness of simulations. Their first category, experiencing, includes cases in which simulations are presented before formal instruction, and are used to set the cognitive stage for future subsequent instruction. They claimed that, when material presented to the learner is new to the learner, simulations can provide experience that is useful for providing

motivation, providing concrete examples, providing an organizing structure for future cognitions, exposing misconceptions, and diagnosing misconceptions.

Thomas and Hooper's second taxonomic category is informing or demonstrating. This way of using simulations is simply for transmitting information to the learner, and few learning benefits were found for students using simulations in this manner as compared with the use of computer tutorials, or direct instruction. They suggest that the informing category can be useful in supplementing or replacing the traditional textbook lecture and discussion demonstration.

Thomas and Hooper's third category, reinforcing, is described as the strengthening of specific learning objectives. The standard rule for simulations classified as being used for reinforcing is that they can direct the student to apply existing knowledge in the same context it was learned. Simulations used for this purpose usually contain feedback. Thomas and Hooper claimed that some learning benefits were found for students using simulations in this particular manner but not perceived as being adequate.

Thomas and Hooper's fourth category is integrating. Integrating is the use of simulations to assimilate isolated pieces of knowledge schemata into functional units, and to promote the reorganization of knowledge. Simulations used this way were believed by Thomas and Hooper to be beneficial in helping students integrate knowledge bases has been learned independently so as to transfer their knowledge to future problem solving situations. Among the four categories of using computer simulations in education, the integrating simulation is potentially the most important category of using computer simulations to aid students' learning. According to Thomas and Hooper (1991), when a particular simulation is used as post-instructional instruction, the simulation experience may provide motivation and may provide an organizing structure or schemata that helps the learner to adopt alternative conceptions. When a simulation is used as pre-instruction, such as before lecture or reading of a textbook, it may facilitate learning by providing an experiential base for learning (Thomas &



Hooper 1991). They also asserted that the effects of experiencing simulations are revealed, not by recognition or recall tests of knowledge, but by tests of application and transfer. Using simulations to give first-hand exposure to students about a concept (experiencing) and using simulations to integrate knowledge and stimulate problem solving approach (integrating) seem to be the two most promising classroom instructions for learning.

#### Research on simulations

Research on the use of simulations in instruction has not produced evidence of a clear-cut advantage for simulations. Cherryholmes (1966) reviewed six studies on educational simulations and concluded that simulations offer no significant advantages with regard to learning, retention, critical thinking, or attitude change compared to results obtained by conventional methods of instruction. Akpan (in preparation ) reviewed about fifty research studies in the area of computer simulations in science education such as the use of computer simulations in animal dissection, simulations in science education, and concluded that simulations can turn a tedious task into one done more easily, quickly, or cheaply for both learners and teachers. Akpan asserted that although simulated instruction can increase learning efficiency and productivity, nevertheless, its classroom use was far from being a panacea for all of the problems facing science educators. The effectiveness of simulations as educational tool depends very much on the purpose for which they are used.

#### Simulations used before or after instruction

The instructional use of simulation either before or after has been the focus of a number of recent research studies (Thomas & Hooper, 1991; Brant, Hooper & Sugrue, 1991). Brant et al. (1993) gave students a genetics simulation on pig breeding to complete either before or after receiving lectures on genetics in an animal breeding course. The group of students who

had received the simulation before didactic instruction scored better on both the application and transfer posttest measures than students who received the simulation after didactic instruction.

Andre and Haselhuhn (1995) compared students who completed a Newtonian motion computer simulation as pre-instruction to students who completed a non-Newtonian computer game as pre-instruction. Participants were students in an introductory psychology class. The independent variables were the type of computer activity (simulation or game) and the position of the computer activity (before or after reading the text). The two types of computer activities were: 1) a simulation designed to illustrate Newtonian principles of motion and 2) commercial games with a non-Newtonian motion. The motion simulation allowed the student to explore the effects of applying impulse forces to a body at rest or moving in a particular direction or space. The computer games were given to students either before or after they read a text dealing with Newtonian motion. There were no significance differences in the pretest means found among the control, simulation-before, and simulation-after text conditions. For males, but not for females, the motion simulation before the text led to superior performance. In a follow-up study, a revised simulation used before didactic text led to superior performance for both males and females (Andre, Duschen, Werner, Mroch, & Akpan, in preparation). Research done by Kinzie, Strauss, & Foss (1993) compared the achievement and attitudes of students who conducted a frog dissection either with or without the use of an interactive video-based simulation (IVD) as a preparatory experience for the dissection. The participants, 61 high school students enrolled in a general biology class, were divided into four approximately equal groups. The IVD prep group used the interactive video-based simulation as a preparation for the laboratory dissection, which they then performed. The video prep group viewed a linear videotape containing the same video materials used in the IVD simulation, but without interaction and then performed the dissections. The dissection-only group conducted the dissection without preparation. The IVD-only group used the IVD simulation but did not dissect. The results indicated that students in the IVD prep group

performed the dissection more effectively than those students who received no preparation and more effectively than students whose preparation consisted of viewing the linear videotape. In addition, those students who dissected after using the video materials as preparation tools learned more about frog anatomy and physiology than those who dissected without preparation.

### Major implications and conclusions

Use of simulations to replace animal dissection in science education is controversial. Many authors have argued that students interaction with simulations should enhance scientific understanding of science and facilitate learning; other authors argue against simulation because they believe simulation reduces the reality of the learning experience. The available research suggests that simulations can lead to equivalent learning as dissections or other hands-on experiences when learning is measured by paper and pencil tests. Further, the research suggested that simulations used before didactic instruction lead to better student learning on both the application and transfer posttest measures than simulation used after didactic instruction. In a related study, Kinzie et al. (1993) suggested that a prior interactive videodisc simulation of a frog dissection could enhance subsequent actual performance in doing a hands-on dissection. The present study was designed to follow up on the Kinzie et al. research.

### Statement of problem

The purpose of this study was threefold: 1) to examine the effectiveness of a computer simulation model of frog dissection in improving students' actual dissection performance and learning of frog anatomy and morphology, 2) to determine whether the effectiveness of the simulation in improving students' actual dissection performance and learning of anatomy and morphology was dependent upon the sequence in which simulation activity was presented and 3) to examine the influence of gender in learning from simulated and actual dissection. Gender

is examined because, as noted above, the genders have been shown to have different attitudes and reactions to dissection. This latter question is important because some evidence suggests that there are gender differences in attitudes towards dissection.

### Research hypotheses

In this study, one treatment group used a frog simulation model before they completed an actual frog dissection. The second treatment group performed the actual frog dissection before they completed the computer simulation model. The third group performed the traditional frog dissection only. Based upon the research reviewed above, the following hypothesis were investigated.

Hypothesis 1: The participants who received a computer simulation before an actual dissection would learn and perform better on a posttest achievement measure and the actual dissection than would the participants who received a simulation after dissection and participants who dissected only.

Hypothesis 2: The mean scores on the posttest achievement measure would be greater for those participants using a simulation than the mean score of those participants not using simulation.

Hypothesis 3: Male participant would do better on the achievement posttest and actual dissection than would female participants.

## **Methodology**

### Participants

The participants were approximately 127 students (59 males, 68 females), ranging in age from 13-15, enrolled in seventh grade life science course in a mid-size midwestern middle school of 800 students. These students had some experience in animal dissection, but had no experience in the use of a simulated dissection. These students participated in the activity as a

normal classroom dissection. All students in the classes participated in the activity, but data were used only for those students who signed, and whose parents returned, permission slips.

### Design

Students participated in their assigned class periods. Four periods taught by the cooperating teacher were used in the study. Of the 101 students in these sections, 12 were absent at some point due to illness or inclement weather. Seventeen special education students were not included in the study because the researcher wanted to use only the regular education students in this study. Five students did not take either the pretest or posttest attitude measures and they were excluded also from the study. Two students whose names could not be not matched with their ITBS scores were also excluded from the pool of this study. These factors reduced the total number from 101 participants to 65 (26 males, 39 females). Participants were randomly assigned to the periods at the beginning of academic school year based on teacher recommendation and final grade in six grade science in a manner so as to equalize ability across sections. In this study, class periods were randomly assigned to three experimental conditions. In Condition 1, students used a simulation model (BioLab Frog Dissection Software from Pierian Spring, Inc.) before they completed an actual frog dissection. In Condition 2, students performed an actual frog dissection before they completed the computer simulation model. In Condition 3, students performed hands-on frog dissection only.

### Materials

Preserved specimens of the most common frog in the United States, *Rana pipiens*, were used in this study. This abundant species is a popular in biology experiments and in dissection. The students were given the following list of common dissection materials. Each item is followed by a brief description of its use in this study:

Blunt probe: a rigid 6-inch steel instrument with a blunt, bent tip. This probe was useful for gentle manipulation of muscles and internal frog organs.

Scissors: 4-7 inches long. Scissors were used to cut through skin, muscles, and other large structures.

Scalpel: 6 inches long with replaceable blades. This scalpel was used to make small incisions.

Needle probe: a 3-4 inch needle attached to a wooden handle. This material was used to attach the specimen to the dissecting tray.

Forceps: about 6 inches long. These are commonly called "tweezers." They were used to grasp frog skins and to move other parts around to view easily

Dissection pan: a 4 x 6 inches long. This was used to hold preservative that came from the frog body and to keep the frog in place.

Surgical gloves: These were of different sizes. They were used to protect participants' hands as they dissected the frogs.

#### Objective for dissection

The dissection activity was one normally used by the classroom teacher. This learning activity had the overall goal of helping students learn to recognize and know the functions of the internal organs of a frog. The specific objectives for dissection were as follows:

1) To remove fifteen internal organ structures that are part of the digestive, circulatory, reproductive, respiratory, and excretory systems of the frog. The primary objective of the dissection was to bring into view structures that cannot readily be seen in their normal environment.

2) To learn the anatomy and morphology of the frog so as to be able to name each structure and describe the functions of each structure.

3) To learn the functions of the frog skin for protection from predation through camouflage and secretion of poison.

### Dissection simulation

The BioLab Frog Software, a computer simulation of a frog dissection, was supplied by Pierian Spring. The software simulates, on a computer screen, an actual frog dissection. As the students view and remove organs in BioLab-Frog, the software displays added information about each item. It also uses QuickTime movies and microscopic pictures to illustrate functions that are normally hidden from view. It reinforces learning with a review quiz after presenting each system. In the quiz, the participants match the function to the structure.

### BioLab simulation goals:

- 1) To provide comprehensive pre-lab information on the anatomy and morphology of frog parts.
- 2) To clarify unanswered questions that sometimes arise during dissections and to provide interactive, in-depth lab experience on the physiology of amphibians.
- 3) The program was similar to traditional curriculum that emphasizes identification of anatomical structures and functions of frog organs.
- 4) Most importantly, the program operates on the Macintosh computer which is available in nearly all the middle school science laboratories.

When students works on the software, they were given a worksheet for key words and definitions to complete (see APPENDIX A)

### Dissection performance posttest

Students were given a preserved frog to observe the external features before dissection (see APPENDIX B). During dissection, students were given a dissection guide (see APPENDIX B). They were to remove fifteen organs properly and placed them in the proper position on the blank worksheet of paper (see APPENDIX C) .

### Frog anatomy and morphology achievement test

The anatomy and morphology achievement test was used as both a pretest and posttest. This test was a 27-item multiple choice and short answer instrument designed by a life science classroom instructor in cooperation with two science experts who had taught life science for a number of years. Ten of these questions focused on identification of frog organs and seventeen of the questions were related to the functional knowledge of frog anatomy and morphology (APPENDIX D)

The test was reviewed by the researcher and the science instructor who had taught life science for a number of years. Example questions include: "During its life, a frog can breathe through? (a) gills (b) lungs (c) skin (d) all of these" and "Tammy and Wily both dissect two different frogs. Tammy has a male. Wily dissects a female. Wily discovers that he has long brownish-orange structures in his frog and Tammy does not. Mrs. Gaylor told Wily that the structures were fat bodies. Why do you suppose Tammy's frog did not have fat bodies?" (see APPENDIX D).

### Attitudes toward frog dissection measure

The attitudes toward dissection instrument consisted of a 22-item test with a 4-point Likert-type response scale (see APPENDIX E). Twenty of the items were adopted from those used by Kinzie, Strauss, & Foss (1993) with a few modifications. Two items were developed by the researcher and reviewed by science educators specifically for this research. Half of the items were positively phrased and half were negatively phrased. In scoring the scale was reversed on negative items so that consistency was maintained across the scale. These twenty two item (1-21, & 23) measured students' attitude toward animal dissection. Before administration of this measure, it was thoroughly reviewed and critiqued by two teachers and the researcher and subsequently revised. The attitudes toward science and school measure



contained eight items (25-32) that focused on how much students liked school and science. Students indicated their level of agreement on a 4-point Likert scale to items such as "I like school." Eleven questions (items 33-43) were used to assess the attitudes of the students toward computers. Students indicated their level of agreement on a 4-point Likert scale to items such as "Animals can be treated with respect in a dissection."

### Procedure

The participants were told of the experiment three weeks prior to the start of the study. To maintain anonymity, student identification numbers were used instead of names. In order to comply with district policies and state law, the students and parents were informed of their right to refuse to participate in the traditional dissection. Approximately three weeks before the dissection and simulation lessons, participants completed the anatomy and morphology multiple choice pretest and the attitude pretest.

The simulation sessions for the simulation before dissection condition and for the dissection before simulation conditions were conducted as follows. Students met during class times in the regular computer lab. The participants were seated individually at computer stations. The students were shown six systems of the frog dissection that they could navigate on their own in any sequence they chose. The participants were introduced to the computer simulation and given an instructional guide which included pictures of dissected frog parts and a description of their functions. They were also shown four interactive minilabs, in which they could investigate the frog's respiration, digestion, circulation and muscular capacity. The posttest was administered three days after the dissection was completed.

In the dissection laboratory, two-student teams worked at one lab table side by side in the room. Two researchers observed and evaluated the students dissection procedures and performance as the students removed the organs and placed them in the proper places. The researchers also videotaped the finished product of dissection. One of the researchers observed

each student team and then, using a 15-item checklist (right/wrong), evaluated team performance. Checklist items evaluated were the same dissection procedures outlined in the lab handout and preparatory materials. The researcher checklist contained items such as “after carefully removing the frog’s inner skin, use your hand to remove kidneys and place them on the proper position in the blank sheet of paper.” Each correctly performed step in the dissection or successfully removed organ was awarded 1 point toward the overall evaluation score. When a team was not able to perform the assigned step or could not remove an organ, the researcher assisted the team by indicating the proper organ and the step that was appropriate after the finished dissection products had been videotaped. To ensure reliability of the evaluation, the researcher evaluated one team at a time(see APPENDIX C).

## Results

### Scale characteristics

The anatomy and morphology achievement test. Item seven was accidentally not included in the pretest. For this reason, this item was not included in the total pretest score. Preliminary Cronbach reliability analysis indicated that two items (Numbers 5, 14) had negative item total correlations and three items (Numbers 15, 25, 26) had item total correlations of zero. These items were eliminated from the achievement pretest for that reason. The internal consistency estimate (using Cronbach’s alpha) of the remaining 21-item scale was 0.57. On the posttest, preliminary Cronbach reliability analysis indicated that item 7 had a negative item total correlation. This item was not included in the final posttest score. The alpha for the remaining 26-item posttest was 0.70. These reliabilities were judged acceptable for this research. (Because student knowledge is typically low on a pretest, lower internal consistency on a pretest is typical.)

Attitude scales. The internal consistency (Cronbach alpha) of the 8 item attitude toward science and school pretest was 0.74; the posttest alpha was 0.76. For the attitude toward computers scale, the pretest alpha was 0.74 and the posttest alpha was 0.80. The alpha for the attitude toward dissection pretest was 0.92; the posttest alpha was 0.81. All these internal consistencies were judged sufficient for this research (see APPENDIX F, Table 3).

Pretest data. In the analyses of differences between conditions, an alpha level of .05 is assumed unless otherwise specified.  $F$ -values are reported for significant effects only.

Achievement pretest. Differences between the three conditions on the pretest were assessed by one-way ANOVA. There were no significant differences found between the three treatment groups in pretest achievement score; the means are reported in Table 1. A t-test was used to compare the mean scores of males and females on the achievement pretest; no significant difference was found. Table 2 presents the means. APPENDIX G, Table 4 presents the analysis of variance.

Pretest attitude scales. On the attitude scales, a rating of 1 represented greatest acceptance of the item; 5 represented least acceptance. A one-way ANOVA on the pretest attitude toward dissection scale indicated a significant difference between the conditions,  $F(2,62) = 3.2$ ,  $p < 0.05$ . Table 1 presents the means. A follow-up Scheffe test indicated that the dissection-only group was significantly more positive toward dissection than the simulation before dissection group. The complete ANOVA table is reported in APPENDIX G.

The one-way ANOVA on the attitude toward science and school scale indicated no significant differences between the conditions. The results of the one-way ANOVA on the attitude toward computers scale indicated no significant difference between the conditions. See APPENDIX G for the complete ANOVA tables.

There were significant differences found in the pretest attitude toward dissection scores between males and females,  $t(64) = -2.9 = p < .004$ . As shown in Table 2, the male students showed more positive attitudes toward dissection than did the female students. Males and females did not differ significantly on the attitude toward science and school scale. Males also were more positive toward computers than were females,  $t(61) = -2.7, p < .008$ . Table 2 presents the means.

Table 1. Cell means, F-ratios, P-values, and standard deviations for each of the variables for each of the conditions.

Factor	Treatments				Total (n=65)	F- Ratio	P-value
	DBS <sup>a</sup> (n=28)	SBD <sup>b</sup> (n=21)	DO <sup>c</sup> (n=16)				
Pretest							
Achievement score (25-items)	M <sup>d</sup>	8.1	8.5	8.9	8.4	.33	.718
	Sd <sup>e</sup>	3.2	2.8	3.1	3.0		
Attitude toward dissection (22) <sup>f</sup>		2.3	2.6	2.1	2.3	3.20	.047
		.6	.6	.7	.6		
Attitude toward sci. & sch.(10)		2.6	2.4	2.2	2.4	.86	.430
		.6	.6	.7	.8		
Attitude toward computers (11)		2.4	2.2	2.4	2.3	1.02	.368
		.6	.6	.7	.6		
Posttest							
Achievement score (43)		15.6	20.0	14.9	16.9	15.06	.000
		3.4	3.0	3.2	3.9		
Dissection performance test (15)		8.1	14.1	7.8	9.9	119.82	.000
		1.3	.7	2.0	3.3		
Attitude toward dissection (22)		2.3	2.5	2.1	2.3	2.07	.135
		.6	.6	.4	.6		
Attitude toward sci. & sch.(10)		2.2	2.4	2.1	2.3	2.23	.116
		.4	.6	.5	.5		
Attitude toward computers (11)		2.0	1.9	2.3	2.1	1.19	.312
		.6	.8	.6	.7		

<sup>a</sup>DBS = Dissection before simulation

<sup>b</sup>SBD = Simulation before dissection

<sup>c</sup>DO = Dissection only

<sup>d</sup>Mean

<sup>e</sup>Standard deviation

<sup>f</sup>For the attitude items the numbers in parentheses represent the number of items on the scale.

For each participant, a mean of responses across the scale items was calculated. The mean reported in the table represents the mean of those mean

Table 2. T-test analysis between respondent means grouped by gender and factor.

Factors		Male (n=26)	Female (n=38)	t- value	t- prob
Pretest					
Achievement score (25-items)	M <sup>a</sup>	8.3	8.5	.26	.792
	SD <sup>b</sup>	2.9	3.1		
Attitude toward dissection (22) <sup>c</sup>		2.0	2.6	-2.98	.004
		.5	.7		
Attitude toward science & sch.(10)		2.2	2.6	-1.96	.055
		.6	.9		
Attitude toward computers (11)		2.1	2.5	-2.73	.008
		.5	.6		
Posttest					
Achievement score (43 items)		16.9	16.8	.02	.987
		4.2	3.8		
Attitude toward dissection (22)		2.1	2.3	-1.63	.108
		.5	.6		
Attitude toward science & sch.(10)		2.2	2.3	-.18	.859
		.5	.5		
Attitude toward computers (11)		1.7	2.3	-4.86	.000
		.4	.7		

<sup>a</sup>Mean<sup>b</sup>Standard deviation

<sup>c</sup>For the attitude items the numbers in parentheses represent the number of items on the scale. For each participant, a mean of responses across the scale items was calculated. The mean reported in the table represents the mean of those means

#### Posttest data

The posttest achievement and dissection performance data were analyzed using a 2 (Gender) X 3 (Condition) ANCOVA with ITBS science score and pretest used as covariates.

The anatomy and morphology achievement posttest. Hypothesis 1 predicted that the simulation before dissection condition would produce better achievement on the posttest than would the dissection before simulation and dissection-only conditions. The ANCOVA revealed a significant main effect of condition,  $F(2, 56) = 21.013, p = .0001$ . As shown in Figure 1, students in the simulation before dissection condition appeared to do better than students in the other two conditions. This apparent difference was assessed by conducting follow-up Scheffe tests. The follow up tests supported the hypothesis.

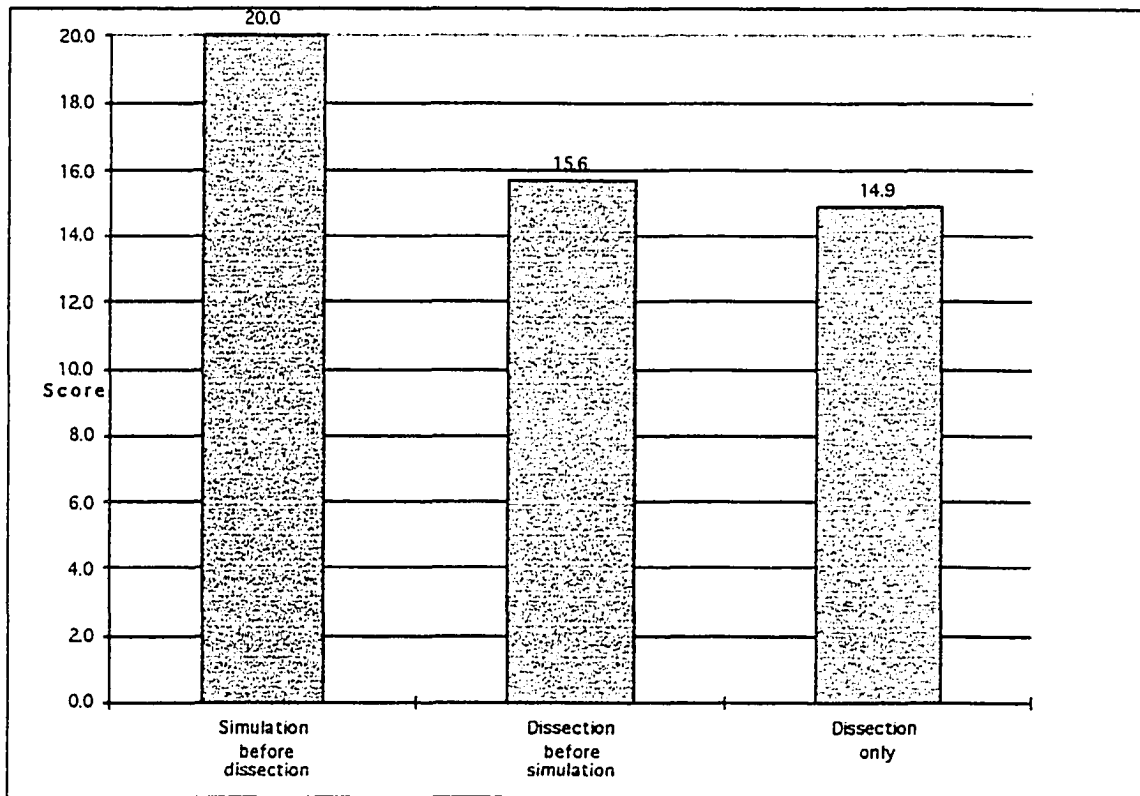


Figure 1. Performance on the achievement posttest as a function of experimental condition (maximum possible was 43 items).

The simulation before dissection condition was significantly superior to the dissection before simulation and dissection-only conditions. The latter two conditions did not differ significantly. This latter result was inconsistent with Hypothesis 2 which had predicted that both the dissection before simulation and simulation before dissection conditions would do better than the dissection-only condition.

Hypothesis 3 predicted that males would do better than females. This prediction was not confirmed. Neither the main effect of gender (males = 16.9; females 16.8) nor the interaction of gender by condition were significant. The ITBS covariate was significant,  $F(1, 56) = 15.778, p < .0001$ . APPENDIX H presents the full ANOVA table and the cell means. The maximum possible number was 43 items.

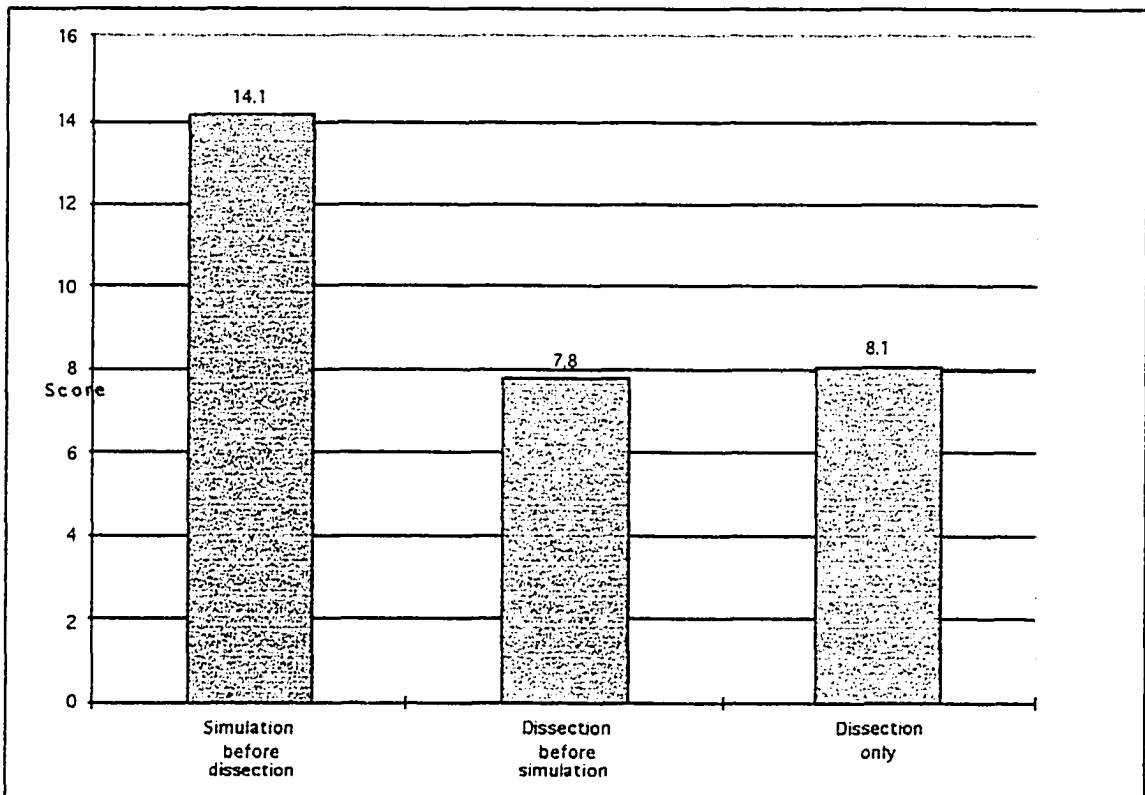


Figure 2. Mean scores for dissection performance test as a function of the experimental (maximum possible was 15 items)

Dissection performance test. Hypothesis 1 predicted that the simulation before dissection condition would perform better on the actual dissection by more accurately removing organs from the frogs than would the dissection before simulation and dissection only conditions. The posttest achievement and dissection performance data were analyzed using a 2 (Gender) X 3 (Condition) ANOVA with ITBS science score and pretest used as covariates. The ANOVA revealed a significant main effect of condition,  $F(2, 56) = 119.817$ ,  $p < .0001$ . As shown in Figure 2, students in the simulation before dissection condition appeared to perform dissection better than students in the other two conditions. This apparent difference was assessed by conducting follow-up Scheffe tests. The simulation before dissection condition was significantly superior to the dissection before simulation and dissection-only conditions. There was no significant difference between the latter two

conditions. APPENDIX H presents the ANOVA on the dissection posttest. Hypothesis 3 predicted that males would do better than females on the dissection performance test. No significant effect of gender was observed thus; the hypothesis 3 was not supported.

Posttest attitude scales. The posttest attitude scales were analyzed using a 2 (Gender) X 3 (Condition) X 2 (Pretest- Posttest) mixed ANCOVA with ITBS science score used as a covariate. Gender and Condition were between-subject factors; pretest-posttest was the within subject factor. The maximum possible number was 15 items.

Attitude toward dissection scale. Only the main effects of experimental condition,  $F(2, 56) = 4.019$ ,  $P < .023$ , and gender,  $F(1, 56) = 9.087$ ,  $P < .004$ , were significant. Follow-up Scheffe tests indicated that the dissection only group was more positively accepting of dissection than were the other two conditions. The male participants were more accepting of dissection than female participants. Table 1 & 2 presents the means. APPENDIX H presents the ANCOVA tables.

Attitude toward science and school scale. Neither the main effects of condition nor interactions were significant. The genders on the attitude toward science and school scale were not significantly different. Tables 1 and 2 present the means and APPENDIX H presents the ANCOVA table.

Attitude toward computer scale. Only the main effects of experimental condition,  $F(2, 55) = 14.615$ ,  $P < .0001$  was significant. Follow-up Scheffe tests indicated that the simulation before dissection group was more accepting of computers than the other two conditions, dissection before simulation, and dissection-only as revealed in Table 1 & 2. APPENDIX H presents the ANOVA table. The results revealed no significant difference between the mean



scores for the (male = 16.9) and the (females = 16.8). Males were more accepting to computer than did the females. Neither male nor female attitude changed toward acceptance of computers.

### Discussion

The results of this study supported the theory that the effectiveness of simulations is dependent upon the sequence of presentation of learning activities to students. The treatment group that completed the simulation activities before the actual hands-on dissection performed significantly better on the achievement posttest and dissection performance test than either of the other groups. This result is consistent with those obtained by Brant, Hooper, & Surgue (1991) who found that presenting a genetic simulation before lecture enhanced learning more than the same simulation presented after lecture. The results are also consistent with those of Kinzie, Strauss, & Foss (1993) who compared the achievement and attitudes of students who conducted a frog dissection with and without the use of an interactive video-based simulation used as a preparatory experience for the actual frog dissection. As in the present study, their results indicated that students in the interactive video simulation preparation group scored significantly higher on the posttest achievement measures than did other three conditions. The results obtained in the current study offered little support for the hypothesis that there would be a significant difference in the learning patterns of male and female on the posttest achievement means and the dissection performance test. No differences in posttest achievement or dissection performance were found between male and female participants in any condition. This failure to find a gender difference in the present study run counter to the results of Andre and Haselhuhun (1995). Andre and Haselhuhun found that males who completed a simulation activity before reading a text on principles of motion learned more from the text than males who did not use the simulation before reading. For females, no significant differences were found. The differences between the Andre and Haselhuhn and the present

study may be due to gender differences in interest and experience with the content. The present study focused on biological content whereas the Andre and Haselhuhn study focused on physics. Differences between females and males in interest in the biological sciences are substantially smaller than differences in interest in physical science and in physical science course taking (Kale & Meece, 1994; Andre, Whigham, Hendrikson & Chambers, 1997).

A second possibility is that the nature of the simulations used related to the gender differences. The simulation used in the Andre and Haselhuhn study was more exploratory and less directive than the simulation used in the present study. In the present study, the simulation directed students to remove particular organs. In a follow-up study involving physics, Andre, Duschen, Werner, Mroch, & Akpan (in preparation) found no gender differences with a more directive simulation.

It may be that directiveness and prior knowledge, experience, or interest interact. When interest, experience or knowledge are low, as in the case with women and physical science, students may have difficulty connecting experience in an open-ended exploratory simulation to later didactic instruction. With higher knowledge levels, or greater directiveness in the simulation activity, connections between a simulation experience and a later experience may be easier for students to perceive. However, these interpretations are speculative; the large number of differences between Andre and Haselhuhn and the present study preclude firm conclusions. But the differences in the studies raise fruitful lines of inquiry for subsequent research.

In the current study, the lack of gender differences support the results of Tyllinski (1994) who found no significant difference in the learning patterns by gender when using either a computer simulation or traditional hands-on method of dissection. The present results also are consistent with Choi and Gennaro (1987) who found no gender differences in their study of the use of simulations to teach volume displacement to eighth grade students.

Thomas and Hooper (1991), in their review of studies using simulations to provide an experiential base for later instruction, noted that the effects of simulation were most evident on tests of transfer and application. Transfer of learning refers to the ability of a student to apply what is learned during instruction to a new but similar situation, usually the intended real performance. The treatment group that completed the simulation activities before the actual dissection performed significantly higher on both the achievement and performance posttest than either of the other groups. The group that completed dissection activities without using simulation was not significantly different from the control group.

The most intriguing result of the present study was that a simulation used before dissection led to better achievement performance than a simulation used after dissection. This difference cannot be attributed to a difference in the amount of instruction received as the students in the simulation before dissection and dissection before simulation conditions had equivalent amounts of instruction. Nor can the difference be attributed to a Hawthorn effect of using a new instructional tool or to a motivational effect of the computer based simulation. Both the simulation before dissection and dissection before simulation conditions received the same computer experience. The difference has to be due to the sequence of presenting the simulation before the dissection.

In a number of studies (Andre, et al., 1998; Andre & Haselhuhn, 1995; Brant, Hooper & Sugrue, 1991), simulations used before either more didactic instruction or another alternative educational experience have yielded more effective learning than simulations used after. Why is this the case? Thomas and Boysen (1989) speculate that one use of simulations is to provide prior experience that helps students understand later instruction. How can such simulated prior experiences lead to increased understanding. One possibility uses Tulving's (1972) ideas of episodic and semantic memory. In Tulving's view, episodic memory contains memories for one's personal experiences whereas semantic memory contains more generalized and abstracted symbolic knowledge. Episodic memory and semantic memory are experienced differently

phenomenologically, and recall from one or the other seems to activate different portions of the brain. Carlsen and Andre (1992) have argued that experience stored in episodic memory is related to symbolic knowledge stored in semantic memory and that the two memory stores interact to produce effective knowledge. In the present case, the prior use of simulations may lead to episodic memories that help students make sense of subsequent complex instructional events. When students are presented with complex didactic instruction after a simulation as in Brant and Hooper (1991) Andre & Haselhuhn (1995), and Andre et al. (1998), they can refer to their episodic memory of the simulation to help make sense of the instruction. When presented with the complex, messy reality of an actual frog, the prior use of the simulation may have laid down episodic memories that help students discriminate and identify particular organs.

What is not clear is why a simulation used after other instruction has less of an effect. It may be that students are unable to form a good memory of the prior instruction because it is too complex and thus cannot relate the subsequent simulation to it. Another possible alternative is that students believe they already know what the simulation covers and attend less to it. The present study cannot provide an explanation but suggests that this is another fruitful line of research. There is a second possible explanation for the present results. The simulation may have sufficiently simplified the complex anatomy of the frog and directly taught students the procedures to follow in doing a dissection. Thus, the better performance on the dissection observed in the simulation before dissection group may have occurred because that group simply had been taught how to do the dissection while the other two groups were engaged in discovery learning while doing the dissection. If this explanation were correct, then a didactic presentation prior to the actual dissection should have the same effect as the simulation. This possibility should be tested in subsequent research. One weakness with this alternative explanation is that it does not deal well with the fact that the dissection before simulation group does worse than the simulation before dissection group on the achievement posttest. The two

groups have had the same two educational experiences at the time of the posttest, albeit in a different order. The dissection-before-simulation group should have caught up. The explanation based on the quality of the memory representations in episodic and semantic memory seems to provide a more straight-forward explanation, but future research should explore the implications of these competing explanations.

The study also looked at the students' attitudes toward dissection. The dissection-only condition was more accepting of dissection than the other two conditions, dissection before simulation and simulation before dissection. However, attitude toward dissection did not change differentially as a function of experimental condition over the study. Similarly, the students' attitude toward computers and attitude toward school and science scale remained consistent from the pretest to posttest. These results supported Kinzie, Strauss, & Foss (1993) who found that the attitudes toward dissection remained relatively stable from pretest to posttest. McCollum (1988) also compared lecture versus dissection in a high school biology and found no significant differences in group attitudes toward frog dissection before and after the end of the experiment. One reason why the student attitudes did not change may be that their opinions were formed across experiences in six school grades. A single experience is unlikely to change such long-term attitudes.

### **Limitations**

The following are limitations of the study:

1. The participants in this study were mostly white, middle class, seventh grade middle school students in a single, midwestern, homogeneous school district. Therefore, the present results should not be generalized to include students at other grades and in other ability levels.

Nevertheless, it is assumed that students in the present study were reasonably representative of the population of white, middle-class, midwestern middle school students.

2. It is possible that taking the pretest influenced posttest scores. This potential influence may mean that data obtained from the study could not be generalized to situations in which pretests are not used.
3. Because the pretest was administered three weeks prior to the time of the actual dissection, it is possible that learning occurred between the pretest and the beginning of the study.
4. The study was completed in three weeks time period. This short duration may have limited generalizability of the study.
5. This study was conducted using Pierian Spring Software which had not been tested elsewhere. The results may be related to this product. However, the fact that other studies have found positive benefits of simulations used before instruction suggests that a more general effect for prior use of simulations is plausible.
6. The assessment tool designed for this study was a modification of a test used by a classroom teacher (the anatomy and morphology test) and may have influenced the results.
7. Because this was the first time the seventh grade students in this school district used this type of interactive simulation software, the novelty of learning via interactive simulation software may have been the reason that participants performed significantly better in the dissection performance achievement test scale.
8. The researcher excluded all the special needs students from the study, and generalizations to special needs students should not be made.
9. Because the standard error of the statistic is decreased with an increased in sample size, the smaller sample size of this study may limit its generalizability.

### **Conclusions**

The presentation of a computer simulation before the actual dissection may provide an experiential base that enhances learning and performance of students on the actual frog dissection. Oral interviews were conducted after dissection activities were completed; the

students doing the computer activity felt that their dissection activity was significantly easier and the simulation helped them to recall more frog parts and functions. It is my opinion that the combination of computer simulations and hands-on dissection in science education can be a viable method of improving students' actual dissection performance.

This study also supports the idea that computer-based simulations can offer a suitable cognitive environment in which students search for meaning, appreciate uncertainty, and acquire responsibility for their own learning. These results are in agreement with previous results that the use of computer simulation before actual dissection can provide a better experiential base for students to master the anatomy, physiology, and morphology of dissected frogs than can the use of simulation after dissection or dissection-only.

## GENERAL CONCLUSION

This dissertation was undertaken to investigate and analyze the conditions under which the instructional sequence followed in the use of simulations influences student learning of the anatomy and morphology of frogs. The literature review focused on the use of simulations in science instruction and discussed conditions under which the use of simulations positively influence science instruction. In the empirical research study, the simulation before dissection condition, which used an interactive simulation as a preparatory tool, before actual dissection, scored significantly higher on the posttest achievement and performance measures than did the dissection before simulation or the dissection-only conditions. Attitudes toward dissection, science and school, and computer remained stable from pretest to posttest. The major finding in the pretest was that computer simulations when presented prior to actual dissection can contribute to the students' understanding of the anatomy and morphology of the frogs.

This study revealed no differences between male and female in the posttest achievement and dissection performance scores. Differences were found between male and female participants on their attitudes toward dissection across pretest and posttest. Males were more accepting of dissection than were the female students. Also differences were found between the attitudes of male and female participants toward computers in both the pretest and posttest; males had more positive attitudes.

The empirical study raised fruitful lines of inquiry and a challenge for science educators and researchers to investigate further the influence of simulations of dissections on student learning. Because dissection is ethically problematic from some individuals and some cultures it is important to further investigate alternatives. For example, Native Americans, in general, do not traditionally consider themselves separate from nature or hierarchically superior to animals or nature. They consider animals as separate nations, each with particular qualities from which one could learn by paying respectful attention. Thus, for Native Americans, dissection in school conflicts with religious values. Similarly, in traditional villages in



Thailand, dogs keep the compounds clean in the absence of bathrooms. Because dogs are valued, dissection would be abhorrent. For such cultures, the theory that rationally grounds the rights of animals also grounds the rights of humans (Fox 1986). To these groups of people animal dissection is ethically wrong and may be seen as damaging to the ecology. For such groups, science education must investigate alternatives to dissection.

APPENDIX A. WORKSHEET FOR KEYWORDS AND DEFINITIONS

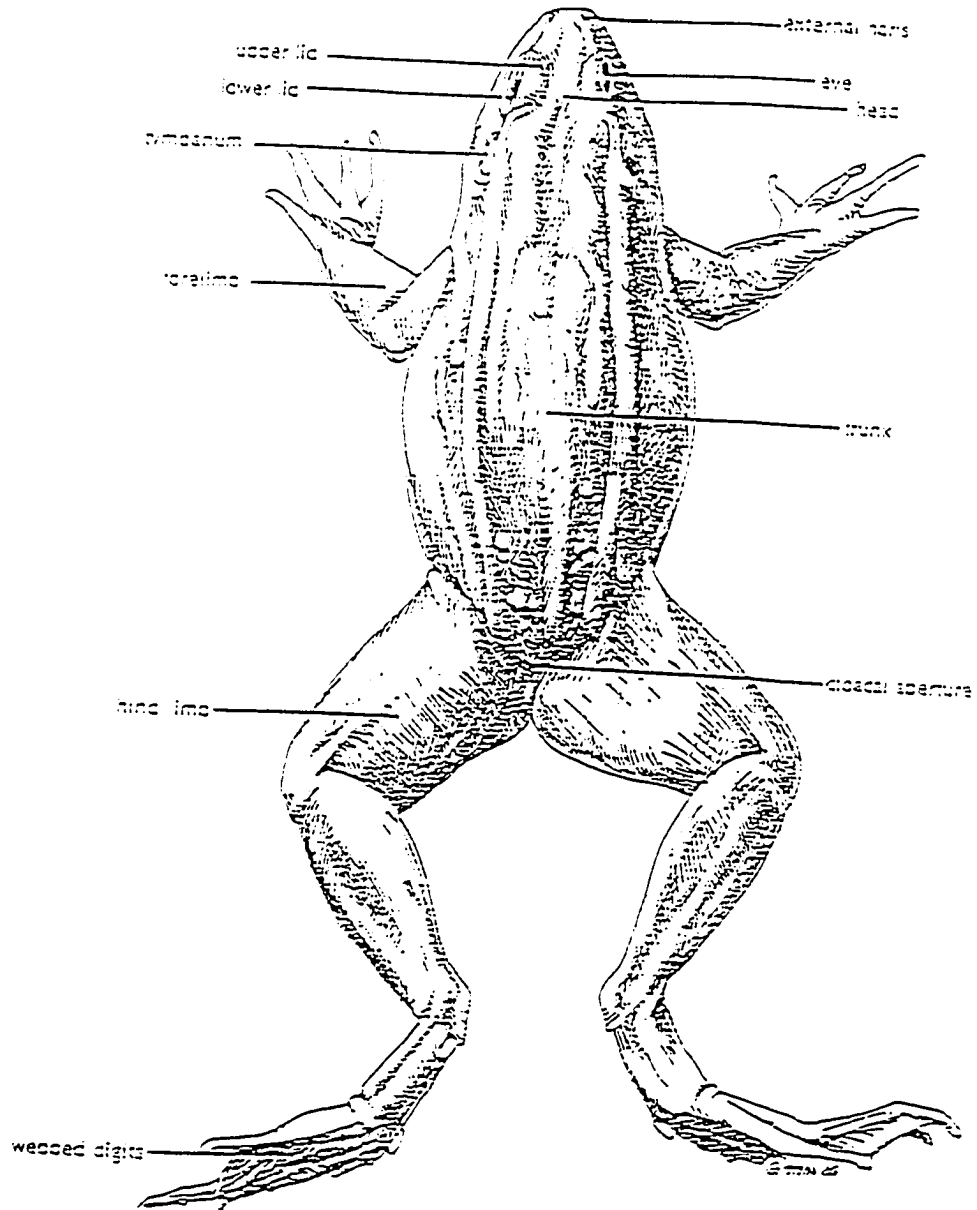




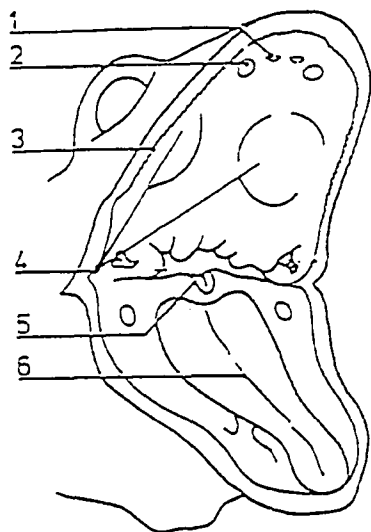




APPENDIX B. FROG DISSECTION ASSESSMENT GUIDE



## FROG DISSECTION

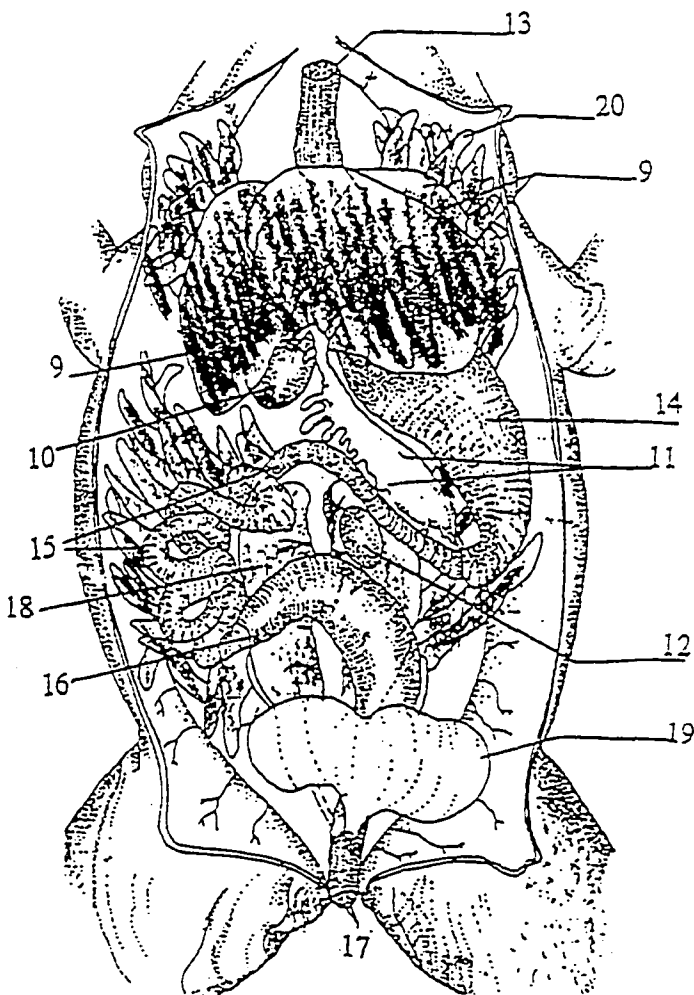


- 1. VOMERINE TEETH
- 2. INTERNAL NOSTRIL
- 3. TEETH
- 4. EYE SOCKETS
- 5. GLOTTIS
- 6. TONGUE

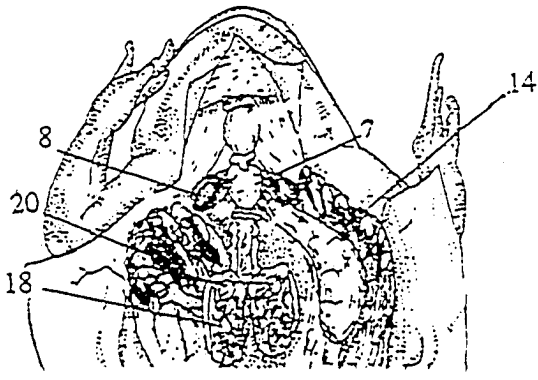
- 7. HEART
- 8. LUNG
- 9. LIVER
- 10. GALL BLADDER
- 11. PANCREAS
- 12. SPLEEN
- 13. GULLET
- 14. STOMACH
- 15. SMALL INTESTINE
- 16. LARGE INTESTINE
- 17. CLOACA
- 18. KIDNEYS
- 19. URINARY BLADDER
- 20. FAT BODY

FEMALE  
 OVARIES  
 OVIDUCTS

MALE  
 TESTIES



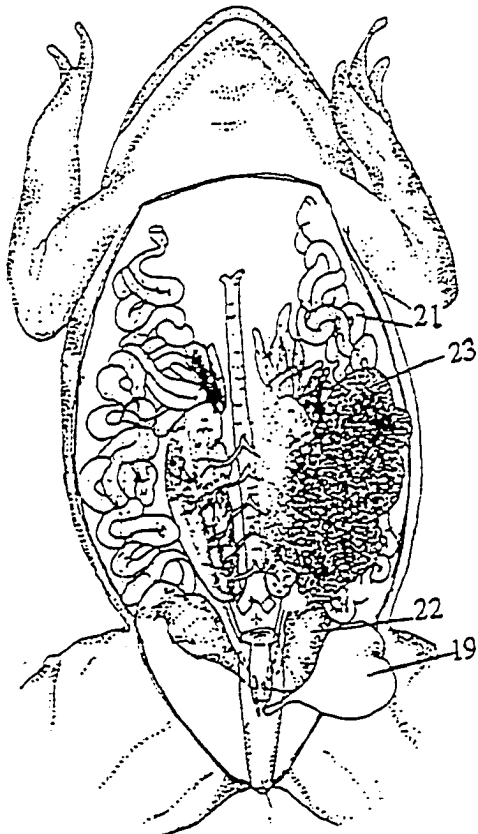




- 7. HEART
- 8. LUNG
- 9. LIVER
- 10. GALL BLADDER
- 11. PANCREAS
- 12. SPLEEN
- 13. GULLET
- 14. STOMACH
- 15. SMALL INTESTINE
- 16. LARGE INTESTINE
- 17. CLOACA
- 18. KIDNEYS
- 19. URINARY BLADDER
- 20. FAT BODY

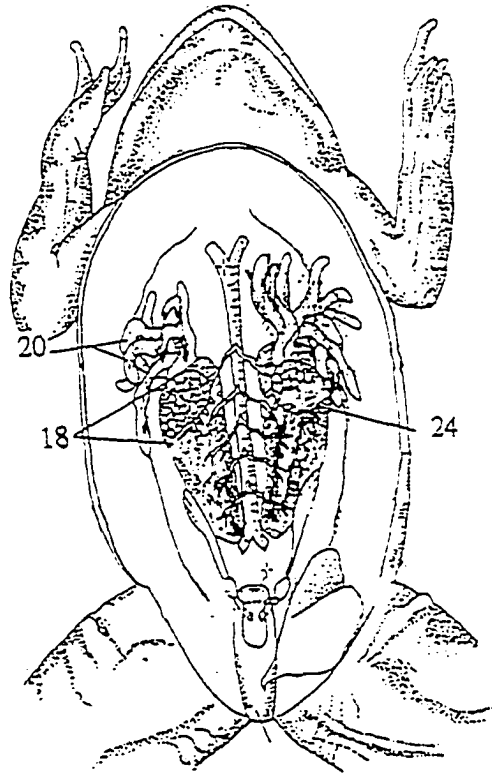
FEMALE FROG

- 21. OVIDUCT
- 22. UTERUS
- 23. OVARY



MALE FROG

- 24. TESTIES



APPENDIX C. FORM WORKSHEET USED FOR DISSECTION PERFORMANCE TEST

NAME \_\_\_\_\_

( ) # \_\_\_\_\_

Remove the frog organs and place in the proper box below

*Period* \_\_\_\_\_

EYE	TONGUE	LIVER
URINARY BLADDER	GALLBLADDER	ESOPHAGUS
SMALL INTESTINE	STOMACH	LARGE INTESTINE
HEART	LUNG	KIDNEY
FAT BODY	OVIDUCT	OVARY

APPENDIX D. FROG ANATOMY AND MORPHOLOGY TEST USED AS PRETEST AND  
POSTTEST

The following items were not included in the pretest scores:

- question 5
- question 14
- question 15
- question 17
- question 25
- question 26

The following item was not included in the posttest scores:

- question 17

ID# .....

Male .....

Female .....

Time period .....

SELECT THE TERM THAT BEST ANSWERS OR COMPLETES THE STATEMENT.

- .....1. During their life a frog can breathe through.
  - a. gills      b. lungs      c. skin      d. all of these
- .....2. An animal that lays eggs using external fertilization usually will lay
  - a. many eggs      b. few eggs      c. one or two eggs
- .....3. The -----removes waste products from the frog's body
  - a. skin      b. liver      c. pancreas      d. kidney
- .....4. The -----stores the bile produced by the liver.
  - a. stomach      b. urinary bladder      c. gall bladder      d. spleen
- .....5. The eggs are produced in the female frog -----
  - a. ovaries      b. testes      c. frog mouth      d. kidney
- .....6. Fertilization takes place -----in the frog.
  - a. externally      b. internally      c. stomach      d. vocal sacs

DESCRIBE THE FUNCTIONS OF THE FOLLOWING FROG PARTS:

- 8. What is the function of the gall bladder? .....
- 9. What is the function of the kidney? .....
- 10. What is the function of the spleen? .....
- 11. What is the function of the frog tongue? .....

COMPLETE THE FOLLOWING.

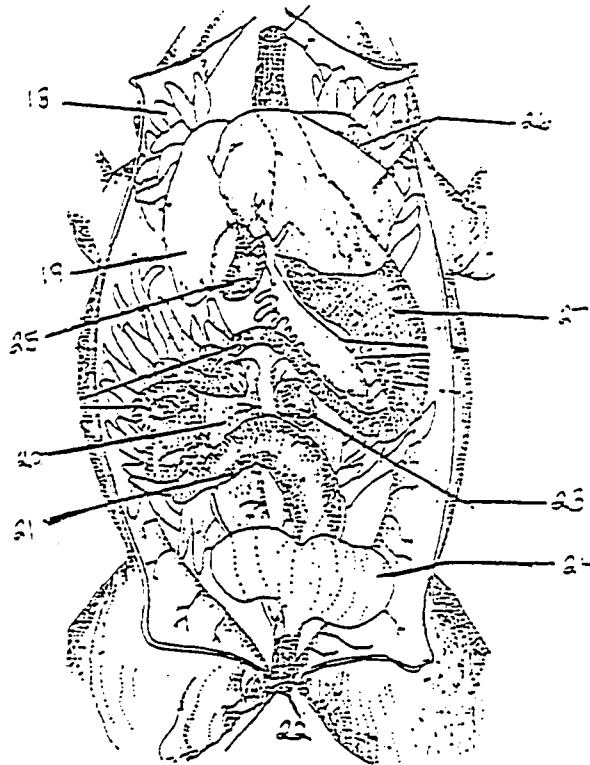
- 12. Give two reasons why amphibians must live near water to live.
  - a.
  - b.
- 13. How was the frogs tongue different from humans tongue?
- 14. What was the purpose of the vomerine teeth used by the frog?
- 15. Tammy and Willy both dissect two different frogs. Tammy has a male. Willy dissects a female. Willy discovers that he has long brownish-orange structures in his frog and Tammy does not. Mrs. Gaylor told Willy that the structures were fat bodies. Why do you suppose Tammy's frog did not have fat bodies?

16. Mr. Clinton just bought a farm with a small pond. Mr. Clinton is sitting quietly on his couch reading a seventh grade science book. Mr. Clinton panics because he reads that a single bull frog can lay as many as 25,000 eggs in one year!! He knows that he has heard bull frogs around his pond and can't imagine what he will do with 25,000 baby frogs!! Explain to Mr. Clinton why he doesn't really need to worry about his pond overrun by bullfrogs.

17. Did the activity help you learn?  
 a. very helpful    b. boring    c. very boring    d. neutral

NAME THE ORGANS OR STRUCTURES OF THE FROG IN THE DIAGRAM.

- 18. \_\_\_\_\_
  - 19. \_\_\_\_\_
  - 20. \_\_\_\_\_
  - 21. \_\_\_\_\_
  - 22. \_\_\_\_\_
  - 23. \_\_\_\_\_
- What is the function of these organs?
- 24. \_\_\_\_\_
  - 25. \_\_\_\_\_
  - 26. \_\_\_\_\_
  - 27. \_\_\_\_\_



**WORD BANK**

Fat bodies, Liver, Stomach, Pancreas, Spleen, Gall bladder, Small intestine, Gullet, Large intestine, Cloaca, Urinary bladder, Kidney, Esophagus

APPENDIX E. ATTITUDES TOWARD DISSECTION, SCIENCE/SCHOOL, AND  
COMPUTERS SCALES



Attitudes Toward Dissection Measure	Male	Female	ID Number	Time	Period
	Strongly Agree 1	Agree 2	Neither Agree nor Disagree 3	Disagree 4	Strongly Disagree 5
1. I don't think that doing frog dissection will help me to learn about frog organs.					
2. Animals can be treated with respect in a dissection.					
3. Dissection is not a good activity in studying life science.					
4. Students should dissect an animal to help them learn about organs and organ systems.					
5. I do not like dissecting an animal.					
6. Dissection is an interesting activity that helps me learn.					
7. Dissection is not a good way to learn life science.					
8. It is not good to kill animals for learning about organ functions.					
9. I believe animal dissection is one way to study about organ and organ systems.					
10. I feel good when I am doing dissection.					
11. There are many ways of learning organs other than dissection.					
12. It is acceptable that animals be killed for doing research.					
13. Dissecting a frog helped me learn about the organs of other organisms.					
14. I feel that learning about frog dissection will be useful to me.					
15. Dissection increases my respect for animals.					
16. Dissection makes my life science class not enjoyable.					
17. I feel okay about dissecting a frog in order to learn about frog parts.					
18. It is not very interesting to do dissection to learn about frog parts.					
19. We should not have to dissect organisms to study animal parts.					
20. I love to find out about frog organs by doing dissection.					

Attitudes Toward Dissection Measure	Strongly Agree	Agree	Neither Agree nor Disagree	Disagree	Strongly Disagree
	1	2	3	4	5
21. I believe that I have the ability to do a frog dissection well.					
22. Studying life science is a task I am able to do well.					
23. Cutting a frog and taking out its body parts would be hard for me to do well.					
24. If given a life science assignment, I know I would have difficulty doing it well.					
25. I like life science.					
26. I am able to do the class work in life science well.					
27. Life science homework is something which I can do well.					
28. I would find it easy to dissect an animal and would be good at doing it.					
29. I like school.					
30. Learning in school is interesting to me.					
31. School is hard.					
32. Taking classes in school is pretty boring.					
33. I like to study using computers.					
34. Computers are fun.					
35. I like to do computer simulations as part of studying.					
36. Computer simulations are a good way to help me learn.					
37. My family has a computer at home.					
38. I play computer games a lot.					
39. I hardly ever use email.					
40. I typically write school papers and homework on the computer.					
41. I use computers a lot besides at home or at school.					
42. I often get on the Internet or the World Wide Web.					
43. I have purchased computers a lot.					

APPENDIX F. CRONBACH ALPHAS FOR PRETEST AND POSTTEST

Table 3. Cronbach Alphas for Each of the Assessment instruments for the Pretest and Posttest

Instrument	Alpha's	
	Pretest	Posttest
Achievement Tests	.57	.70
Attitudes toward dissection	.92	.91
Attitudes toward science	.74	.76
Attitudes toward computer	.74	.80

APPENDIX G. ANOVA TABLES FOR PRETEST MEASURES

Table 4. ANOVA on pretest achievement conditions

Group	Count	Mean	Standard Deviation	F Ratio	F Prob.
Dissection before simulation	28	8.1	3.2	.3329	.7181
Simulation before dissection	21	8.5	2.8		
Dissection only	16	8.9	3.1		

Table 5. ANOVA on attitude toward dissection scale

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Eta Squared	Observed Power
EXPCNDTN	3.021	2	1.511	3.671	.031	.106	.655
Error	25.512	62	.411				

Table 6. ANOVA on attitude toward school and science scale

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Eta Squared	Observed Power
EXPCNDTN	.1024	2	.512	.856	.430	.027	.191
Error	36.461	61	.598				

Table 7. ANOVA on attitude toward computer scale

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Eta Squared	Observed Power
EXPCNDTN	.744	2	.372	1.017	.368	.032	.220
Error	22.304	61	.366				

APPENDIX H. DESCRIPTIVE STATISTICS AND ANCOVA TABLES FOR POSTTEST MEASURES

Table 8. ANOVA on posttest achievement conditions

Group	Count	Mean	Standard Deviation	F Ratio	F Prob.
Dissection before simulation	28	15.6	3.4	15.0597	.0000
Simulation before dissection	21	20.0	3.0		
Dissection only	16	14.9	3.2		

Table 9. Means and standard deviation on the achievement test as a function of gender and experimental condition

Condition		Groups		
		Male	Female	Total
Dissection before simulation	N <sup>a</sup>	6	9	15
	M <sup>b</sup>	15.8	14.2	14.9
	SD <sup>c</sup>	3.6	3.1	3.29
Simulation before dissection		11	17	28
		15.1	15.9	15.6
		3.09	3.09	3.41
Dissection only		9	12	21
		19.8	20.2	20.0
		3.49	2.72	3.00
Total		26	38	64
		16.9	16.9	16.9
		4.2	3.8	3.9

<sup>a</sup>Number<sup>b</sup>Mean<sup>c</sup>Standard deviation

Table 10. Means and standard deviations on the dissection performance test as a function of experimental condition.

Gender	Condition	M	SD	N
Male	Dissection before simulation	7.8	1.2	6
	Dissection only	7.9	2.2	11
	Simulation before dissection	14.5	0.5	9
	Total	10.2	3.6	26
Female	Dissection before simulation	8.2	1.4	9
	Dissection only	7.6	1.9	17
	Simulation before dissection	13.8	0.7	12
	Total	9.7	3.2	38
Total	Dissection before simulation	8.1	1.3	15
	Dissection only	7.8	2.0	28
	Simulation before dissection	14.1	0.7	21
	Total	9.9	3.3	64

<sup>a</sup>Mean<sup>b</sup>Standard deviation



Table 11. ANCOVA on attitude toward science and school scale

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Eta Squared	Observed Power
ITBS score	.799	1	.799	2.741	.104	.048	.369
EXPCNDTN	.103	2	0.005	.176	.839	.006	.076
GENDER EXPCNDTN	.619	1	.619	2.124	.151	.038	.299
*GENDER	.839	2	.419	1.440	.246	.051	.295
Error	15.732	54	.291				

Table 12. Tests of within-subject effects on attitude toward science and school scale

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Eta Squared	Observed Power
TIME	0.0002	1	0.0002	.001	.975	.000	.050
TIME* NG	0.002	1	0.002	.007	.933	.000	.007
TIME * EXPCNDTN	1.432	2	.716	2.391	.101	.081	.462
TIME * GENDER	1.006	1	1.006	3.357	.072	.059	.436
TIME * EXPCNDTN	.115	2	0.05	.192	.826	.007	.078
* GENDER Error (TIME)	16.179	54	.300				

Table 13. ANCOVA on attitude toward computers scale

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Eta Squared	Observed Power
Intercept	28.515	1	28.515	60.653	.000	.524	1.000
ITBS score	.180	1	.180	.383	.538	.007	.093
EXPCNDTN	1.485	2	.742	1.579	.215	.054	.321
GENDER	6.871	1	6.871	14.615	.000	.210	.964
EXPCNDTN *GENDER	.969	2	.485	1.031	.363	.036	.221
Error	25.857	55	.470				

Table 14. Tests of within-subject effects on attitude toward computers scale

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Eta Squared	Observed Power
TIME	.482	1	.482	1.919	.172	0.34	.275
TIME* NG	.165	1	.165	.657	.421	.012	.125
TIME * EXPCNDTN	.527	2	.263	1.049	.357	.037	.224
TIME * GENDER	.594	1	.594	2.367	.130	.041	.327
TIME * EXPCNDTN * GENDER	.129	2	0.06	.257	.774	.009	.089
Error (TIME)	13.807	55	.251				

Table 15. ANCOVA on attitude toward dissection scale

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Eta Squared	Observed Power
ITBS score	0.002	1	0.002	.004	.948	.000	.050
EXPCNDTN	4.111	2	2.055	4.019	.023	.126	.695
GENDER	4.647	1	4.647	9.087	.004	.140	.842
EXPCNDTN * GENDER	.628	2	.314	.614	.545	.021	.147
Error	28.638	56	.511				

Table 16. Tests of within-subject effects on attitude toward dissection scale

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Eta Squared	Observed Power
TIME	.432	1	.432	2.182	.145	0.37	.306
TIME* NG	.539	1	.539	2.720	.105	.046	.367
TIME * EXPCNDTN	.136	2	0.06	.342	.712	.012	.102
TIME * GENDER	.129	1	.129	.653	.422	.012	.125
TIME * EXPCNDTN * GENDER	0.008	2	0.004	.022	.978	.001	.053
Error (TIME)							

Table 17. ANCOVA on dissection performance test

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Eta Squared	Observed Power
NEWPRE	2.772	1	2.772	1.203	.277	.021	.190
ITBS score	7.536	1	7.536	3.269	.076	.055	.428
GENDER	0.007	1	0.007	0.003	.954	.000	.050
EXPCNDTN	552.408	2	276.204	119.817	.000	.811	1.000
GENDER * EXPCNDTN	3.608	2	1.804	.782	.462	.027	.177
Error	129.092	56	2.305				

Table 18. ANCOVA on anatomy and morphology achievement test

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Eta Squared	Observed Power
NEWPRE	4.866	1	4.866	.559	.458	.010	.114
ITBS score	137.460	1	137.460	15.778	.000	.220	.974
EXPCNDTN	366.130	2	183.065	21.013	.000	.429	1.000
GENDER	4.578	1	4.578	.525	.472	.009	.110
EXPCNDTN	12.569	2	12.569	.721	.491	.029	.166
* GENDER Error	487.878	56	8.712				

## REFERENCES

- Akpan, J. P. (1998). Computer simulations and learning science: A review of the literature (in preparation ).
- Alessi, S. M., & Trollip, S. R. (1985). Computer-based instruction: Methods and development. Englewood Cliffs, NJ: Prentice Hall.
- Alexander, J. (1970). Dissection versus prosection in the teaching of anatomy. Medical education, 45(8), 600-608.
- Alessi S. M. (1988). Fidelity in the design of instructional simulations. Journal of Computer Based Instruction 15(2) 40-47.
- Andre, T., & Haselhuhn, C. (1995). Mission Newton! using a computer game that simulates motion in Newtonian space before or after formal instruction in mechanics. Paper presented at the American Educational Research Association Annual Meeting, (April 1995).
- Andre, T., Whigham, M., Hendrikson, A., & Chambers, S. (1997). Attitudes of elementary school students and their parents towards science and other school subjects. Paper presented at the annual convention of the National Association of Research in Science Teaching, Chicago, (April 1997).
- Andre, T., Duschon, A., Werner, B., Mroch, A., & Akpan, J., (1998 in preparation). The influence of thinker tools as a pre-test experience.
- AAUW. (1989). American Association Union of Women Report New York: New York Review/Random House, revised edition, 1989.
- Baggott, J., Lawrence, M., Shaw, F., Galey, M., & Devlin, T. M. (1977). Efficiency of do-it yourself slide-tape programs as an alternative to the lecture in medical biochemistry. Journal of Medical Education, (2), 157-159.

- Baird, M. R., & Rosenbaum, S. E. (1991). Animal experimentation: the moral issues. New York: Prometheus Books.
- Baird, W. E. (1986). Conference abstracts: NECC' 86. Journal of Computers in Mathematics and Science Teaching, 5(4), 63-4.
- Baird, W. E., & Koballa, T. R. Jr. (1988). Changes in preservice elementary teacher's hypothesizing skills following group and individual study with computer simulations. Science Education, 72(2), 209-233.
- Baker, S. P. (1988). Comparison of effectiveness of interactive videodisc versus lecture-demonstration instruction. Journal of Physical Therapy, 68(5), 699-703.
- Becker, H. J. (1991). How computers are used in United States Schools. Journal of Educational Computing Research, 7(4), 385-407.
- Becker, H. J. (1983). Schools use of microcomputers: Report #2 from a national survey. Journal of Computers in Mathematics and Science Teaching, 3(2), 16-21.
- Bernard, G. R. (1972). Prosection demonstrations as substitutes for the conventional human gross anatomy laboratory. Journal of Medical Education, 47(11), 726-728.
- Bourque, D. R., & Carlson, G. R. (1987). Hands-on versus computer simulation methods in chemistry. Journal of Chemical Education, 64(3), 232-236.
- Bowd, A. D. (1989). Alternatives to dissection as an instructional technique. The Av, 8 7-5.
- Brant, G., Hooper, E., & Sugrue, B. (1991). Which comes first the simulation or the lecture? Journal of Educational Computing Research, 7(4), 469-481.
- Bredemeier, M. E., & Greenblat, C S. (1981). The educational effectiveness of simulation games. Simulation and Games, 12, 307-332.
- Brooks, M., & Brooks, J. G. (1985). Teaching for Thinking. IMPACT on Instructional Improvement 19, 3.
- Bross, T. R. (1986). The microcomputer-based science laboratory. Journal of computers in mathematics and Science Teaching, 5(3), 16-18.

- Bruner, J. (1966). Toward a theory of instruction. Cambridge, MA: Harvard University Press.
- Carlsen, D., & Andre, T. (1992). Use of a microcomputer simulation and conceptual change text to overcome student preconceptions about electric circuits. Journal of Computer-Based Instruction, *19*(4), 105-109.
- Carpenter, C. R. (1953). A theoretical orientation for instructional film research. AV Commun. Rev, *1*(3) 38-52.
- Chambers, J. A., & Sprecher, J. W. (1983). Computer-assisted instruction: its use in the classroom. Englewood Cliffs, NJ: Prentice Hall.
- Chambers, S. K., Haselhuhn, C., Andre, T., Mayberry, C., Wellington, S., Krafka, A., Volmer, J., & Berger, J. (1994). The acquisition of a scientific understanding of electricity: Hands-on versus computer simulation experience; conceptual change versus didactic text. Paper presented at the American Educational Research Association Conference, New Orleans.
- Chambers, S., & Andre, T. (1991). Sex, interest, experience, and conceptual change text. Paper presented at the meeting of the American Educational Research Association, Chicago, IL.
- Chambers, S., & Andre, T. (1992). The relationship of conceptual change text to learning about electricity. Paper presented at the Annual Meeting of the National Consortium for Instruction and Cognition, Chicago.
- Chambers, S., & Andre, T. (1990). A text-based approach for facilitating conceptual change in learning science: The role of interest in evidence for long term effects. Paper presented at the Annual Meeting of the Iowa Educational Research and Evaluation Association, Cedar Rapids.

- Cherryholmes, C. H. (1966). Some current research on effectiveness of education simulations: Implications for alternative strategies. American Behavioral Scientist, 10 4-7.
- Choi, B., & Grennaro, E. (1987). The effectiveness of using computer simulated experiments on junior high students' understanding of the volume displacement concept. Journal of Research in Science Teaching, 24(6), 539-552.
- Clark, R. E. (1983). Reconsidering research on learning from media. Review of Educational Research, 53(4), 445-459.
- Clark, R. E. (1985). Confounding in educational research. Journal of Educational Computing Research, 1(2), 137-147.
- Dekkers, J., & Donatti, S. (1981). The integration of research studies on the use of simulation as an instructional strategy. Journal of Educational Research 74, 424-27.
- DeRosa, B. (1986). Is dissection necessary? Children & Animals. 10(3), 1-2.
- Duffy, T. M., & Jonassen, D. H. (1992). Constructivism: new implications for instructional technology. In Duff, T. M. & Jonassen, D. H. (Eds.), Constructivism and the technology of instruction (pp. 1-16). Hillsdale, NJ: Lawrence Erlbaum Associates.
- Dweck, C. S. (1986). Motivational processes affecting learning. American Psychology, 41(10), 1040-1048.
- Dwyer, C. S. (1978). Strategies for improving visual learning. (p. 33). State College, PA: Learning Services.
- Ebner, D. B., Danaher, B., Mahoney, J. B., Lippert, H. T., & Balson, P. M. (1984). Current issues in interactive videodisc and computer-based instruction. Instructional Innovator, 29(3), 24-29.
- Fawver, A. L., Branch, C. E., Trentham, L., Robertson, B. R., & Beckett, S. D. (1990). A comparison of interactive videodisc instruction with live animal laboratories. Advances in Physiology Education, 4(1), 11-14.



- Fennessey, G. M. (1972). Simulation, gaming, and conventional instruction: An experimental comparison. (ERIC Document Reproduction Service No ED 062303).
- Fortner, R. W., & Lyon, A. E. (1994). Effects of a cousteau television special on viewer knowledge and attitudes. Journal of Environmental Education, 3(12), 12-19.
- Fortner, R. W., Shar, J. F., & Mayer, V. J. (1986). Effect of microcomputer simulations on computer awareness and perception of environmental relationships among college students. (ERIC Document Reproduction Service No ED 270311)
- Fowler, S., Brosius, E. J. (1968). "A research study on the values gained from dissection of animals in secondary school biology. Science Education, 52(1), 55-57.
- Fox, M. A. (1986). The case for Animal Experimentation. Berkeley, Calif.: University of California Press.
- Gagne, R. M. (1962). Training devices and simulation: Some research issues. The American Psychologist, 95-107.
- Gilmore, D. R. (1991). Politics and prejudice: Dissection in biology education. The American Biology Teacher, 33(4), 212-213.
- Gredler, M. E. (1992). Educational games and simulations: A technology in search of (research) paradigm. Handbook of Research of Technology and Communications chapter 17, 521-538. Macmillan Library Reference, Simon and Schuster Macmillan, New York, NY.
- Guy, J. F., & Frisby, A. J. (1992). Using interactive videodisc to teach gross anatomy to undergraduates at The Ohio State University. Academic Medicine, 67(2), 132-133.
- Hargrave, C., & Andre, T. (1993). Examining the use of computer simulations, reflective journals, and peer group interactions to facilitate conceptual change about electricity. Doctoral dissertation, Iowa State University, Ames, IA.

- Harper, B. H. (1995). The effect of using interactive video frog dissection software on learning, attitudes and state-anxiety of high school biology students. (Ed. D Boston Univ. 1995).
- Hollen, Jr., T., Bunderson, C. V., & Dunham, J. L. (1971). Computer-based simulation of laboratory problems in qualitative chemical analysis. Science Education, 55(2), 131-136.
- Hoskins, B. B. (1979). Sensitizing introductory biology students to biotech's issues. The America Biology Teacher, 41 151-153.
- Igelstud, D. (1986). Frogs. The America Biology Teacher, 48, 435-436.
- Jones, N M, Olafson, R. P., & Sutin, J. (1978). Evaluation of gross anatomy program without dissection. Journal of Medical Education, 53 198-206.
- Kahle, J. B., & Meece, J. (1994). Research on gender issues in the classroom. In D. L. Gable (Ed.), Handbook of Research on Science Teaching and Learning, New York: Macmillan. (pp. 552-557).
- Kinzie, M. B., Foss, M. J., & Powers, S. M. (1993). Use of dissection-related courseware by low-ability high school students: A qualitative inquiry. Educational Technology Research & Development, 41(3), 87-101.
- Kinzie, M. B., Strauss, R., & Foss, M. J. (1993). The effects of an interactive dissection simulation on the performance and achievement of high school biology students. Journal of Research in Science Teaching, 30(8), 989-1000.
- Kozma, R. B. (1991). Learning with media. Review of Educational Research, 61 179-211.
- Leonard, W. H. (1985). Biology instruction by interactive videodisc or conventional laboratory: A qualitative comparison. Paper presented at the Annual Meeting of the National Association for Research in Science Teaching (French Lick Springs, In, April 15-18, 1985) (ERIC Document Reproduction Service No ED 258 811)

- Leonard, W. H. (1989). A comparison of student reactions to biology instruction by interactive videodisc or conventional laboratory. Journal of Research in Science Teaching, 26(2), 95-104.
- Leonard, W. H. (1992). A comparison of student performance following instruction by interactive videodisc versus conventional laboratory. Journal of Research in Science Teaching, 29(1), 93-102.
- Lieb, M. J. (1985). Dissection: A valuable motivational tool or a trauma to the high school students? (Master's Thesis, The Foster G. McGraw school of the National College of Education).
- Lock, R. (1995). GCSE students' attitudes to dissection and using animals in research and product testing. Journal Biology Education, 77(279), 15-21.
- Lunetta, V. N. (1981). Simulations in science education. Science Education, 65(3) 243-252.
- Mackenzie, I. S. (1988). Issues and methods in the microcomputer-based lab. Journal of Computers in Mathematics and Science Teaching, 7(3), 12-18.
- Manning, D. T., Balson, P., Ebner, D. B. & Brooks, F. R. (1983). Student acceptance of videodisc programs for paramedical training. T. H. E. Journal, 11(3), 105-108.
- McCollum, T. L. (1988). The effect of animal dissection on student acquisition of knowledge and attitudes toward the animals dissected. (ERIC Document Reproduction Service No Ed 294 749.
- Mills, T. J., Amend, J., & Sebert, D. (1985). An assessment of water resource education for teachers using interactive computer simulation. Journal of Environmental Education, 16(4), 25-29.
- Munro, A., Fehling, M. R., & Towne, D. M. (1985). Instructional intrusiveness in dynamic simulation training. Journal of Computer-Based Instruction, 12(2), 50-53.
- Murphy, P. J. (1986). Computer simulations in biological education: Analogues or models?. Journal of Biological Education, 20 201-205.

- Olsen, J. R., & Bass, V. B. (1982). The application of performance technology in the military: 1960-1980. Performance and Instruction, 21(6), 32-36.
- Offner, S. (1993). The importance of dissection in biology teaching. The American Biology Teacher, 55(3), 147-149.
- Orlans, F. B. (1988). Debating dissection. The Science Teacher, 55(8), 36-40.
- Orlansky, J., & String, J. (1979). Cost-effectiveness of computer-based instruction in military training, Training, IDA Paper P-1375, Institute for Defense Analysis, Alexandria, Virginia.
- Reigeluth, C. M. (Ed.). (1987). Instructional theories in action. Hillsdale, NJ: Lawrence Erlbaum Associates.
- Posner, G. J., Strike, K. A., Hewson, P. W., & Gertzog, W. A. (1982). Accommodation of scientific conception: Toward a theory of conceptual change. Science Education, 66(2), 211-227.
- Pierfy, D. (1977). Comparative simulation game research: Stumbling blocks and steppingstones, Simulation & Games, 8(2) 255-268.
- Prentice, E. D., Metcalf, W. K., Quinn, T. H., Sharp, J. G., Jensen, R. H., & Holyoke, E. A. (1977). Stereoscopic anatomy: Evaluation of a new teaching system in human gross anatomy. Journal of Medical Education, 52 758-762.
- Rivers, R. H., & Vockell, E. (1987). Computer simulations to stimulate scientific problem solving. Journal of Research in Science Teaching, 24(5), 403-415.
- Saettler, P. (1968). A history of instructional technology. New York: McGraw-Hill.
- Salomon, G. (1981). Communication and education, social and psychological interactions. Beverly Hills, CA: Sage Publications.
- Sharon K. Chambers, Charlotte Haselhuhn, Thomas Andre, Christine Mayberry, Shawn Wellington, Amy Krafka, Jason Volmer, and Joshua Berger (1994). The acquisition of a science understanding of electricity: Hands-on versus computer simulation

- experience: conceptual change versus didactic text. Paper presented at the American Educational Research Association Conference, New Orleans.
- Schrock, J. R. (1984). Computers in science education: Can they go far enough? How we gone too far? The American Biology Teacher, 46, 252-256.
- Sherwood, R. D., Hasselbring, T. S., & Marsh, E. J. (1990). An evaluation study of a level one videodisc based chemistry program. Paper presented at a poster Session at the Annual Meeting of National Association for Research in Science Teaching (Atlanta, GA, April 8-11, 1990) ERIC Document Reproduction Service No ED 320 772).
- Showalter, V. M. (1970). Conducting science investigations using computer simulated experiments. The Science Teacher, 10 46-50.
- Snir, J., Smith, C., & Grosslight, L. (1988, June). The truth, but not the whole truth: An essay on building a conceptually enhanced computer simulation for science teaching. Technical Report, Educational Technology Center, Cambridge, MA.
- Spraggings, C., & Rowsey, R. E. (1986). The effect of simulation games and worksheets on learning of varying ability groups in a high school biology classroom. Journal of Research in Science Teaching, 23(3), 219-229.
- Strauss, R. & Kinzie, M. B., (1994). Student achievement and attitudes in a pilot study comparing an interactive videodisc simulation to conventional dissection. American Biology Teacher, 56(7), 398-402.
- Thomas, R. & Hooper, E. (1991). Simulation: An opportunity we are missing. Journal of Research on Computing in Education, 23(4), 497-513.
- Thomas, R. A., & Boysen, J. P. (1989). A taxonomy for the instructional use of computers, AEDS Monitor, 22(11-12), 15-17.
- Tulving, E. (1972). Episodic and semantic memory: In E. Tulving & W. Donaldson (Eds.), Organization of memory (pp. 38-403). New York: Academic Press.

- Tylinski, J. D. (1995). The effect of a computer simulation on junior high students' understanding of the physiological systems of an Earthworm Dissection. (Ed D. Indiana Univ. of Pennsylvania, 1994)
- Welser, R. R. (1969). An evaluative investigation of silent loop films in the teaching of anatomy. (ERIC Document Reproduction Service No ED 029 796).
- Winders, A., & Yates, B (1990). The traditional science laboratory versus a computerized science laboratory: Think carefully before supplanting the old with the new. Journal of Computers in Mathematics and Science Teaching, 2(3), 11-15.
- Windschilt, M. & Andre, T. (1995). Using computer simulations to enhance conceptual change: The roles of constructivist instruction and student epistemological beliefs. Journal of Research in Science Teaching.
- Wood, A. W. (1979). CAL in biology. In learning through computers, (Ed.). 11-21 London Macmillan.
- Zeitsman, A. I., & Hewson, P. W. (1986). Effect of instruction using microcomputer simulations and conceptual change strategies on science learning. Journal of Research in Science Teaching, 23(3), 27-39.
- Zim, H. S. (1940). Science interesting and activities of adolescents. In R. W. Boening (Ed.), Research in Science Education 1938 through 1947 (pp. 266-273). New York: Teachers College press.

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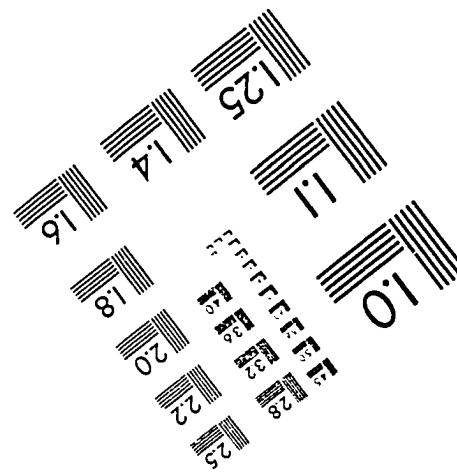
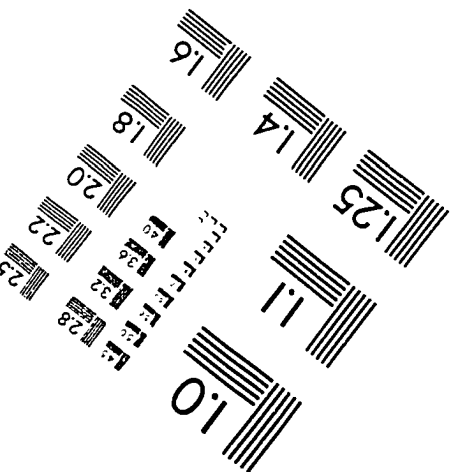
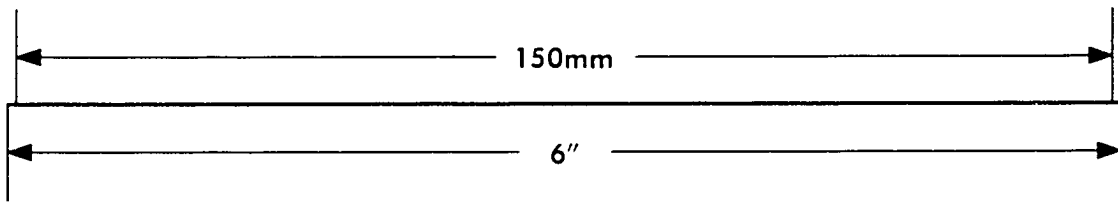
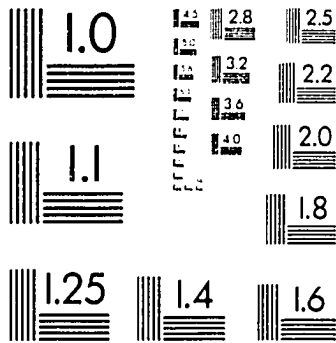
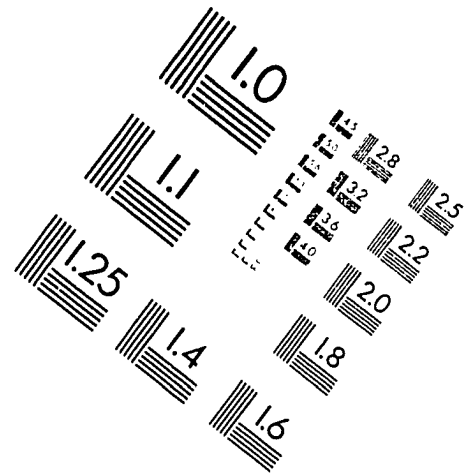
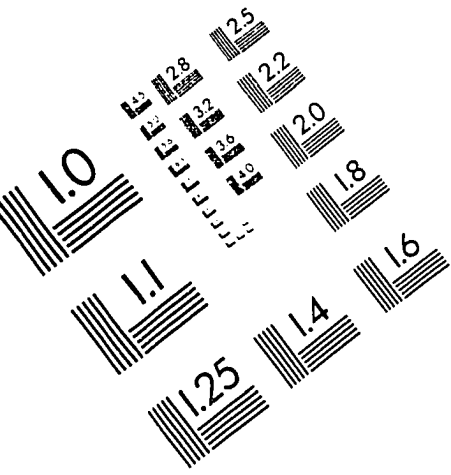
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# IMAGE EVALUATION TEST TARGET (QA-3)



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