VIRTUAL FETAL PIG DISSECTION AS AN AGENT OF KNOWLEDGE ACQUISITION FOR FEMALE HIGH SCHOOL BIOLOGY STUDENTS

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ABSTRACT
This study attempted to determine if a virtual fetal pig dissection can be used as a viable alternative for an actual dissection for females enrolled in high school biology classes by comparing the knowledge acquisition between the experimental (virtual dissection) and control (actual dissection) groups. Two hundred and twenty four students enrolled in biology classes in a suburban all-girl parochial high school participated in this study. Female students in an all-girl high school were chosen because research shows differences in science competency and computer usage between the genders that may mask the performance of females on computer-based tasks in a science laboratory exercise. Students who completed the virtual dissection scored significantly higher on practical and objective tests that were used to measure knowledge acquisition. Further research is suggested to determine if a virtual laboratory experience can be a substitute for actual dissections, or may serve as an enhancement to an actual dissection.

KEYWORDS
Dissections, virtual dissections, girls and science, girls and technology

INTRODUCTION

Educational technology has been introduced to many schools across the world, mainly through the addition of computers into classrooms. At the heart of these acquisitions is one large question: Can all students learn through the use of these computers? One way to determine this is to introduce a lesson taught completely via computers and compare the results with those gained when the same lesson is taught in a traditional manner. For this study, I chose to introduce a virtual fetal pig dissection into a high school biology classroom and compared its results to those obtained from a traditional, or actual, fetal pig dissection. Archbishop Stephens High School, a pseudonym, a southern all-girls parochial high school, has traditionally required the dissection of fetal pigs by their biology students. Due to the rising costs of the specimens and the objections to actual dissection on moral and ethical grounds by the students, finding a viable alternative to dissection is imperative. Until the advent of the Internet and its multimedia design, a viable alternative had not been present. More specifically, this study attempted to determine if a virtual fetal pig dissection could be used as a viable alternative for an actual dissection by comparing the knowledge acquisition between the experimental (virtual dissection) and control (actual dissection) groups. Knowledge acquisition was measured through objective and practical tests administered after the completion of the actual or virtual dissections. Maloney (2002) developed the virtual fetal pig dissection used in this study by modifying an existing laboratory exercise on the Internet.

Few studies have been performed which examine the use of virtual laboratories in science classrooms. Most of these studies have focused on virtual frog dissections (Apkan & Andre, 2000; Kinsie, Strauss & Foss, 1993; Sweitzer, 1996), and one with mixed-gender college students (Matthews, 1998) on fetal pig dissections. Of these studies, none have focused exclusively on the performance of females on virtual

dissection in a single-sex classroom setting. The population chosen for this study was girls enrolled in high school biology courses. I chose to study girls because research shows that fewer women choose to enter the science and technology fields and often encounter difficulties in those fields (Barley & Philips, 1998; Hanson, 2000; National Science Foundation, 2000; Scholar, 1998). One way to attract more women into these fields may be to enhance their science and technology instruction while they are still in high school as studies have shown that girls do not perform as well as their male counterparts in science and computer classes (Bain, Hess, Jones & Berelowitz, 1999; Crombie, Ararbanel & Anderson, 2000). Research also tells us that differences exist between males and females with respect to computer usage (Barrett & Lally, 1999; Charlton, 1999; Kadijevich, 2000; Kafai & Sutton, 1999).

Since these differences in science competency and computer usage may mask the performance of females on computer-based tasks in a science laboratory exercise, I chose to study girls in a single-sex classroom in a single-sex school to study, more accurately, the effect of technology on girls in a science class. This setting eliminated the confounding variables of male-female instruction in the classroom and the treatment effects of the teacher who may interact differently with males and females (Crombie et al., 2000; Sadker, 1999). The results of this study could serve as a baseline measure for future studies of females in mixed-gender classrooms.

THEORETICAL FRAMEWORK

The theoretical framework underlying Computer Assisted Learning (CAL) is very difficult to define because CAL exists in so many forms. Kemmis, Atkin and Wright (1977) may have devised the clearest system of classification for this type of learning. The authors set up a classification system for computer programs consisting of four paradigms: instructional, revelatory, conjectural, and emancipatory.

The virtual fetal pig dissection used in this study exists in two paradigms: emancipatory and revelatory. The emancipatory paradigm contains aspects of the other paradigms. This student-centered paradigm is based on the idea that computer software can be a labor saving device. Computer programs that allow the student to create text documents or graphs would be in this category. Smeets and Mooij (1999) would classify a fetal pig dissection in this paradigm. They stated, "Examples are the use of a word processor, the use of the computer for calculations, and the use of multimedia for performing "virtual experiments" (p.489).

The second category in which this virtual dissection laboratory exercise fits would be revelatory. According to Smeets and Mooij (1999), "A learning environment is created which stimulates students to find connections in the available information" (p.489). Simulations fall into this category because they allow students to make these connections of information. This paradigm would be based on the discovery learning ideas of Bruner (1960).

Limitations and Delimitations

The subjects in this study were females enrolled in an all-girls school. Without the presence of males in the class, it is not possible to determine if the results can be generalized to girls in a mixed-gender classroom. I am not concerned with the reaction of males to a virtual fetal pig dissection, or to using computers in the biology laboratory. I am also not concerned with the reaction of females in a mixed-gender classroom. These ideas are beyond the scope of this study.

Another limitation of this study is that the students were enrolled in a parochial school. The results from this setting may not generalize to those obtained from a public school setting. Additionally, the subjects in this study were enrolled in two different levels of biology: core, and academic. Although differences may be found between the two levels of students, these samples are too small to generalize to all levels of biology. More research is definitely needed to determine if a virtual pig dissection works as a viable alternative to all levels of biology classes.

The author of the original virtual fetal pig dissection, Dr. Earl Fleck, used this computer laboratory in studies with his students enrolled in college biology courses. This program has only been used with high school biology students in the pilot study performed by this researcher. Due to this fact, further use of this program with high school students is recommended before broad generalizations of the results are made.

The National Science Foundation (2000) also reports an unequal percentage of minority women in the science and engineering labor force. The report states that 83% are White, non-Hispanic, 10% are Asian/Pacific Islander, 3% are Black, non-Hispanic, 3% are Hispanic, and .3% are American Indian/Alaskan (p.52). As Archbishop Stephens is predominately composed of White, non-Hispanic students, the results of this study cannot generalize across racial boundaries. Future study is needed to determine if a virtual dissection experience appeals equally to various racial and ethnic groups.

PARTICIPANTS

The sample for this study was 224 female students who were enrolled in core or academic level biology classes at Archbishop Stephens High School. Eighty eight girls completed an actual dissection, and 136 completed a virtual dissection. These high school students were in 11 different classes taught by three different teachers. Although all three of the teachers were female, they vary in their years of experience at the school and differences may have occurred in their teaching. To minimize the effects of the different teachers' instructional methods, the students were given the same information and assignments, and followed the same schedule to complete the dissection laboratory exercise.

Another difference between the 11 biology classes is that 4 of the classes were being taught at the core, or basic level, and 7 of the classes were taught at the academic level. Core level students at Archbishop Stephens are characterized as students who score low on standardized tests, and learn at a slower pace than the students taught on the academic level. Both of these levels are considered college preparatory at the high school.

Of these classes, 4 of the academic classes completed the actual dissection, and all of the core classes completed the virtual. This less than ideal situation in the construction of the groups was to maintain the teaching method for each teacher for each of her scheduled laboratory periods. Due to space and time considerations, this design was necessary so that in the shared biology laboratory there would either be virtual dissections conducted on computers, or actual dissections with specimens, throughout each day during the same two week period. This also enabled each teacher to conduct all of her classes within one method, virtual or actual, regardless of the level of students.

Instrumentation

The objective test used in this study to measure the students' knowledge acquisition was designed by one of the teachers at the school. It consisted of 60 questions that were matching, true and false, and multiple-choice in design. The students' visual recognition of fetal pig anatomical structures was measured with a practical test. A practical test had for many years been conducted in the laboratory setting with the students at the school walking from table to table and identifying structures marked with a pin. Approximately four years before, one of the biology teachers at the school had prepared a PowerPoint presentation composed of slides containing pictures of structures identified with numbers. Since this teacher felt confident that her students were performing as well on this type of presentation as they had on the original laboratory practical, the other biology teachers at the school adopted this type of practical test. Maloney (2002) modified the original PowerPoint presentation with pictures taken by the students on the yearbook staff added to those she had taken herself. The practical test used in this study consisted of 27 PowerPoint slides containing 45 structures to be identified by the students.

PROCEDURES

Instruction packets were distributed to the students that contained instructions for the entire laboratory experience. When all of the paperwork was distributed and completed, the students who actually dissected a fetal pig proceeded to the biology laboratory to begin their dissection, and the students who virtually dissected a fetal pig reported to the library to complete their laboratory exercise. A video of an actual fetal pig dissection was shown to both groups of students before they began their dissections.

The library of Archbishop Stephens High School was chosen as the location for the virtual dissection because of a bank of 15 computers that were connected to the Internet and located on the far side of the library. This location assured the classes of biology students a measure of privacy in an otherwise busy library. In addition, this proved to be the only location in the school where this many computers were connected to the Internet and available for classes to reserve for use. These 15 computers allowed the students to work in groups of two allowing for maximum exposure to the virtual exercise, and little or no wait time for computers. The three biology teachers who participated in this study were each assigned two weeks to complete the dissection. This meant that the dissections in this study, both actual and virtual, should have been performed during a six-week period. However, in order to reserve the library, the students who would virtually dissect had to be scheduled for two weeks later in the semester, almost one and one half months after the students who completed the actual dissection.

Class length at the school is 75 minutes and, with a rotating schedule, the classes met five to six times each within the two-week period. During these class periods, the students completing an actual fetal pig dissection worked in groups of two with one pig assigned to each group. The students completing a virtual dissection also worked in groups of two with one computer assigned to each group. Since it was not allowable to bring fetal pig specimens to the library for the students to view, one additional day of laboratory work was scheduled for the virtual dissection students so that they could go to the biology lab and view displays of the actual specimens. This meant that the students who virtually dissected actually spent one more day on the dissection exercise than the students who actually dissected a fetal pig.

Each day of the dissection laboratory, the students began by reading their packet and following the instructions. The students in both groups received the same instruction packet, regardless of the type of dissection in which they would participate. To enable both groups of students to use the same packet, the students who virtually dissected were instructed to ignore the dissecting instructions in the packet.

Daily Schedule

The actual dissection group and the virtual dissection group followed the same dissection schedule. The students' lab schedule for dissections can be found in Table 1.

Table 1. Daily Lab Schedule

Day	System to be Dissected
Day 1	External Structure
Day 2	Mouth, Neck and Throat Organs
Day 3	Organs of the Thoracic Cavity – Lungs and Heart
Day 4	Digestive System
Day 5	Urogenital System
Day 6	Nervous System

The students were instructed to complete their journal entries which contained the answers to the questions in the packet, drawings of the organs and systems they studied that day, and their thoughts and feelings concerning how they and their partners worked during that period and on the dissection experience itself. In addition, the students were to create a chart of the structures studied that day which included columns for the organs' description, position within the body, other associated organs and the

function of the organ or organ system being studied that day. These packets were turned in to their respective teachers at the completion of the laboratory exercises. Once the students had completed the dissections, they were given both objective and practical tests to determine knowledge acquisition.

DATA ANALYSIS PROCEDURES

The grades from the objective and practical tests were statistically analyzed using ANCOVA and compared across the experimental and control groups. Statistical analysis of the test scores was ANCOVA so that the students' science scores on the PLAN test, a standardized test given at the high school to freshmen and sophomores, could be used as a covariate in an effort to minimize any existing difference in achievement between the two groups.

Research Hypotheses

Hypothesis 1: The mean scores of the practical test taken by the students completing a virtual fetal pig dissection will be greater than the mean scores of those completing an actual dissection.
Hypothesis 2: The mean scores of the objective tests taken by the students completing a virtual fetal pig dissection will be greater than the mean scores of those completing an actual dissection.

Independent and Dependent Variables

The independent variable in this study is the use of a virtual fetal pig dissection. Two students on the yearbook staff of Archbishop Stephens High School took original photographs with a digital camera during dissections performed by another biology teacher at the school. This original material and additional pictures taken by this researcher, were integrated with an existing virtual pig dissection found on the web to design the virtual experience as close as possible to the structure of the actual dissections. The excellent virtual dissection on the World Wide Web was created by Earl W. Fleck while at Whitman College in Walla Walla, Washington. It can be found at http://www.whitman.edu/biology/vpd/main.html. Dr. Fleck gave permission to this researcher to use his virtual fetal pig dissection through email correspondence. The web-based program used in this study was designed by the researcher and can be found on the World Wide Web at http://tec.uno.edu/George/Class/2002Fall/EDCI4993603/webSites/BMaloney/pigdissection.htm

The dependent variable in this study is knowledge acquisition. The acquisition of knowledge was measured using objective and practical tests administered by the teachers at the end of the laboratory exercise. The results of these tests were statistically analyzed with ANCOVA to determine if any differences between the groups were significant.

RESULTS AND DATA ANALYSIS

The quantitative data collected in this study consisted of standardized science test scores from the PLAN test and scores from practical tests and objective tests. All of the students were given the same practical and objective tests regardless of the type of dissection they performed. To compensate for any existing differences in the students' performance, an ANCOVA test was conducted on the results using the students' science standardized test scores from the PLAN test as a covariate. The results from the practical and objective tests were analyzed using SPSS version 10.0.

Quantitative Data

The first hypothesis that addressed the students' acquisition of knowledge was:
Hypothesis 1: The mean scores of the practical tests taken by the students completing a virtual fetal pig dissection will be greater than the mean scores of those completing an actual dissection.

The practical test given to the students consisted of twenty-seven PowerPoint slides that contained pictures of organs and structures from actual fetal pig specimens. The teachers showed this PowerPoint practical test on a large computer monitor in front of the class. The students were instructed to fill in the name of the highlighted structure(s) on each slide on a numbered answer sheet. An ANCOVA test

was performed on the students' test scores using the students' PLAN scores as covariates. In addition, Levene's Test of Equality of Error Variances was performed (F=.319, p=.573). Since the probability of the test is greater than the alpha level, the assumption of homogeneity of error variance is maintained. The results indicate that the students who completed a virtual dissection scored higher (37.5760) than the students who completed an actual dissection (30.6522). This difference was significant (F= 62.037, p<.001) at the .05 level. These results indicate that the mean scores from the practical test of the students who performed a virtual fetal pig dissection are significantly higher than the mean scores of those students who performed an actual dissection. The results from the ANCOVA tests on the students' practical test scores can be found in Table 2.

Table 2. ANCOVA Summary Table for Practical Test Scores

Source	SS	Df	MS	F	Sig.
Between groups	337.004	1	337.004	8.744	.003
Within Groups	2390.932	1	2390.932	62.037	<.001
Total	249022.000	194			

Hypothesis 2: The mean scores of the objective tests taken by the students completing a virtual fetal pig dissection will be greater than the mean scores of those completing an actual dissection.
The objective test given to the students consisted of sixty questions pertaining to the anatomy and physiology of the fetal pig. An ANCOVA test was performed on the students' test scores using the students PLAN scores as covariates. In addition, Levene's Test of Equality of Error Variances was performed (F=.027, p=.870). Since the probability of the test is greater than the alpha level, the assumption of homogeneity of error variance is maintained. The results of the ANCOVA test indicate that the students who completed a virtual dissection scored higher (44.7760) than the students who completed an actual dissection (43.7681). This difference was significant (F=6.188, p=.014) at the .05 level. These results indicate that the mean scores on the objective test of the students who performed a virtual dissection were significantly higher than the mean scores of the students who actually dissected a fetal pig. The results from the ANCOVA tests on the students' objective scores can be found in Table 3.

Table 3. ANCOVA Summary Table for Objective Test Scores

Source	SS	Df	MS	F	Sig.
Between groups	433.121	1	433.121	9.347	.003
Within Groups	286.765	1	286.765	6.188	.014
Total	386104.000	194			

DISCUSSION AND CONCLUSIONS

This study attempted to determine if a virtual fetal pig dissection could be used as a viable alternative to an actual fetal pig dissection. Viability was defined as knowledge acquisition. The research question for this study was: How does a virtual fetal pig dissection, as compared to an actual fetal pig dissection, affect female students' knowledge of anatomy?

Summary of the Study

Knowledge acquisition was measured quantitatively through the use of practical and objective tests. Statistical tests showed that there was a significant difference between the scores earned by the students who dissected virtually and those who actually dissected a fetal pig. The students who participated in the virtual dissection scored higher on both of these tests.

The difference in mean scores of the practical test were both statistically significant and educationally significant. The students who virtually dissected received a mean score of 37.5760 points. This mean score translates to an 83.50%, which is a letter grade of C at Archbishop Stephens. The mean score of

the students who actually dissected was 30.6522 that translated to a score of 68.12%. This mean score would fall into the F grade range at the high school. This is an educationally significant result in that the average score of the students who virtually dissected was two grade levels higher than the average scored by the students who actually dissected. Additionally, the construction of the actual dissection at the school should be examined to determine if it could be changed in any way that might contribute to the students' test scores on the practical. Future research is needed to determine if the PowerPoint practical, while easier to set up and administer, is adequately testing the students' who complete actual dissections knowledge of anatomy.

The results of the comparison of the objective test score grades were significant, but not educationally significant. The students who virtually dissected received a mean score of 44.7760 (74.63%), and the students who actually dissected received a mean score of 42.7681 (71.28%). Although this difference in mean scores is significant, both of these scores fall into the D grade range at Archbishop Stephens. So, although the students who virtually dissected scored significantly higher on their objective tests, both groups of students scored in the same letter grade range.

One reason why the students who participated in the virtual dissection scored higher on the practical test could be that the test was composed of PowerPoint slides which were displayed on a large computer monitor. As the students who completed a virtual dissection worked exclusively on computers, they might have had an advantage because they were familiar with the medium. A few of the biology teachers had for the past few years been using PowerPoint slide shows for their practical tests because they were faster to set-up and administer, and the students could not tamper with the placement of the pins marking the structures in question. Although the familiarity with the computer may have been a contributing factor, this fact did not necessarily skew the results. The students who completed an actual dissection would have been tested using the same media, as the biology teachers at the school had begun using the PowerPoint practical tests a few years before. Since this type of practical test was already in use at the school, I did not think that the comparison between the actual and virtual groups on the PowerPoint test would be partial to one group or the other.

It is more difficult to find a reason for the students who virtually dissected to have performed better on the objective test. Other than the treatment, the only other mitigating factor could be that the virtual dissection was scheduled almost one and a half months after the actual dissection. This could mean that the students had the opportunity to learn more anatomy in their biology classes. Through discussion with the teachers, I could not find any discernable difference in the amount of material covered across the groups as they had followed slightly different chapter sequences so that the actual dissection group would be exposed to as much anatomy as possible before their scheduled dissection. Although this may have been a source of contamination to the test grades, I do not think it was a contributing factor. So, it is apparent that completing the virtual dissection enabled the students to score significantly higher on their objective tests.

DISCUSSION OF HOW THESE FINDINGS SUPPORT THE RESEARCH

The literature reviewed for this study covered four broad categories: dissection, science, educational technology and gender issues. The findings from this study are discussed as they pertain to each of these categories.

Dissection Research

These results did support the findings of some dissection studies. Fowler and Brosius (1968) and Predevac (2001) found that the students in their studies scored higher on knowledge acquisition tests when exposed to an alternative to dissection. Both of these studies used mixed-gender classes, and the undergraduate students in Predevac's study had previously dissected the animal on which his study is based. Future research is definitely needed to compare different groups of females in different surroundings and socioeconomic groups. It is my hope to further this research and to then compare the results with different groups of male high school biology students.

Science Research
In respect to the literature advocating a changing environment in the science classroom, this virtual laboratory exercise was certainly a prime example (see, for example, Bruner, 1996; National Research Council, 1996; Rakow, 1999; Rutherford & Ahlgren, 1989). The students completed the virtual dissection with very little instruction from the teachers. The teachers mainly facilitated the instruction by roaming the area and answering questions as needed. The teacher of the students who actually dissected had to do much more demonstration and give many more instructions. This virtual laboratory showed how the teachers and students can work together as partners in science.

Although this dissection laboratory exercise is not based on discovery learning or inquiry (Bruner, 1996; National Research Council, 1996), the non-linearity of the virtual dissection did allow the students to search anywhere on the site for information they needed. They were free to re-examine body systems they had completed, or go ahead to another body system that they would learn later. This non-linearity did allow for a limited amount of discovery for the students as they had more freedom to complete the assignments using any of the links on the web site. I observed students going freely back and forth from the virtual dissection to other dissection sites looking for more information. This hypermedia allows the students to explore a topic in depth, and to make it their own. This finding is consistent with that of Clark, Hosticka and Huddlestun (1999).

Educational Technology Research
The literature on educational technology consisted of mixed results. Mellon (1999) stated, "I am doubtful that any tool of learning can have the same impact as a good teacher" (p.14). I think that the results of this study are consistent with this statement. The teacher who conducted the actual dissection had been teaching dissections for 30 years. The teachers who conducted the virtual dissection were new to the experience. Although the results of the knowledge acquisition tests were significant, I firmly believe that a good teacher is necessary for the proper implementation of any technology in the classroom.

Gender Research
Several issues relating to gender were discussed in the literature reviewed for this study. One of these issues was found by Roychoudhury, Tippins and Nichols (1995) in that it was important to create a "cooperative and supportive environment" for female science students. (p.902) This finding was upheld by the results of this study, as the students worked in pairs with supportive teachers acting as facilitators. In terms of gender studies, this study focused specifically on females enrolled in high school biology. It is beyond the scope of this study to comment upon the interactions between males and females in science classes. It is my hope that the results of this study could be used as a baseline measure for future research in this area.

IMPLICATIONS FOR FUTURE RESEARCH

Since this study focused on females enrolled in a single sex biology class, it would be interesting to repeat the study on males enrolled in a single sex biology class. This would provide an interesting comparison as to how males and females react to the virtual dissection without the interfering factors inherent in a mixed-gender class. In addition, the males should be enrolled in a school of similar demographics.

The subjects in this study were mostly white, middle-class students. Future study is needed using subjects of various demographic backgrounds. In addition, these students were enrolled in a parochial high school. Future study is needed to determine if these results can be generalized to students required to dissect in a public school setting.

Although, according to the results of this study, this virtual dissection has proven to be a viable alternative, teachers may choose to utilize it along with an actual fetal pig dissection. Future study is needed to determine if students may benefit from the exposure to both types of dissection. Some

possible scenarios could be to use the virtual dissection before, during, or after the actual dissection. These results may illustrate the best use of a virtual laboratory.

CONCLUSION

In summary, the results of this study were that the students who virtually dissected scored significantly higher on their practical and objective tests. Technology is prevalent in today's schools, and teachers must learn to incorporate this technology into their curricula in meaningful ways. This study shows that students can learn using a virtual dissection in a high school biology class. Biology teachers should take heart that there is technology available to teach anatomy to their students, and feel free to suggest a virtual dissection alternative to their students. Gone are the days of lengthy reports for students who object to the dissection. Gone are the days of the students only being able to view specimens for one hour in the lab. A well-designed virtual fetal pig dissection either online or downloaded to CD-ROMs may be the answer to the expense and moral and ethical considerations of animal dissections. Further research is needed to determine if these results generalize to females in mixed–gender classes. Hopefully, the results of this study can be used as a baseline for this future research.

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