ED 436 157 IR 019 782

AUTHOR Marszalek, Christine S.; Lockard, James
TITLE Which Way To Jump: Conventional Frog Dissection, CD-Tutorial, or Microworld?
PUB DATE 1999-02-00
NOTE 16p.; In: Proceedings of Selected Research and Development Papers Presented at the National Convention of the Association for Educational Communications and Technology [AECT] (21st, Houston, TX, February 10-14, 1999); see IR 019 753.
PUB TYPE Reports - Research (143) -- Speeches/Meeting Papers (150)
EDRS PRICE MF01/PC01 Plus Postage.
DESCRIPTORS *Anatomy; Anxiety; Biology; *Cognitive Style; Comparative Analysis; *Computer Assisted Instruction; Conventional Instruction; *Dissection; Grade 7; Instructional Effectiveness; Interaction; Intermode Differences; Junior High Schools; Microworlds; Pretests Posttests; *Retention (Psychology); *Science Instruction; Sex Differences
IDENTIFIERS Frogs; *Science Anxiety

ABSTRACT

This study investigated and compared the level of initial and long-term retention of frog internal anatomy among students using an interactive CD tutorial, a desktop microworld, and conventional frog dissection. Students' anxiety toward science was also compared across the three treatment groups and between genders. Additional data on students' preferred learning style were used to explore possible interaction effects with their respective instructional activity. Subjects (n=280) were seventh-grade students in one junior high school. Classes were randomly assigned to the three modes of instruction. Data collection and testing occurred prior to treatment, one day after treatment, and three months after treatment. Data analysis showed mixed results for all measures taken. Differences in achievement favoring the conventional treatment from pretest to both posttests leveled out somewhat over time. Although anxiety levels declined for both genders after treatment, females reported significantly higher science anxiety than males both before and after treatment. There appeared to be a relationship between treatment and gender in terms of effect on science anxiety. No significant difference in achievement by learning style was observed. However, the interaction between learning style and treatment was significant in some cases. In looking at achievement defined as gain scores among the three achievement measures, some cases within the microworld treatment proved to be significant. (Contains 40 references.) (MES)

Which Way to Jump: Conventional Frog Dissection, CD-Tutorial, or Microworld?

By:

Christine S. Marszalek & James Lockard

WHICH WAY TO JUMP: CONVENTIONAL FROG DISSECTION, CD-TUTORIAL, OR MICROWORLD?

Christine S. Marszalek
Twin Groves School, Kildeer Countryside CCSD96

James Lockard
Northern Illinois University

Abstract

The purpose of this study was to investigate and compare the level of initial and long-term retention of frog internal anatomy among seventh-grade students using an interactive CD tutorial, a desktop microworld, and conventional frog dissection. Students' anxiety toward science was also compared across the three treatment groups and between genders. Additional data on the students' preferred learning style were used to explore possible interaction effects with their respective instructional activity.

Subjects participating in the study were all seventh-grade students in one junior-high school, numbering 280 in total. Classes were randomly assigned to one of three modes of instruction. The conventional treatment was traditional physical dissection using a preserved frog specimen and lab dissection tools. The CD-tutorial treatment was the interactive tutorial Digital Frog from Digital Frog International. The microworld treatment was an environment composed of Operation Frog on CD supplemented with other programs and resources to provide additional avenues for learning. Data collection and testing occurred prior to treatment, one day after treatment, and three months after treatment.

Data analysis showed mixed results for all measures taken. Differences in achievement favoring the conventional treatment from pretest to both posttests appear to have leveled out somewhat over time.

Although anxiety levels declined for both genders after treatment, females reported significantly higher science anxiety than males both before and after treatment. There appears to be a relationship between treatment and gender in terms of effect on science anxiety.

For all three measures taken -- pretest, immediate posttest and delayed posttest -- no significant difference in achievement by learning style was observed. Learning style alone does not appear to be related to achievement in this study. However, the interaction between learning style and treatment was significant in some cases. In looking at achievement defined as gain scores among the three achievement measures, some cases within the microworld treatment proved to be significant.

Introduction

This study was born from the familiar, frustrating scene of physical frog dissection, which occurs annually in school systems everywhere, and in this particular case, a suburban junior high school. The problem facing the biology teachers was to find an alternative means of instructional delivery that would yield substantially the same cognitive knowledge development in the students, help address the declining frog population, address the issue of science anxiety among students at the junior high level, and accommodate the learning styles of the students.

Despite the long history of dissection in biology coursework, it has become controversial (Kinzie, Foss, & Powers, 1993; Langley, 1991; Orlans, 1988; Strauss & Kinzie, 1991). As one result, the Florida legislature passed a bill in 1988 protecting the rights of students who do not wish to participate in dissection.

To explore potential new approaches, it was first necessary to look at the various alternatives available such as anatomical models, charts, laserdiscs, reference books, advanced coloring books, computer programs, and interactive Internet sites. Secondly, it was necessary to select appropriate alternative means of instruction for this grade level and the depth of coverage desired. Although there are many alternatives to dissection, the extent to which computer models, videotapes or other non-animal material can replace dissection entirely in schools remains open to question and appears to have had little impact on animal use.

Many of the alternatives are faulted for their low levels of realism or for limited opportunities for active student participation (Strauss & Kinzie, 1991). Whether or not the alternatives are interactive appears to be an important factor in ensuring success (Strauss & Kinzie, 1994). With this in mind during our search for a suitable alternative to an actual frog dissection, we examined various forms of instructional material involving computers as the delivery medium because of their inherent constructivist and hands-on elements, which should more closely parallel the essence of an actual dissection activity. These materials fell into one or more of the following general categories (Piskurich, 1993): hypertext, hypermedia, simulation, multimedia, virtual reality, and microworld.

It soon became clear that no one delivery system existed that would cover the subject matter needed, at the grade level needed, or with a constructivist hands-on approach to parallel that of an actual dissection. It also became clear that there had been few efforts to evaluate the learning effectiveness of alternatives to dissection (e.g., Langley, 1991).

The team decided to use two alternative forms of frog dissection within this study in order to look at the supposed benefit of a hands-on approach to learning. The selected alternatives were the CD tutorial, *Digital Frog*, and a desktop microworld with *Operation Frog* providing the hands-on element of the dissection process. It became necessary to combine elements of each delivery system category to form a microworld of frog dissection in which to immerse the students. This microworld consisted of the multimedia simulation *Operation Frog* CD, digitized movies of the various stages of frog dissection, 3D movies of frog anatomy and human anatomy, sounds, and digitized still images.

Problem of the Study

With the richness of computer-based microworlds come many questions as to how these environments compare with actual reality. Little work has been done in comparing the two "realities" with regard to comprehension and recall of material; whether all learners or only those with certain learning styles can follow the conceptual model; how the classroom teacher can harness the power of these computer-based environments; and how students and teachers interact with a microworld. Even less work has been done specifically in the areas of alternatives to physical dissection and their impact on cognitive development gains, long-term retention, science anxiety, and differing learning styles.

Related Literature

There have been calls for additional research to identify the educational setting, types of students, and the areas of education that will benefit most from the inclusion of hypermedia (Lamb, 1991; Jonassen, 1989; Spiro & Jehng, 1990). Questions include whether this type of presentation improves comprehension and recall of material, whether all learners or only those with a "hyper-mind" can follow the conceptual model (Maurer, 1993), and how the classroom teacher can harness the power of hypermedia systems (Heller, 1990). In hypermedia, elements of constructivist theory combine to accommodate the evolving nature of knowledge by encouraging students to engage in a continuing search for improved understanding (Resnick, 1989; Bednar, et al., 1991; Black & McClintock, 1995; Lebow, 1993; Wilson, Teslow, & Osman-Jouchoux, 1995; Duffy & Jonassen, 1992; Wilson, et al., 1995; Cunningham, Duffy, & Knuth, 1993). Hypermedia microworlds designed in such a way as to give users exploratory experiences within a carefully controlled range of concepts and principles offer a practical compromise between instructivism and constructivism (Spiro & Jehng, 1990; Papert, 1980; Rieber, 1996).

Contradictions fill the literature concerning the use and effectiveness of computer-based instructional simulations (Carroll, 1982; J. A. Kulik, 1994; Mills, Amend, & Sebert, 1985). More and better simulations might be needed to influence student examination performance. Extensive research is needed on simulation design and use (Thomas & Hooper, 1991).

Students struggle when they try to learn in ways that aren't natural or easy for them. Effective education depends upon a sound match between characteristics of the student and characteristics of the programs and persons the student encounters (Messick, 1976). Although numerous studies have examined learning style (Helm, 1990; Ewing & Yong,1992) and numerous others have explored CAI (Wang & Sleeman, 1993; Wise & Okey, 1983), there has been much less research conducted pertaining to the relationships between CAI and learning preferences (Ester, 1994-1995).

Knowledge acquisition has been used to contrast the effectiveness of different instructional methods (Johnstone & Sleet, 1994, Moore & Miller, 1996, Grieve, 1992). The ease with which something is retrieved from long-term memory is directly proportional to how well it was stored in the first place (Baddeley, 1976; 1990; Ormrod, 1995). This simply indicates that when re-testing takes place, some material is no longer accessible. The question arises of whether hands-on technology-based activities enhance learning by reinforcing cognitive knowledge and improving retention (Korwin & Jones, 1990; Harrison, 1995).

Researchers have defined student attitude toward science as the student's feelings of like or dislike toward science (LaForgia, 1988; Koballa, Crawley & Shrigley, 1990; Atwater, Wiggins & Gardner, 1995). The question is to whether activity-oriented science instruction can help develop favorable attitudes toward science. Teaching strategy is related to student anxiety and performance levels (Westerback, 1982). Highly anxious elementary and junior-high students favored a less directive environment, while their less anxious counterparts favored stronger direction. Learning environments need to be created where students of different personalities and learning aptitudes can be successful, regardless of instructional mode, because students do not learn equally well from all modes of instruction.

Purpose of the Study

The purpose of this study was to investigate and compare the level of initial learning and also long-term retention of the frog's internal anatomy between seventh-grade students using an interactive CD tutorial, a desktop microworld, and conventional frog dissection. Students' anxiety toward science was also compared across the three treatment groups. Additional data were collected on the students' preferred learning modality to explore possible relationships with the level of learning or long-term retention and their respective instructional treatments.

Subjects

The population used within this study was comprised of 354 seventh-grade students in fourteen classes in a suburban school district. Of the mostly Caucasian students, 181 were boys, and 173 were girls. Due to attrition and/or absence during one or more phases of the data collection, 74 students whose data were incomplete were excluded from the analysis, reducing the subject pool to 280 subjects, 142 males and 138 females. None of the students had had any instruction in frog dissection prior to the study.

Research Design

A quasi-experimental research design was used, specifically the nonequivalent control-group research design (Gall, Borg, & Gall, 1996), because the research participants could not be randomly assigned to the experimental and control groups due to the naturally occurring environment. Therefore, intact classes were randomly assigned to treatments. All subjects took a pretest, a posttest, and a delayed posttest. Except for random assignment, the steps involved in this design are the same as for the classic pretest-posttest control-group experimental design.

Variables

The independent variable or treatment was the method used to deliver instruction on frog dissection. The dependent variables were the achievement scores on the pretest, posttest, and delayed posttest; scores on a science anxiety instrument administered at the start and end of the experiment; and the preferred learning style of the students.

Treatments

The three treatments used within this study consisted of two experimental treatments, a desktop microworld and an interactive tutorial, and conventional physical frog dissection. The media for creating a desktop microworld and an interactive tutorial of a frog dissection had to be readily available, relatively easy to use and able to run on existing platforms within an average educational setting. After careful consideration of existing media for frog dissection, *Digital Frog* from Digital Frog International was chosen for the interactive tutorial. However, a combination of programs had to be assembled to create a desktop microworld environment.

Digital Frog *Interactive CD-ROM*

Digital Frog is a commercial interactive CD-ROM that incorporates full-motion video, animations, sounds, narration, in-depth text, full color photographs and a comprehensive workbook in three modules -- Dissection; Anatomy; and Ecology. The dissection module uses a tutorial approach with the dissection proceeding in a step by step presentation manner. Users can access multimedia files to view a frog dissection being performed, but do not actually "perform" a dissection themselves.

Desktop Microworld

The desktop microworld environment was built around the commercial product *Operation Frog* on CD with other programs serving as auxiliary forms of instructional delivery. *Operation Frog* contains a tutorial simulation of the dissection of a frog, male or female. Unlike *Digital Frog*, *Operation Frog* allows students to actually perform the dissection, not just view it. However, unlike a real dissection, students also can reconstruct the frog. Using graphical surgical scissors, a probe, forceps, and a magnifying lens, students probe and snip body organs, remove organs to the examination tray, and investigate frog body systems close-up.

To help compensate for some of the limitations of *Operation Frog* and to build a stronger microworld environment, the students were given access to three additional modes of instruction:

- 3D QuickTime movies of the frog at various stages of dissection, created locally and/or downloaded to each computer's hard disk prior to the treatment from the Internet site *Virtual Frog*. [http://george.lbl.gov/ITG.hm.pg.docs/dissect/info.html]
- QuickTime movies of the stages of dissection being performed, downloaded to each computer's hard disk prior to the dissection activity from the Internet site *NetFrog*. [http://curry.edschool.Virginia.EDU/ go/frog/]
- Digitized pictures and sounds downloaded from various other sites on the Internet.

These components were accessible to students at appropriate times during the dissection process as indicated on their worksheets by icons matched with file names, which had been arranged at the top of the Apple menu for ease of access.

Conventional Frog Dissection

The conventional physical dissection method was used as the control treatment within this study. It was the traditional method of providing a preserved specimen of a frog for every two students within the class. Students used traditional dissection trays and related tools. The dissection activity was conducted in the science classrooms, which contain lab tables for science activities. Teachers guided students through the dissection process aided by worksheets given to the students.

Lab Worksheets

Lab worksheets were composed of the "Frog Dissection Laboratory Investigation" from the *Prentice Hall Life Science Laboratory Manual* as well as material used by the science team over the course of several years. The content and questions asked remained the same for all subject groups. However, the directions given within the worksheets reflected the individual treatments within the study.

The lab worksheets given to the control group performing the conventional dissection included directions for performing the physical dissection. The lab worksheets given to subjects in the experimental desktop microworld contained additional directions on where to go on the computer for certain activities. These directions were in the form of symbols, e.g., a movie camera symbol followed by a movie title for accessing the QuickTime movies, a camera followed by an image file name for accessing digitized images, etc. The lab worksheets for the subjects using the interactive tutorial, *Digital Frog*, contained directions for getting started in the program.

The format of the lab worksheets was designed to be easy-to-follow and to allow the students to complete the investigation largely on their own, leaving the instructor free to provide necessary help to individuals or groups of students. The lab worksheets also asked for observations after the procedure at each level of dissection and asked students to draw conclusions that encouraged them to use critical-thinking skills.

Procedures

The study was conducted within the prescribed seventh grade biology curriculum following the completion of the unit on cold-blooded vertebrates, which is the last unit curriculum conducted each school year. Students had performed dissections on earthworms earlier in the year and were familiar with dissection instruments and general lab procedures and safety precautions.

Each of the fourteen intact science classes involved in the study was randomly assigned an instructional delivery system subject to scheduling constraints (each teacher was to have at least one class of each treatment to help control for bias) and availability of conventional or computer lab space. This process resulted in four classes using the interactive tutorial, six classes using the desktop microworld, and four classes using the conventional dissection method. No class exceeded 30 students. Prior to the actual dissection activity, teachers received training in manipulating the computer treatments, using the same lab worksheets as the students would use.

The students in the experimental sections conducted their alternative dissection activity using the interactive tutorial or desktop microworld in the auxiliary computer lab at the school. This lab contains 15 Macintosh computers, which necessitated the partnering of subjects, two to a computer. This was appropriate, as the control group was also partnered, two to a dissection pan, as they historically had been grouped within the school.

For all groups the dissection took place over a span of four consecutive days with each class having a 43-minute instructional time period each day. The testing, preparation and closure took place during three class periods. All achievement tests used the same instrument. The pretest and preparation occurred on the day before the dissection activity began. The immediate posttest and closure occurred on the day following the dissection activity. The class period for administration of the delayed posttest was three months following the dissection activity, during the opening days of the following school year. The science anxiety survey was administered in each class two days prior to the start of the dissection activity to establish a baseline for comparison and then again on the second day following the conclusion of the dissection activity.

Data Collection / Instruments

The three regular science teachers conducted the classes and graded the pretest, posttests, and lab worksheets. They also administered the science anxiety survey. The study skills teacher at the school had previously conducted the learning style self-assessment.

The 43-item science anxiety instrument was adapted from one developed for high school age students (Wynstra & Cummings, 1993). The first 35 items asked students to indicate how nervous they would feel if they had to do each of the listed science-related activities. They responded using an ordinal scale from "a" (indicating "Not at all Nervous") through "e" (indicating "Very Nervous".) The remaining eight questions were general questions such as their gender and their interest in science related topics. The interest questions were not used within this study, as the science teachers deemed them geared toward the high-school aged student.

Since the science anxiety instrument was originally targeted at high-school age students, the reliability of the instrument for this age group was tested by administering the instrument prior to the study to one class chosen at random from the fourteen classes of subjects. With a maximum possible value of 1, Cronbach's Alpha yielded an alpha level of .9005 as the reliability coefficient. Thus the instrument was deemed reliable for this study.

The pretest and posttest were identical and were administered to both the control group and the experimental groups. The test was comprised of items from the *Prentice Hall Life Science* text for the junior-high school student and the lab worksheets used within the science curriculum for conventional dissection. Items consisted of multiple-choice, true-false, and matching questions that either had already been tested for this subject area and level using item-analysis techniques and been found to be reliable or had been judged to be reliable by the science team at the school over the years.

Data Analysis

Statistical analysis of data was completed using *SPSS 7.5* software. The level of significance for all tests was set at 0.05.

Demographic data concerning the subjects were tabulated using frequency counts. Because the subjects could not be randomly assigned to treatments, the issue of initial equivalency among the subjects was addressed. A pre-test was administered and when the scores were analyzed by gender using a $\underline{t}$ test and by treatment group and specific class using analysis of variance (ANOVA), no significant differences were found (see Table 1 for pretest statistics). To address the research hypotheses, which focused on differences across the three treatments, several techniques were employed. Achievement and retention were defined as the change in individuals' scores on the achievement test from pre-test to post-test, from post-test to delayed post-test, and from pre-test to delayed post-test. Means and standard deviations were calculated for each test by treatment to identify patterns. The "gain" scores for test pairs were calculated and submitted to one-way ANOVAs to identify any statistically significant findings relative to each hypothesis. With three treatment conditions, further analysis of significant ANOVAs was required to identify the individual pair(s) that differed significantly. Contrast tests were selected for this aspect of the analysis. The possible interaction effect on achievement of treatment and learning style of subjects was also explored. Analysis of these data utilized descriptive statistics, analysis of variance across learning styles within treatment, as well as a factorial ANOVA for the three treatments by the seven identified learning styles.

Table 1. Pretest Scores by Gender, Treatment, and Class Section

	N	Mean	SD
Gender			
Male	142	21.38	5.31
Female	138	22.12	4.36
Treatment			
CD Tutorial	86	21.97	4.62
Microworld	125	22.13	4.66
Conventional	69	20.78	5.44
Class			
M1	25	22.72	4.84
M2	26	22.27	3.87
M3	22	22.05	4.61
M4	18	21.78	5.17
M5	23	23.13	4.43
M7	24	21.96	6.00
S1	18	23.11	3.85
S2	22	20.95	3.40
S3	18	21.61	5.13
S4	15	20.20	7.34
S5	17	23.29	3.90
S6	15	20.93	4.45
W4	18	19.33	5.92
W5	19	19.95	4.22

Findings Pertaining to Research Question One

Research question one asked, What are the relative effects on student achievement of instruction using an interactive tutorial, a desktop microworld, and a conventional dissection of a frog? Three hypotheses proposed no significant difference among the three treatment groups in gain from pretest to posttest, pretest to delayed posttest or posttest to delayed posttest.

In looking at the relationship between treatment and gain scores, significant differences were observed. The mean gain from pretest to immediate posttest for students participating in the conventional dissection (Mean = 11.99) was significantly higher [$t = 2.97$, $p = .007$] than for students in the microworld treatment (Mean = 9.78). The conventional dissection group (Mean = 7.36) also showed a significantly higher mean gain score from pretest to delayed posttest than either the microworld group (Mean = 4.24, $t = 4.03$, $p = .000$) or the CD-tutorial group (Mean = 4.14, $t = -3.862$, $p = .000$). There was no significant difference in long term retention among treatments as evidenced by gain scores from posttest to delayed posttest.

In summary for the first research question and its three hypotheses, the data supported rejecting the hypothesis of no significant difference in achievement by treatment in the case of gain from pretest to immediate posttest as well as in the case of pretest to delayed posttest scores. Results favored the conventional dissection treatment. However, the data did not support rejecting the hypothesis in the case of gain from immediate posttest to delayed posttest, suggesting a leveling of results over time. Regardless of the measure, students in the conventional dissection treatment did outperform those in the two experimental treatments, which did not differ significantly from one another.

Findings Pertaining to Research Question Two

The second research questions was What are the relative effects and the effects of gender on students' level of science anxiety of instruction using an interactive tutorial, a desktop microworld, and a conventional dissection of a frog? Two hypotheses proposed no significant difference in science anxiety by treatment group or gender. The science anxiety survey was given before the start and after the conclusion of the frog dissection unit. Results showed the three treatment groups were not equivalent in anxiety at the beginning. Contrast tests revealed that students assigned to the conventional treatment reported significantly lower science anxiety than students in either the CD tutorial ($t = 3.11$, $p = 0.002$) or the microworld treatment ($t = 2.84$, $p = 0.005$.) The mean science anxiety score for students in the CD tutorial group did not differ from that of the microworld group.

These initial findings did not change after treatment, and no single treatment group showed a significantly different change in anxiety compared to the other treatment groups. Contrast tests showed that students experiencing the conventional treatment reported significantly lower science anxiety after treatment than students in either the CD tutorial group ($t = 2.71$, $p = 0.007$) or the microworld treatment ($t = -3.56$, $p < 0.001$.) The mean post-treatment score for students in the CD tutorial group did not differ from the microworld group.

In looking at the results of the science anxiety measures by gender, some interesting patterns emerged. A t test showed that females reported significantly higher initial science anxiety than males ($t = -3.46$, $df = 278$, $p = 0.001$). Although anxiety levels declined for both genders after treatment, females continued to report significantly higher science anxiety than males ($t = -3.36$, $df = 278$, $p = 0.001$). Therefore, the hypothesis of no significant difference in anxiety by gender was rejected for both the pre-treatment and post-treatment survey.

Looking at differences in anxiety levels by treatment received and by gender, the three treatment groups displayed varying results. Males and females in the CD tutorial treatment showed a significant difference before treatment ($t = -2.13$, $df = 84$, $p = 0.036$) but not after treatment ($t = -1.195$, $df = 84$, $p = 0.236$). Participation in the CD tutorial treatment appears to have closed the gap between the genders. This was in contrast to the conventional treatment subjects who, although showing a general decline overall in anxiety levels after treatment, showed a significant difference between genders both before ($t = -2.92$, $df = 67$, $p = 0.005$) and after treatment ($t = -2.35$, $df = 67$, $p = 0.022$). Apparently the conventional dissection was not effective in reducing the disparity in anxiety between male and female subjects. For the microworld group, anxiety levels across genders did not differ significantly before treatment. However, after treatment, the difference did approach significance ($t = -1.94$, $df = 123$, $p = 0.55$), with anxiety declining more amongst males than females.

In summary for the second research question and its two hypotheses, the data supported rejecting the hypothesis of no significant difference in students' level of science anxiety. The three treatment groups were not equivalent in anxiety at the beginning and this pattern held after treatment as well. The data also supported rejecting the hypothesis in the case of gender. Females consistently reported a significantly higher science anxiety level than their male counterparts, both before and after treatment. When looking at differences in anxiety levels by treatment received and by gender, the data again supported rejection of the null hypothesis. While the means by gender for the CD tutorial treatment and the conventional treatment were significantly different before treatment began, males and females in the microworld treatment did not differ significantly. After treatment males and females in the CD tutorial treatment no longer showed a significant difference. For the microworld group, the post-treatment mean difference approached but did not reach a level of significance, with anxiety declining more among male students than female students. Within the conventional treatment group, although the level of anxiety lowered across genders, there was still a significant difference between males and females after treatment.

Findings Pertaining to Research Question Three

The third research question asked Is there a relationship between students' preferred learning style and comprehension gain scores as they relate to the type of instructional delivery? Hypotheses were that there was no significant difference in achievement by learning style and no interaction between treatment and learning style. When looking at the relationship between students' preferred learning style and achievement, no significant difference in achievement by learning style was found for any of the three measures taken -- pretest [$F(5,274) = 1.125$, $p = 0.347$], immediate posttest [$F(5,274) = 0.707$, $p = 0.619$], or delayed posttest [$F(5,274) = 0.664$, $p = 0.651$]. Learning style alone does not appear to be related to achievement in this study.

However, significant interactions were observed between treatment and preferred learning style in terms of achievement. An analysis of variance found the interaction between learning style and treatment on the immediate posttest was significant [$F(10,269) = 2.11$, $p = 0.024$]. To identify the source of this interaction, separate analyses of variance were performed on the immediate posttest data by learning style for each of the three treatments. The results for the CD tutorial treatment were not significant [$F(5,80) = 0.589$, $p = 0.709$]. Likewise, the results for the microworld treatment were not significant [$F(5,119) = 1.703$, $p = 0.139$]. However, the results for the conventional treatment were significant [$F(5,63) = 2.396$, $p = 0.047$]. To determine which pairs differed significantly, contrast tests were used. These tests showed that the immediate posttest mean score for visual-kinesthetic learners in the conventional treatment ($M = 26.00$) was significantly lower than the mean score for auditory learners ($M = 32.63$), auditory-kinesthetic learners ($M = 35.50$), kinesthetic learners ($M = 34.18$), and visual learners ($M = 34.73$). The computed t-test values are shown in Table 2.

Table 2. T-test Values for Significantly Different Means, Immediate Posttest by Learning Style, Conventional Treatment

Mean Pair	Difference	T	DF	Sig
VK – A	-6.63	2.411	63	0.019
VK – AK	-9.50	2.534	63	0.014
VK – K	-8.18	2.714	63	0.009
VK – V	-8.73	3.026	63	0.004

VK = visual-kinesthetic
A = auditory
AK = auditory-kinesthetic
K = kinesthetic
V = visual

An analysis of variance for the delayed posttest scores by treatment within learning style showed no significant interaction [F(10,269) = 1.047, p = 0.404].

To summarize briefly, the hypothesis of no significant interaction between treatment and preferred learning style was rejected for the immediate posttest scores, but only for the conventional dissection treatment. Visual-kinesthetic learners scored significantly lower on average on the posttest than their peers who preferred either the auditory, auditory-kinesthetic, kinesthetic, or visual learning styles. No such difference existed initially, and it disappeared again at the delayed posttest.

Turning to achievement defined as gain scores, an analysis of variance of the gains from pretest to immediate posttest by learning style and treatment yielded a significant interaction (Table 3). Comparable analyses of gains from pretest to delayed posttest and from immediate to delayed posttest showed no significant interaction.

Table 3. Analysis of Variance, Gain from Pretest to Immediate Posttest by Learning Style and Treatment

Source	SS	DF	MS	F	Sig
Main Effects	141.54	7	20.22	0.850	0.547
LS	101.15	5	20.23	0.850	0.515
Treatment	28.19	2	14.095	0.592	0.554
Interaction	117.64	10	44.77	1.912*	0.017
Residual	6232.86	262	23.79		
Total	8318.84	279	29.82		

*p < .05

Contrast tests revealed the significant interaction of learning style and treatment was attributable to four pairings of scores by learning style preferences within the microworld treatment. Students showing a preference for the kinesthetic learning style achieved significantly lower gain scores (Mean = 8.24) than students with a preference for the auditory learning style (Mean = 10.84; t = 2.29, p = .030). Gain scores for kinesthetic learners were also significantly lower than for auditory-kinesthetic learners (Mean = 10.67, t = 2.10, p = .045) and for auditory-visual learners (Mean = 14.20, t = 3.29, p = .005).

In addition, the mean gain from pretest to immediate posttest among students exhibiting a preference for the auditory-visual learning style (Mean = 14.20) was significantly higher [t = 3.00, p = .010] than the gain for those students preferring the visual learning style (Mean = 9.08). It should also be noted that the gain scores for students with a preference for the auditory-visual learning style approached, but did not quite reach, significance [t = -2.10, p = .058] compared to students demonstrating a preference for the Visual-Kinesthetic learning style (Mean = 10.30).

Based on the preceding analyses, the hypothesis of no significant interaction between learning style and treatment relative to achievement (defined as gain scores) was rejected for some cases within the microworld treatment. Students who preferred the three variations on auditory learning attained the greatest gains, and each of the three was significantly higher than the gain for students with a kinesthetic preference. Students in the auditory-visual group also significantly outperformed those who preferred the visual learning style.

In summary for the third research question and its two hypotheses, the hypothesis of no significant difference in achievement by learning style preference could not be rejected for any of the three measures taken -- pretest, immediate posttest, or delayed posttest. Learning style alone does not appear to be related to achievement in this study. However, the hypothesis of no significant interaction between treatment and preferred learning style was rejected for the immediate posttest scores from the conventional dissection treatment. Here, visual-kinesthetic learners scored significantly lower on average than their peers who showed a preference for any of the other four learning styles. This difference was not found on the pretest and disappeared at the delayed posttest.

When looking at the interaction between learning style and treatment relative to achievement defined as gain scores, the hypothesis was rejected for some cases within the microworld treatment. The greatest gains were reported by students preferring the three auditory learning variations, with each showing a significantly higher gain than students with a kinesthetic preference. In addition, students in the auditory-visual group significantly outperformed those who preferred the visual learning style.

Discussion and Conclusions

A discussion of the results and conclusions based on these results are presented next, based on the broad areas of inquiry defined by the research questions.

Relative Effects on Student Achievement

In looking at the relationship between instructional treatment and gain scores achieved, significant differences were observed. Conventional dissection appears to generate greater learning than the microworld treatment when looking at gains from pretest to immediate posttest. However, no difference was found between the conventional dissection and the CD-tutorial treatment. Therefore, if the desired outcome is immediate gain of knowledge, the preferred delivery system would appear to be either the conventional dissection or the CD-tutorial.

The question is why students within the microworld treatment scored significantly lower than both other treatments. If the hands-on component is thought to provide better encoding of information, then the logical conclusion would be that both the conventional and the microworld treatment groups would outperform the CD tutorial group on the immediate post-test. Perhaps the explanation lies in the findings of Thomas and Hooper (1991). They suggested that the effects of simulations are revealed not by tests of knowledge but by tests of transfer and application. Another explanation can also be offered by looking at the students' experience with the various forms of instructional treatment. All students had previous dissection experience and all students had experience with CD tutorials, albeit not one in which an entire science unit was delivered via this method. However, the microworld environment was completely new to their range of experiences and may have resulted in a lowering of their immediate achievement gain due to unfamiliarity with the format.

When looking at the mean gain score over time, from pretest to delayed posttest, students in the conventional dissection method showed significantly better retention than those in either the microworld or the CD-tutorial treatment. This seems to give the clear advantage to the conventional method of dissection, but this advantage disappears when looking at the gain scores from posttest to delayed posttest. Here the differences favoring the conventional treatment have disappeared, as no one treatment proved to be significantly better for retaining knowledge gained over the long term than either of its counterparts. In other words, the knowledge decrement (Grieve, 1992) was not significantly different across treatments.

When looking at knowledge retained over the long term, this study's results support the view that alternatives to dissection are as effective as the actual practice of physical dissection. This lends support to the National Association of Biology Teachers (NABT) official policy supporting alternatives to dissection and vivisection in the biology curricula wherever possible, as long as those alternatives satisfy the objectives of teaching scientific methodology and fundamental biological concepts. In the debate over animal dissection in the classroom, a number of studies (Downie & Meadows, 1995; Leonard, 1989; Quentin-Baxter & Dewhurst, 1992; Strauss & Kinzie, 1991; Strauss & Kinzie, 1994; Kinzie, Larsen, et al., 1996) have attempted to find suitable alternatives to animal dissection. This study has shown two forms, a CD tutorial and a desktop microworld, to be viable alternatives to physical frog dissection in retaining knowledge gained over the long term.

Relative Effects on the Level of Science Anxiety

When looking at the data from the science anxiety survey given before the start and after the conclusion of the frog dissection unit, the conventional treatment group showed significantly lower levels of anxiety both before and after treatment. While at first glance this appears puzzling, closer inspection reveals two possible explanations.

The first concerns the timing of the unit of instruction and the arrangement of lab facilities. Because the frog dissection unit was conducted at the end of the academic year and this was the first time that two alternatives to conventional dissection were to be offered, the teachers involved needed an uncommon level of coordination to plan use of lab facilities. Unfortunately, these teachers had no common planning period, and therefore coordination of facilities had to occur before and after school, as well as in the halls between class periods. All these discussions took place at times when students may have been present and overheard the planning. This could have resulted in students having an idea of which treatment their class would receive and therefore may have skewed the initial findings of pre-treatment anxiety levels.

A related explanation comes from the experiences of this study's subject pool. The subjects within this study had had previous exposure to dissection activities during their seventh grade life-science curriculum. While these dissection activities were limited to relatively simple exercises in the anatomy of a worm and a squid, the students were familiar with this type of instructional activity. Conversely, the students had received no prior exposure to a unit of instruction delivered entirely through a desktop microworld or a CD-tutorial. Koballa (1993) stated that activity-oriented science instruction can help develop favorable attitudes toward science. Previous exposure to a like activity could have skewed the results of the science anxiety measurements in favor of the physical dissection activity.

When looking at the level of change in anxiety across treatment groups, no single treatment group showed a significantly different change in anxiety compared to the others. Apparently the treatment received had no bearing on change in the level of science anxiety exhibited.

It is interesting to note the relatively low levels of anxiety reported by students across the board. All but one of the mean anxiety level scores fell below 2.00 on a range of possible scores from 1 (Not at all Nervous) through 5 (Very Nervous). This finding may be a result of the timing of the study at the end of a yearlong, seventh-grade, life-science curriculum that stressed active participation by students. This follows the conclusions of Hill et al. (1995) that overall attitude toward science improved significantly when students were engaged in active participation within a seventh grade life-science curriculum over time. This study falls within their call for additional research to focus on particular connections among specific science instructional activities, in this case, approaches to a frog dissection unit.

Examining science anxiety measures by gender revealed some interesting patterns. Females reported significantly higher initial science anxiety than males. After treatment, although anxiety levels declined for both genders, females continued to report significantly higher science anxiety than males overall.

The three treatment groups displayed varying results in anxiety levels by gender. The initial gender difference within the CD-tutorial group was no longer present after treatment, suggesting a beneficial effect for that treatment in reducing female science anxiety. For subjects in the microworld treatment, the difference was not significant either pre-treatment or post-treatment. However, after treatment, the difference in means for males and females did approach significance, with anxiety declining more among males than females. It appears that the microworld treatment was more beneficial for males. Finally, for the conventional dissection group, the difference between genders was significant both before and after treatment. The experience of conventional dissection had no effect on the disparity in science anxiety between males and females.

It is interesting to note that the CD-tutorial treatment seemed to reduce the level of science anxiety more for female students, while just the opposite was occurring within the microworld treatment group as the level of anxiety lowered more for males after treatment. This might be due to the fact that students in the microworld treatment were active participants in their use of the computer and had much more control over the flow of information presented than those students in the CD-tutorial treatment, who merely observed a dissection taking place. Because the microworld group actually performed a frog dissection utilizing representations of dissection tools, they faced the very real possibility of making a mistake in the dissection process. This possibility did not exist for students in the CD-tutorial treatment as they merely watched as the computer performed the various dissection activities. Additional research is needed to pursue the interaction effect of active versus passive role and gender as to levels of anxiety exhibited.

Overall, this study demonstrated that science anxiety is clearly related to gender, which confirms the findings of Wynstra (Wynstra, 1991; Wynstra & Cummings, 1993). Wynstra suggested that in classes that involve activities that could make one squeamish, alternative delivery systems could be used. In this way students would have the option of working with charts, models, or interactive computer software instead of having to dissect once-living creatures such as frogs or pigs. The results of this study support Wynstra's findings.

Our world has rapidly become one based on scientific inquiry that crosses all economic, political, and geographical boundaries. Educators have long called for a fuller, stronger, and more fundamentally sound science curriculum within our schools and the development of ways to encourage students to pursue a scientific career path. Atwater, Wiggins, and Gardner (1995) concluded that the less anxious a student was toward science, the more positive that student was toward the sciences in general. In their review of the research, Koballa, et al. (1990) found that the years 8 to 13 are the critical ages for influencing science attitudes. By understanding what components of a science unit of study produce anxiety amongst students, middle-school teachers can better offset those levels of anxiety with the methods they use to teach science concepts.

This study showed the desktop microworld to be beneficial in reducing the level of anxiety among males while the CD-tutorial helped in reducing female science anxiety. Considering these results, it can be said that technology-based alternatives to conventional frog dissection appear to offer benefits in addressing the science anxiety issue.

Preferred Learning Style and Achievement

The data from this study did not support any claims of a general effect on achievement for the students' preferred learning style. This was true when looking at differences in achievement for pretest scores, posttest scores, and delayed posttest scores. Within this study, learning style alone does not appear to be related to achievement.

It was only when looking at differences in gain scores by preferred learning style within treatment that statistical differences began to emerge. The conventional dissection treatment seems to have the least effect on those students with a preference for the visual-kinesthetic learning style. These students significantly under-performed their counterparts within the same treatment who displayed a preference for the auditory, the auditory-kinesthetic, the kinesthetic, and the visual learning style modalities.

The microworld treatment seems to have particular merit for students who prefer any of the auditory learning style modalities (auditory, auditory-kinesthetic, and auditory-visual) as they outperformed their counterparts with a kinesthetic preference from the pretest to the posttest. In fact, students with a preference for the auditory-visual learning style had the best performance overall of any subgroup in any treatment. They also showed significantly higher gain scores than students within the microworld treatment group who preferred the visual learning style.

Both the conventional dissection treatment and the desktop microworld alternative offered not only visual and auditory channels but also kinesthetic channels in the form of actually participating in the dissection process. However, within the CD-tutorial treatment, students merely observed the dissection take place. The findings of this study support the contention of researchers (Craik & Tulving, 1975; Ellis & Hunt, 1983; Korwin & Jones, 1990) that hands-on activities help to encode knowledge acquired into long-term memory and that knowledge decrement (Grieve, 1992) is less following activities that address all the varying modalities of learning. However, these hands-on activities must not be exclusively kinesthetic, but rather incorporate all modalities of learning.

Limitations Evident Within the Study

Several limitations were evident within this study. They are presented in no particular order, but should be addressed to more fully understand the results of the data obtained.

To assess the preferred learning style of a student, this study was limited to data from the school's study skills teacher. The instrument used to obtain these data allowed for categorizing students into groups reflecting a balance between the three major learning styles: Auditory, Visual and Kinesthetic. This resulted in small numbers of subjects falling into the shared categories of auditory-kinesthetic (12), auditory-visual (30), and visual-kinesthetic (21). Taken by themselves the numbers reflected in these groupings would not pose a problem, however when they were further divided by the instructional treatment received, the numbers in some cases were very small. This occurred most noticeably within the following categories: CD-tutorial treatment and auditory-kinesthetic (2 subjects); CD-tutorial treatment and visual-kinesthetic (6 subjects); conventional treatment and auditory-kinesthetic (4 subjects); conventional treatment and visual-kinesthetic (5 subjects); and microworld treatment and auditory-kinesthetic (6 subjects). Researchers attempting similar future studies should either utilize an instrument for assessing preferred learning style that would not allow for cross-groupings or increase the number of subjects included within the pool to offset the small numbers that might occur in any one group.

This study was conducted at the very end of the school year. Problems inherent with this timing are the built-in distractions to students of end-of-the-year activities, anticipation of summer vacation looming in the immediate future, and attrition due to students leaving school early for family vacations and/or relocation. All these factors can play a role in the level of concentration attainable by students and a reduction in the number of subjects included in the final assessment pool.

As stated previously, the timing of the study left little opportunity for teachers to coordinate the use of facilities. This led to a possibility of students overhearing teachers discussing arrangements during periods of the day when students were present. If this study were to be replicated, care should be given in the discussion of implementation plans to ensure that students are unaware of their treatment group prior to the actual start of the instructional unit.

Another limitation in this study was the makeup of the subject pool. The subjects participating in this study were predominantly Caucasian middle-class suburbanites. Only 2.1% fell within the low-income economic bracket. The racial makeup of the population consisted of 88% White, 7.6% Asian/Pacific Islander, 1.7% Black, 2.4% Hispanic, and 0.3% Native American. In addition, students classified as Limited-English-Proficient comprised only 2.3% of the school population. Taking all this into consideration, the results of this study cannot be extrapolated to the general populace, only to those populations with a similar makeup.

Suggestions for Further Research

In the course of conducting this study and in the analysis of the data collected, many questions arose that provide a varied base for further research. In order to offset the effects of previous experience on the levels of science anxiety reported, studies should be conducted comparing the various instructional treatments using a hands-on activity earlier in the year. It would be necessary to limit the subject pool to those students who had no experience in completing a scientific unit of study through conventional dissection, desktop microworld or CD-tutorial. It would also prove valuable to conduct ethnographic studies to provide insight into particular connections between science instruction, science attitudes, science achievement, and cultural background for groupings such as Asian-American students and African-American students.

The studies of Ester (1994-1995) and Messick (1976) revealed a significant interaction between instructional approach and student learning style. This study supports those findings in the case of the microworld treatment but not for the conventional treatment or the CD-tutorial treatment. The question that naturally follows is, why didn't the pattern that appeared within the microworld treatment also appear within the conventional treatment, if both treatments incorporated all the modalities of learning within their environments? Further research in this area is needed in order to answer that question.

Addressing the gender issue in regards to the level of science anxiety displayed, several questions for future research emerge. If females exhibit a higher level of science anxiety overall than males during the middle-school years, will that difference increase, decrease, or remain the same in subsequent years? And if there is a change, what are the forces that cause that change? A follow-up study of the subjects within this study as they progress through high school could shed light on what influences science anxiety differences among males and females.

The belief that the effects of simulations are not revealed by tests of knowledge but rather by tests of transfer and application suggests further study. How would the microworld treatment compare with the CD-tutorial treatment if observations were made on the students' performances in later dissection procedures or life-science exercises?

The level of retention from posttest to delayed posttest bears a closer look in future research. While most tests within the school curriculum are geared toward immediate achievement gains, the goal of most educational institutions is to help students not only learn but to retain that which they have achieved. This leads to the following questions. Once knowledge is gained, how much is lost over time? And which methods of instructional delivery help the most in the retention of that knowledge? Further research into these areas is a must if we are to attain an educated populace.

There is a definite need for more research in the area of desktop microworlds. With access to the World-Wide Web increasing throughout our schools, spurred on by government initiatives, questions arise as to what can be done with all the information so readily available once it is accessed. This is particularly true for multimedia elements such as digitized pictures, sound and movies. Desktop microworlds composed of these downloaded elements and run by shareware programs offer a relevant and easily upgradable instructional environment. There are then many questions concerning these desktop microworlds and their role in the instructional process. How best can they be incorporated into today's learning environments? Will they be effective vehicles for information transfer for all students? Are they more effective if created by students for students? Do they allow for student control over the pacing of information flow and the pathways followed? If so, do they allow for the molding of the program to the student's preferred learning style? Just how do teachers and students interact with a microworld to gain the greatest benefit?

References

Atwater, M. M., Wiggins, J., & Gardner, C. (1995). A study of urban middle school students with high and low attitudes toward science. Journal of Research in Science Teaching, 32(6), 665-677.

Bednar, A. K., Cunningham, D., Duffy, T. M., & Perry, J. D. (1991). Theory into practice: How do we link? In G. Anglin (Ed.), Instructional technology: Past, present and future. Denver, CO: Libraries Unlimited.

Black, J. B., & McClintock, R. O. (1995). An interpretation construction approach to constructivist design. In B. Wilson (Ed.), Constructivist learning environments (pp. 137-157). Englewood Cliffs, NJ: Educational Technology Publications.

Craik, F. I. M., & Tulving, E. (1975). Depth of processing and the retention of words in episodic memory. Journal of Experimental Psychology: General, 104(3), 268-294.

Cunningham, D. J., Duffy, T. M., & Knuth, R. A. (1993). The textbook of the future. In C. McKnight (Ed.), Hypertext: A psychological perspective. London: Ellis Horwood.

Downie, R., & Meadows, J. (1995). Experience with a dissection opt-out scheme in university level biology. Journal of Biological Education, 29(3), 187-196.

Duffy, T. M., & Jonassen, D. H. (Eds.). (1992). Constructivism and the technology of instruction: A conversation. Hillsdale, NJ: Lawrence Erlbaum Associates.

Ellis, H. D., & Hunt, R. R. (1983). Fundamentals of human memory and cognition (3rd ed.). Dubuque, IA: Brown.

Ester, D. (1994-1995). CAI, lecture, and student learning style: The different effects of instructional method. Journal of Research on Computing in Education, 27(Winter 1994-1995), 129-140.

Grieve, C. (1992). Knowledge increment assessed for three methodologies of teaching physiology. Medical Teacher, 14, 27-32.

Heller, R. (1990). The role of hypermedia in education: A look at the research issues. Journal of Research on Computing in Education, 22(2), 431-441.

Jonassen, D. H. (1989). Hypertext/hypermedia. Englewood Cliffs, NJ: Educational Technology Publications.

Jonassen, D. H., Campbell, J. P., & Davidson, M. E. (1994). Learning with media: Restructuring the debate. Educational Technology Research and Design, 42(2), 31-39.

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., Larsen, V. A., Burch, J. B., & Baker, S. M. (1996). Frog dissection via the World-Wide-Web: Implications for widespread delivery of instruction. Educational Technology Research & Development, 44(2), 59-69.

Koballa, T. R. (1993). Synthesis of science attitude research for elementary grades. Paper presented at the 1993 annual meeting of the National Association for Research in Science Teaching, Atlanta, GA.

Koballa, T. R., Crawley, F. E., & Shrigley, R. L. (1990). A summary of research in science education-1988. Science Education, 74(3), 252-407.

Korwin, A. R., & Jones, R. E. (1990). Do hands-on, technology-based activities enhance learning by reinforcing cognitive knowledge and retention? Journal of Technology Education, 1(2), 26-33.

Lamb, A. C. (1991). Emerging technologies and instruction: Hypertext, hypermedia, and interactive multimedia: A selected bibliography. Englewood Cliffs, NJ: Educational Technology.

Langley, G. R. (1991). Animals in science education -- Ethics and alternatives. Journal of Biological Education, 25(4), 274-279.

Lebow, D. (1993). Constructivist values for instructional systems design: Five principles toward a new mindset. Educational Technology Research & Development, 41(3), 4-16.

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.

Maurer, H. (Ed.). (1993). Educational multimedia and hypermedia annual, 1993: Proceedings of ED-MEDIA 93 -- World Conference on Educational Multimedia and Hypermedia. Charlottesville, VA: Association for the Advancement of Computing in Education.

Messick, S. (Ed.). (1976). Individuality in learning. San Francisco: Jossey-Bass.

Orlans, F. B. (1988). Debating dissection. The Science Teacher, 55, 36-40.

Papert, S. (1980). Mindstorms: Children, computers, and powerful ideas. New York: Basic Books.

Piskurich, G. M., (1993). The ASTD handbook of instructional technology: American Society for Training and Development. New York: McGraw-Hill.

Quentin-Baxter, M., & Dewhurst, D. (1992). An interactive computer-based alternative to performing a rat dissection in the classroom. Journal of Biological Education, 26(1), 27-33.

Resnick, L. (Ed.). (1989). Knowing, learning, and instruction. Hillsdale, NJ: Lawrence Erlbaum Associates.

Rieber, L. P. (1996). Seriously considering play: Designing interactive learning environments based on the blending of microworlds, simulations, and games. Educational Technology Research & Development, 44(2), 43-58.

Spiro, R. J., & Jehng, J. (1990). Cognitive flexibility and hypertext: theory and technology for the nonlinear and multidimensional traversal of complex subject matter. In D. Nix & R. Spiro (Eds.), Cognition, education, and multimedia: Exploring ideas in high technology. (pp. 163-205). Hillsdale, NJ: Lawrence Erlbaum Associates.

Strauss, R. T., & Kinzie, M. B. (1991). Hi-tech alternatives to dissection. The American Biology Teacher, 53(3), 154-158.

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.

Surry, D. W. (1997). Diffusion theory and instructional technology. Instructional Technology Research Online. [On-line]. Available: http://intro.base.org/docs/diffusion/, February 20, 1997.

Thomas, R., & Hooper, E. (1991). Simulations: An opportunity we are missing. Journal of Research on Computing in Education, 23(4), 497-513.

Wang, S., & Sleeman, P. (1993). Computer-assisted instruction effectiveness: A brief review of the research. International Journal of Instructional Media, 20(4), 333-348.

Wilson, B., Teslow, J., & Osman-Jouchoux, R. (1995). The impact of constructivism (and postmodernism) on ID fundamentals. In B. B. Seels (Ed.), Instructional design fundamentals: A review and reconsideration (pp. 137-157). Englewood Cliffs, NJ: Educational Technology Publications.

Wise, K. C., & Okey, J. R. (1983). The impact of microcomputer-based instruction on student achievement. Paper presented at the Annual Meeting of the National Association for Research in Science Teaching, Dallas, TX: April, 1983.

Wynstra, S. (1991). A study of high school science anxiety including the development of a science anxiety instrument. Unpublished doctoral dissertation (Doctoral Dissertation, Northern Illinois University, 1991). Dissertation Abstracts International, 53-01A, 0116.

Wynstra, S., & Cummings, C. (1993). High school science anxiety. Science Teacher, 60(7), 18-21.

NOTICE

REPRODUCTION BASIS

☒ This document is covered by a signed "Reproduction Release (Blanket) form (on file within the ERIC system), encompassing all or classes of documents from its source organization and, therefore, does not require a "Specific Document" Release form.

☐ This document is Federally-funded, or carries its own permission to reproduce, or is otherwise in the public domain and, therefore, may be reproduced by ERIC without a signed Reproduction Release form (either "Specific Document" or "Blanket").