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A Comparison of OnLine Pre-Laboratory Simulations to Traditional Text Methods in an Inquiry-Based High School Biology Course

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A COMPARISON OF ONLINE PRE-LABORATORY SIMULATIONS TO TRADITIONAL TEXT METHODS IN AN INQUIRY-BASED HIGH SCHOOL BIOLOGY COURSE

By

Clarence E. Rudat

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Abstract

A COMPARISON OF ONLINE PRE- LABORATORY SIMULATIONS TO TRADITIONAL TEXT METHODS IN AN INQUIRY-BASED HIGH SCHOOL BIOLOGY COURSE

By

Clarence E. Rudat

The purpose of this study was to compare the effect of web-based computer simulation activities to traditional text methods in preparing inquiry-based laboratory activities in high school biology classes. Students' attitudes were evaluated as well as their knowledge of material and understanding of the scientific method. Ease of implementation of the wet-laboratory was evaluated with both methods. Seventy-six sophomore students in four biology classes from a small rural Michigan high school participated in the study. Subjects were assigned to either web-enhanced instruction or a text-based handout with the same information. The web-enhanced instruction group used the commercial web site *Biology.com* to develop constructivist-based laboratories patterned after the Advanced Placement Biology Laboratory Manual. The control group received the same information on text-based handouts. Both groups were assessed using the Process of Biological Inquiry Test (PBIT) and a comparison of pretest/posttest results were used to determine the effectiveness of each method.

This study showed that on average there was an eight percent higher increase in post-test scores of the web-based group when comparing the two methods. The findings suggest that students, while initially hesitant to engage in the constructivist web-enhanced instructional method, prefer the web-based approach to the traditional text method. Web enhanced instruction (WEI) is using computers and web-based courseware to enhance the traditional face-to-face classroom environment by exposing students to content-specific information delivered over the internet.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

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Chapter 1

Background

The U.S. Commerce Department announced that internet traffic is doubling every 100 days (Abernathy, 1999). The use of computers and web-enhanced instruction (WEI) has dramatically increased in the past five years. This remarkable expansion has provided new potential for teachers to enhance instruction and for students to learn and obtain information (President's Committee of Advisors on Science and Technology, 1997).

Computers and the internet are increasingly available as a delivery platform for educational resources. In 1999, 95 percent of public elementary and secondary schools had internet access (NCES 2000–086), and 78 percent of students in grades 1–12 reported using the internet at school (Indicator 45, *The Condition of Education 2000*). Despite students' apparent familiarity with computers, only one-third of teachers in 1999 reported feeling "well prepared" or "very well prepared" to use computers or the internet for instruction (Indicator 39, 2000).

The use of the internet for instruction has not kept pace with the technology in part because software developers and educational publishers have been slow to catch up with the changing infrastructure provided by the Telecommunications Act of 1996. Most uses of the internet and WBI in schools are informational in nature. The highly rated Yuckiest Site on the Internet, <http://yucky.kids.discovery.com/>, Cells Alive! <http://www.cellsalive.com/>, and University of Arizona's Biology Project <http://www.biology.arizona.edu/> are all valuable internet sites limited to use as an informational resource. At best these sites provide limited graphics, animations, databases, and demonstrations. So much of the internet has been informational in nature that teachers and experts in the field refer to the use of the internet as information technology and telecommunications (Barron, 1999, p7). Given this information the question of how to effectively use internet based activities with the constructivist theory of learning needs to be explored.

Many science teachers, educators, and researchers have proposed employing computer-assisted instruction (CAI) and web-enhanced instruction (WEI) in the science classrooms. While CAI and WEI both use computers to deliver instructional programs according to the pace and characteristics of the student, CAI uses program software either on the computer hard drive or is accessed through CD-ROM while WEI is delivered via the internet. However, contradictory findings on the comparative effectiveness of CAI versus traditional instruction are found in the literature of science education research. Technological advancements are occurring at such a rapid pace that researchers are having a difficult time collecting useful data to test the effects of these new tools. (Gallini and Barron, 2001)

Some studies concluded that CAI was effective in improving students' science and mathematics achievement or problem-solving skills (e.g., Ferguson and Chapman, 1993 [biology]; Hughes,1974 [physics]; Levine, 1994 [general science]; while other studies (Weller 1996, 1997), noted that over one-third of the studies reported little or minimal advancement of science learning as a consequence of computer use. More importantly, Weller added that most of the studies "did not aim to investigate comprehension in the products and processes of science" (1996, p. 5).

Other studies have focused the use of specific types of CAI such as interactivity or animation. Studies by Baek and Layne (1988), Mayton (1991), Rieber (1990), and

Szabo and Poohkay (1996), indicate increased achievement in CAI from the use of animation with both adults and children. These studies used pre-test/post-test assessment methods and focused on learning relative to static graphics and text-based instruction delivered by CAI rather than the effectiveness of the CAI method compared to traditional learning methods.

Bell (1998) notes that "it is still far too common for technological and curricular innovations to be brought into schools without it being a research-minded or research-informed endeavor" (p. 3). Technology can provide the means for enhancing students' learning but a sound theoretical basis for teacher and student action is necessary if technology is to be put to such productive use (Salomon & Almog, 1998).

Thomas (2001) noted, however, that "longer-term investigations using predominantly qualitative data collection and fine-grained analysis have yielded rich information and provided insights into the ways teachers and students use and interact." Only by active research can teachers get a real picture of the learning that is taking place from technology due to the complexity of the multiple variables that interact in a classroom. Teaching in a passive learning environment using technology will likely produce results typical of the passive setting whereas an active learning environment using technology will likely produce results typical of an active setting. (Peck, 2002) reports that when teachers do employ technology:

> "It usually supplements a familiar, teacher-centered repertoire-lecture, class discussion, textbook-based assignments and factual transmission . . . which most often employ computers as low-end instructional devices that allow students to type final drafts of essays or to conduct an internet search."

It is apparent that teachers utilizing computers to successfully provide development of critical and higher-order thinking skills will need to change their perception of how students learn effectively. Van den Akker et al. (1992) suggested that successful integration of computers into schools would require teachers to deepen their understanding of the potential for computer use in classrooms, to learn new instructional strategies, and to revise their beliefs regarding how students learn.

These are not the only hurtles for effective integration of computers into classrooms. The time necessary to implement instructional technology is hard to find. Additionally, student-centered active learning is difficult in a 50-minute class period. Not only is time a factor in searching for appropriate, relevant websites, and other computer based activities, but limited resources are available for professional development, training and courseware.

The challenge for schools is not in acquiring computers or obtaining connections, but in finding meaningful and useful content and/or instruction. Although most teachers know how to do word processing or even search the internet, they don't have any concept about how to truly integrate technology into their teaching (Molenda, 2002). Teachers need to consider pressure from policy makers who approve million-dollar technology grants as they enthusiastically endorse standardized tests, which, in the view of many educational researcher, seldom encourage or reward computer use (Peck, 2002). Concerns from parents, teachers, and students over access to colleges, based on high performance on standardized tests of recognized skills and facts, often lead to a dependence on traditional instruction (McLaughlin & Talbert, 1993).

Peck further states that, 'administrators dutifully equip their schools with expensive equipment, while raising graduation rates and improving test scores still remain their central concerns' (p.480). Rowan (1990) suggests teachers' success, if it is measured at all, is typically determined by their students' standardized test scores. Success on such tests usually requires more knowledge of facts than it does higher-ordered thinking. It is easier for teachers to teach to the test than teach the valuable problem-solving and critical thinking skills that come with active leaning. A growing emphasis on standardized tests often influences teachers' practices--sometimes they alter subject matter to teach to the test, or use didactic methods in order to "get through" material quickly.

Constructivist teaching, by contrast, is difficult and time-consuming (McLaughlin & Talbert, 1993). In the constructivist theory, the emphasis is placed on the learner or the student rather than the teacher or the instructor. It is the learner who constructs his/her own conceptualizations and solutions to problems. Understanding is greater and new learning more lasting if learners are active builders of knowledge structures and constructors of meaning, rather than passive recipients of information transmitted to them by teachers. A constructivist approach to staff development models constructivist teaching, where instructors guide and facilitate rather than tell or dictate. (Oates, 2001) "To understand is to discover, or reconstruct by rediscovery, and such conditions must be complied with if in the future individuals are to be formed who are capable of production and creativity and not simply repetition." (Piaget 1973)

According to the National Association of Secondary School Principals (NASSP) and the Carnegie Foundation: "Teachers should prepare themselves to offer courses that take advantage of methods that depend less on the teacher as purveyor of all wisdom... Teachers should be adept at acting as coaches and as facilitators of learning to promote more active involvement of students in their own learning." (NAASP, 1996, pp. 22-23).

The methods used in the traditional classroom have long been a concern. Dewey (1902) claimed that "classrooms typically consist of teachers presenting the "right" way to solve problems (or even the "right" solution). Knowledge, in this situation, is symbolic and isolated; this type of learning does not typically motivate students or provide them with problem-solving skills they can apply to other situations." High-school classrooms for most of this century have used these traditional methods (Boyer, 1983; Goodlad, 1984; Powell, Farrar, & Cohen, 1985), and many still do. Meaningful learning is an active, rather than passive, process of knowledge construction. (Conley, 1993)

Computers have been used to try to bridge the gap between traditional learning and a meaningful, active learning process. Several factors have developed simultaneously to alter the emphasis of computers in learning. First, the convergence in digital technology has provided user-friendly multimedia instructional platforms. Secondly, the emergence of a cognitive learning theory that emphasizes inquiry surfaced. Thirdly, changes in the needs of society, whereby the work-force of tomorrow needs to be encouraged to have the skills of abstraction, system thinking, experimentation, and collaboration. (Awbrey, 1996)

It is not difficult to see the dilemma many science teachers face. Should teachers take the time to explore new technology methods? Are CAI and WEI compatible to the goals of effectively teaching science with a constructivist approach? The goal of teaching science is summed up by Germann (2002):

> "Our task as teachers is to help students make sense of science. This means that their learning must be meaningful. The science must be meaningfully connected to their prior knowledge and experience, meaningfully explain natural phenomena around them, and meaningfully integrated and assimilated into their mental knowledge frameworks. Science with this kind of depth is useful in understanding the world they move in and solving problems they encounter. This must be the goal of science learning." (Germann, 2002)

Most teachers realize the need to encourage critical thinking and to develop constructivist learning environments. However, our current system of education encourages gathering facts and following set procedures. Information technology and the internet have been an extension of that system. Follansbee et al. (1998) found that teachers who integrated telecommunications into their curricula were more likely to use computers with their students to enhance achievement through gathering, organizing, and presenting information. The National Sea Grant Non-indigenous Species web site on the spread of Zebra Mussels <www.sgnis.org/av/zmmap.htm> and the UW-River Falls wolf tracking site <www.uwrf.edu/biology/bergland/wolfproject01.htm> allow students to gather specific information, place it into a spreadsheet using a program like Microsoft Excel, and present the graphical information to a class using a program like PowerPoint. The internet is extremely efficient at providing access to information that would not otherwise be available in classrooms but inquiry, creativity, and critical thinking skills are usually not addressed.

Jones and Paolucci (1997) argue that claims for the influence of technology in education, while substantial, is largely unfounded and serious consequences may result if teachers continue to use technology in limited methods. Few suggestions have been made as to how to measure the effects of web-based instruction on student creativity or inquiry that would enhance active learning of the scientific process.

However, there is significant research indicating that WEI can positively affect student attitudes and motivations. For example, Chiu (1996) found that tenth-grade students who used network resources in science demonstrated significantly more positive attitudes toward both school and science. The challenge is to use the motivation that WEI can provide to help students develop critical thinking and analytical skills that will benefit them in learning science.

For schools to prepare students for the rapidly changing technological society the educational system must provide students with the skills that will enable them to think critically and creatively. Educators need to engage students in scientific problem solving by facilitating an environment that teaches students not only to think, but to think creatively (Olson, 1974). Programs like Access Excellence's Science Mystery Spot <http://www.accessexcellence.org/AE/mspot/> encourage students to use high-order thinking to solve a particular mystery using a case study scenario. WEI can use an open inquiry approach with a case study were students would review a scenario then use the scientific method to develop a wet-lab that would test a specific hypothesis.

One of the most highly rated incentives for using telecommunications with students is increasing students' inquiry and analytical skills (Honey and Henriquez 1993). There are few data to support this strategy. In reality, success of the WEI may be dependent more on the methods and approach used by the teacher when using computers than in the content of the information.

CAI and WEI are becoming popular methods of instruction for many teachers. This is due in part because commercial companies offer software that can be obtained inexpensively relative to hands-on lab equipment. Digital Frog International is offering a number of virtual field trips such as The Rainforest using adaptive technology as well as more traditional virtual dissections. Cyber Ed Inc. <http://www.cybered.net/>, is offering an extensive library of science software that is interactive, allowing students to try differing variables in a virtual laboratory.

Publishing companies are developing electronic textbooks on CD-ROM and internet based textbooks like iText to enhance the traditional textbook. Glencoe/McGraw-Hill is now offering a free on-line database called Biolab <http://www.glencoe.com/sec/science/biology/bio2000/chapter9/interbio.shtml> where students submit lab data to the internet which is posted to the site and can be viewed by other students from around the country. Other free database sites such as the Global Rivers Environmental Education Network (GREEN) <http://www.green.org/> are sponsored by corporations or foundations. The interactivity of these programs opens new windows to interaction with students from all over the world, allowing students to keep current on events and activities that would not be available to them with out the internet.

While these innovations are helpful with their immediate feedback, digital audio/visual capabilities, and interactive tutorials, most simulation software falls short of providing for creative inquiry-based experiences. There is a considerable amount of research that supports the idea that computer simulations make little or no difference in the acquisition of knowledge. There is speculation by some researchers that computer simulations may have a positive effect on creativity (Betz, 1996). However, these researchers offer no empirical evidence to support that claim. Jones and Paolucci (1997) estimate that less than 5% of published research is sufficiently empirical, quantitative and valid to support conclusions with respect to the effectiveness of technology in educational learning outcomes.

Hargrave (2001) does offer promising research into the effective use of WEI when used for pre-instructional simulations by giving students opportunities to a) explore science phenomena, b) test ideas, c) develop interest in the topic, and d) generate questions. Other research asserts that students using pre-instructional simulations have a more personal understanding of the content and are more prepared to assume cognitive-active learning roles in making sense of the content. (Brant, Hooper, & Sugrue, 1992)

As numerous forms of CAI like WEI become increasingly popular in the classroom, educators must examine the effectiveness of the technology as an educational tool that promotes critical thinking in the biology lab and classroom. Educators need to develop effective methods of integrating technology into the biology curriculum if the preconceived advantages of technology will be realized. The technology should augment what is taking place in the classroom, not attempt to replace it.

> "Substantial investment in hardware, infrastructure, software, and content will be largely wasted if K-12 teachers are not provided with the preparation and support they need to effectively integrate information technologies into their teaching."
>
> -- Report to the President on the Use of Technology to Strengthen K-12 Education in the United States, 1997

Purpose of Study

The purpose of this study was to compare the effects of a web-based pre-laboratory simulation to a text-based pre-laboratory preparation in an active learning environment. This study of WEI in the biology classroom is necessary to determine how effective the WEI technology is in developing problem solving and critical thinking skills when used as a tool to support the facilitation of student understanding and creative use of the scientific process when preparing laboratory exercises.

This study will attempt to provide a valid insight into using WEI to meet the demands of good science teaching while balancing the perceived needs of policy makers, students, parents, and administrators. This study will also attempt to answer the hard question -- by using new computer technologies in science, are we doing something different, or the same thing differently? (Galas 1997)

Significance

WEI can be used in a number of ways. For the purposes of this research WEI uses an inquiry approach based on the constructivist theory of learning. The inquiry approach supports the objectives of WEI. Research shows that there are many indicators of effectiveness for using inquiry as a basis for laboratory exercises. These indicators include conceptual understanding of science principles, comprehension of the nature of scientific inquiry, and a grasp of application of science knowledge to societal and personal issues (Anderson, 2002). In addition, computers enable students to take more responsibility for their learning (Ronen & Eliahu, 1998).

Not all teachers, parents and policy makers are convinced, however, that these objectives are as important as more specific knowledge and facts. In meeting the challenges of the "more is better" mentality in an information society, educators are pushed to prepare students for a variety of standardized tests, which in most cases assess a very basic level of knowledge. With the advent of the Michigan Virtual High School by Michigan Governor John Engler and the Michigan Economic Development Corporation, the focus of technology education has become more towards information technology (Engler, 1998) than technology as a tool for high-order learning. In fact, the Michigan Virtual High School proudly claims that what it provides to students and parents is ". . . a way to build technology skills and tools that help them succeed on high-stakes, standardized tests." (Michigan Virtual High School, 2002) In Michigan, students are awarded a $2,500 scholarship incentive to take and pass the standardized High School Proficiency Test.

It is evident that CAI plays an important role in teaching and learning of science concepts. The *Benchmarks for Science Literacy* (American Association for the Advancement of Science [AAAS], 1993, p. 18) specifically state that "Computers have become invaluable in science education because they speed up and extend people's ability to collect, store, compile, and analyze data, prepare research reports, and share data and ideas with investigators all over the world." Use of word processors, spreadsheets, databases, e-mail, web publishers, and presentation software as well as the advancement in hardware and connection capabilities has provided science educators with capabilities that were unheard of just a decade ago. Recent science education standards in the United States describe instructional technology as "technology that provides students and teachers with exciting tools—such as computers—to conduct inquiry and to understand science" (National Research Council [NRC], 1996, p. 24). The constructivist theory of learning applied to WEI is an attempt to take advantage of these tools to foster quality learning environments in science education.

Hypotheses

If using WEI with the constructivist theory of learning is an effective method of developing problem solving and critical thinking skills of students by promoting higher order cognitive learning; and if students use WEI as pre-laboratory simulations for lab preparation verses a text-based lab preparation method in a constructivist approach, then students using WEI would:

1. Improve overall understanding of the scientific method.
2. Spend less time preparing for the lab.
3. Become more efficient with the time spent in the wet-laboratory setting.
4. Show more interest in the wet-lab and be more motivated.
5. Make fewer mistakes in executing the lab exercises.
6. Improve understanding and application of general scientific concepts.
7. Improve understanding of content.

Assumptions

This study was based on these assumptions:

1. Students in this study were representative of tenth grade biology students in West Michigan.
2. Socioeconomic status, intelligence, creativity, and computer literacy were equally distributed among students and did not contribute to the results.

3. Students in the control group did not access computer-based information from students in the treatment group, who had access to this information

Limitations

This study was conducted with the following limitations in mind:

1. Although students in the treatment group were requested to access computers and the internet only during class, the computer accessibility at home could not be monitored.
2. Computer speed and accessibility to the internet should be taken into consideration. Students in the treatment group that had slower computers and/or had technical problems spent more time accessing information due to the limitations of the technology.

The control group was the group of selected students who do not receive web-enhanced instruction (WEI), but did have text-based instruction. The treatment group (experimental group) is the group of selected students who received WEI. Active learning methods based on the constructivist theory were used in both the treatment and control groups.

Implications

Practical implications of this research are connected to collaborative action research (Shymansky & Kyle, 1992), where research results help teachers reflect and improve on their practices of teaching science. Information gathered in this study will be used to refine teaching methods the instructor uses in students' lab preparations. Results will be used in collaboration with science teachers in Montague and teacher/researchers participating in laboratory intensive summer research sessions at Michigan State

University. The National Science Teachers Association (1990) acknowledges reflective thinking as the central element of the action research process. Teachers participating in action research become more critical and reflective about their own practice (Oja & Pine, 1989). Reflecting on the discoveries made and the situations that arose during the course of this research allowed for refinement of the WEI process to take place.

Chapter 2

Methodology

Participants included seventy-six 10th grade high school students attending four biology classes and a biology teacher (the author) who taught the above classes at a modern rural public high school of 460 students located in the West Michigan. Ninety six percent of the district population is white with an average household income of $28,670. (United State Census, 1990) There was one Hispanic student and one special needs student confined to a wheelchair. These students were typical of 10th graders; with a mean age of 16. Class periods were 50 minutes long with an academic support period (ASP) each day. Academic support period is a 40 minute period where students can make up lab work, homework, get additional assistance from teachers, or use a computer lab. Students primarily used two sources for information during the study. The Biology Place was used as a web-based source and the text Modern Biology was used for non-web-based materials.

There were two groups of students that alternated between being the control and treatment groups. Group A consisted of 40 students in two class periods while group B consisted of 36 students in two class periods.

Students were active learners in that they were responsible for constructing laboratory exercises based on specific information as opposed to following set of "cookbook" procedures in conducting lab experiments. While developing activities, students followed guidelines given by the instructor based on the AP biology lab manual.

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Research Design

The author developed a number of hypertext activities (Figure 1) that were developed for web-based activities that loosely mirrored the commercial site developed by The Biology Place. The activities were placed on the schools web server and accessed by students from school computers. The activities developed centered on a study of the biotic and abiotic factors of the area surrounding the high school with an emphasis on microorganisms of forest communities. (Appendix C)

Figure 1 - Example of Instructor Developed WEI

A number of difficulties developed with these instructor-designed sites. The school administration claimed ownership of these materials once placed on the school's server. After reaching an agreement, the school's entire sever was lost during a power surge. The entire network was not available for a month. The biggest problems arose when students started working with these instructor-developed WEI. The first WEI exercise was fungal culture and abundance. The serial dilution pre-lab materials for the text-based control group were too vague and students couldn't comprehend the concept without the instructor walking them though step by step.

The algae lab (see Appendix C) was more successful. However, this time the students using the WEI found themselves not being able to get back to the original web site because they had followed connecting links outside the site. Students spent too much time exploring links that took them outside the original site. Students also had problems accessing programs to which the site had taken them because the appropriate plug-in or software was not installed on their computer. After two failed attempts the instructor decided that using the commercially produced site *The Biology Place at Biology.com* would be much more effective at producing consistent results.

About *Biology.com*

This site was selected for pre-lab information based on the ease of use, consistency of format, and the constructivist methods of presenting information to students. The commercial site provided background information (key concepts), a description of what was going to happen (design), a simulation of results (analysis) and assessment (Figure 2). Tips for using proper laboratory and safety procedures as well as hints to help formulate a successful experiment were among other attributes of the site.

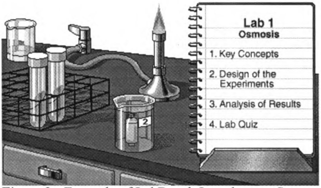


Figure 2 - Example of LabBench Introductory Screen

Pre-lab topics were presented in a format called LabBench activities at the secure web-site *Biology.com,* published by Peregrine Publishers. There is a subscription fee for each student, thereby limiting access. Animations and interactive questions within the site are designed to help students connect laboratory procedures to the biological principles that they are studying. Laboratory investigations included an overview of laboratory procedures and provided for opportunities for experimental design.

Laboratory topics were chosen to correlate to the units covered in class. Since these labs are based on the AP Lab Manual, the topics selected were based on students ease of use, understanding of material, background knowledge of the subject and experience. The set of lab activities in this study is structured after and coordinated with the Advanced Placement biology laboratory program (College Board, 2001). Topics covered were:

(AP Lab 4) Plant Pigments - Chromatography

(AP Lab 1) Diffusion & Osmosis

(AP Lab 12) Animal Behavior

(AP Lab 5) Cell Respiration

(AP Lab 10B) Cardiovascular Fitness

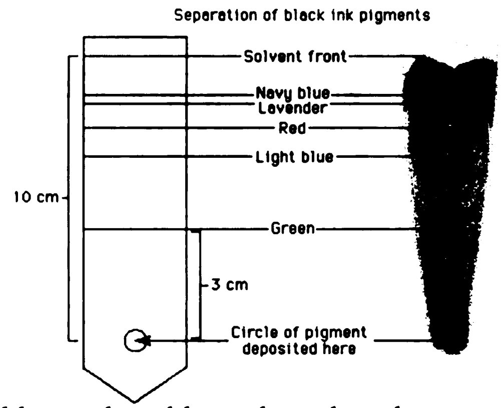
(AP Lab 10C) Heart Rate in *Daphnia*

Key Concepts - The web site *Biology.com* provided students with the background information on the specific subject being designed under a heading called key concepts and included links to definitions of key terminology (Figure 3).

Key Concepts I: Plant Pigment Chromatography

Paper chromatography is a technique used to separate a mixture into its component molecules. The molecules migrate, or move up the paper, at different rates because of differences in solubility, molecular mass, and hydrogen bonding with the paper.

For a simple, beautiful example of this technique, draw a large circle in the center of a piece of filter paper with a black water-soluble, felt-tip pen. Fold the paper into a cone and place the tip in a container of water. In just a few minutes you will have tie-dyed filter paper!



The green, blue, red, and lavender colors that came from the black ink should help you to understand that what appears to be a single color may in fact be a material composed of many different **pigments** — and such is the case with **chloroplasts**.

Figure 3 - *Key Concepts* Portion of the Chromatography Section

Design --The design portion of the web site gives an overview of what will be happening in the experiment. From the information, students used the scientific process to develop a testable hypothesis and appropriate protocol. This format allowed students to identify what problem was being tested and then develop hypotheses along with the methods to test their predictions (Figure 4).

Exercise 1: Diffusion
In this activity, you fill a dialysis bag with a sugar/starch solution and immerse the bag in a dilute iodine solution. Water, sugar, starch, and iodine molecules will all be in motion, and each molecule will move to a region of its lower concentration, unless the molecule is too large to pass through the membrane. Your task is to determine relative size of the various molecules and gather evidence of molecular movement.

Hint: One piece of information that will help you is to recall that when iodine comes in contact with starch, it changes from an orange-brown color to blue-black.

Figure 4 - Example of the design portion of the diffusion lab exercise.

From the description of the activity, students would identify what was taking place, derive the 'if' or 'action' part of the hypotheses and build a protocol around a testable hypothesis based on their prior knowledge and understanding. This part of the exercise would also provide hints to students about prior experiences that would help them develop a successful protocol. These hints were printed with the text-based method as well. Laboratory partners would consult with one another to obtain a consensus as to the protocol they would use while still attempting to solve their individual hypothesis.

Students then proceeded to the next part of the web-site which provided them with simulation activities. This part of the site provided animations and interactive questions that provided students with opportunities to replay specific examples until they felt comfortable with the concept. Students could also attempt to answer question related to the content and get immediate feed back from there answers along with a review of the text and or animation (Figure 5).

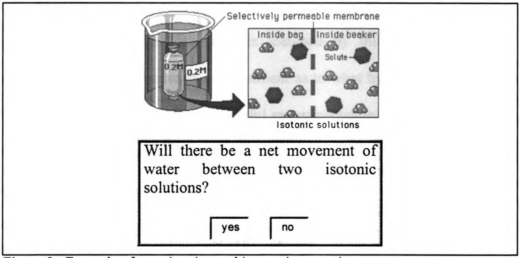


Figure 5 - Example of an animation and interactive question.

A pretest–posttest (Appendix A), control-group design was used for each laboratory activity. The participants in both groups were tested before and after each laboratory exercise. Six laboratory exercises were used in the research. Each group participated as the experimental group for three labs and as the control group for three labs. The experimental group of students used the web-based biology.com to prep laboratory exercises whereas the control group of students received a copy of the same information only printed directly from the computer without any supplementary computer or web-based instruction. The print version was a black and white photo copy that looked like the computer version only lacking in animation and interactive tutorials. Permission was granted by the publisher to use the printed versions.

Both groups received equal amounts of instructional time and were taught the same content material. Instructional time given to complete each assignment was strictly controlled to class time and academic support time to assess the amount of time it would take to complete each method.

Lab Preparation

Students worked with lab partners assigned by the teacher to discuss the laboratory preparation and come to an agreement as to what hypothesis would be tested and the methods used to conduct a successful experimentation. Each lab protocol to be completed after the pre-lab included the following:

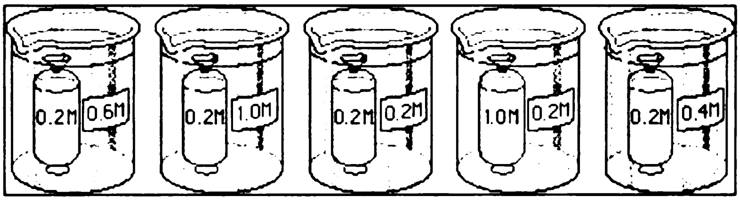
- Purpose/Problem
- Background Information
- Testable Hypothesis
- Independent and Dependent Variables
- Adequate controls
- Materials
- Step by step procedure
- Data table

Students then completed the actual laboratory that they and their partner had designed. They completed written reports describing all the steps of the experiments focusing on whether their hypotheses were supported or not (Appendix M). Students were encouraged to develop questions throughout the experiment with recommendation on how they would refine the experiment. With the exception of the Heart Rate in *Daphnia* lab, both the control and treatment groups repeated exercises to help students refine the labs and try different protocols.

Data Collection

Pre-test administration was given before the pre-lab activity. Post-test assessments were given at the conclusion of the wet-lab, prior to any class discussion of the laboratory results. This was done to in an attempt to ensure that the data collected was based on the pre-lab prep methods not on instructor lecture and/or discussion.

Pre/post-tests (Appendix A) consisted of questions developed by the web site *Biology.com*, from the AP biology lab manual and from reflective questions developed by the teacher. Questions were used to assess student understanding of knowledge, comprehension and application for each of the labs. The following is an example of a questions developed by *Biology.com* (Figure 6).



3. Arrange the beakers in order of the mass of the bags inside them after the experiment has run for 30 minutes. List the bag that loses the most mass first.

a. 2, 1, 3, 4, 5
b. 1, 5, 2, 3, 4
c. 4, 3, 5, 1, 2
d. 3, 2, 1, 4, 5
e. 2, 1, 5, 3, 4

Figure 6 - Post-lab Assessment Example

The Process of Biological Inquiry Test (PBIT) was administered in a pre-test/post-test method (Appendix N). The final PBIT assessment was given after both groups had completed both the web-based and text-based activities. The PBIT was developed by Paul Germann, PhD, as a tool to assess students' critical and analytical thinking in biology. This assessment tool was used to determine whether students showed changes in the ability to use the scientific method using the constructivist approach to teaching science.

Analysis of Data

This section will analyze the background, procedures, and data collection of each of the laboratory exercises. An overview of the purpose of each lab will be provided. As mentioned earlier, complete information about each lab can be obtained by purchasing the AP biology lab manual from the College Board (College Board, 2001). Time spent in the wet-lab and changes made to facilitate completion of the exercises are discussed for each lab. Data regarding assessment of understanding and time for lab preparation are included.

Diffusion & Osmosis

Three specific exercises were used in this activity. These exercises included diffusion (College Board, AP – Ex 1A), osmosis (College Board, AP – Ex 1B), and calculation of water potential (College Board, AP – Ex 1C). The first exercise was to investigate the effects of solute size and concentration on the diffusion of a starch/glucose solution through a semi-permeable membrane. Two lab periods were used for the lab preparation. Initially the treatment group had trouble navigating through the related web-site and identifying the objective of their search. Most of the problems occurred because there were five activities listed on the site and they were only to concentrate on diffusion. Most of the first period was spent on the key concepts portion. The second period was focused on the lab prep with a discussion by both groups on identifying the problem and developing a testable hypothesis from the information they were given. Once navigational problems by the treatment group were overcome, both groups had similar questions and concerns.

Two lab periods were used for the wet-lab as well. Initially neither the treatment group nor the control group had sufficient confidence to set up the lab. Most of the students wanted to know if they "were doing it right." Both groups had a difficult time understanding that they were going to be allowed to make mistakes and were apprehensive because when they made mistakes they had to start over. Problems in executing technique occurred with things like labeling or a few students not realizing that both ends of the dialysis tubing needed to be tied. All students in both groups started over at some point.

The second exercise investigated the relationships between molar solute concentration and the movement of water by osmosis. One class period was used for lab prep, one period was used to discuss and review molarity, and one period was used for the wet-lab. Most students tested the solutions for the initial presence of glucose and were dismayed to find that they had contaminated the solutions in this exercise.

The third exercise used differing molar concentrations of sucrose to determine the water potential of cells of potato cores. One class period was used for prep and simulation of water potential by both the treatment and control groups. An assessment of calculating water potential was given before the wet-lab. Two class periods were used for the wet-lab. Potato cores were prepared by the instructor. Results from student controls indicated that numerous solutions were contaminated from student errors in lab technique when tying the dialysis tubing or adding sucrose. The instructor prepared a second lab and completed the exercise as a lab demo. Students used data from the instructor's lab demo to complete lab reports (Appendix H). The instructor observed a number of difficulties in procedure and execution of proper lab technique (Table 1). The most difficult aspect for the instructor was to allow students to make those errors.

Table 1 – Difficulties with Lab technique & procedure
Difficulty in tying the dialysis bag
Placing the correct solutions in correct place
Difficulty in filling the dialysis bag
Remembering to conduct a control
Contamination of solutions
Difficulty in keeping bag completely submerged

Group A (n=40) was the treatment group in the diffusion & osmosis lab and group B (n=36) was the control group. Overall scores increased by 30% in the test group compared to 24% in the control. (Table 2)

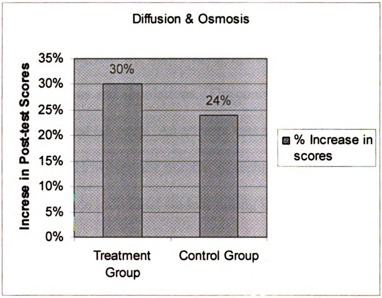


Table 2 - Test Score Improvement for Osmosis & Diffusion

Following the lab preparation, both the treatment group and the control group were given a homework assignment on water potential. The treatment group was to complete the WEI exercise and the control group was given a handout. Students were assessed with an unannounced quiz the following day (Table 3). Students not completing homework responded that they didn't attempt to complete it because they either didn't remember or didn't think it would significantly impact their grade. Both groups were reminded that they would be responsible for the material and improvements were made.

Table 3- Assessment of Water Potential Homework		
	Treatment Group	Control Group
Students attempting homework	43%	38%
Quiz score of those attempting homework	93%	89%
Quiz score that didn't attempt	10%	6%
Average Quiz Score on water potential	40%	36%
Scores after lab and lecture *	95%	80%

* Students were given a similar problem with different data.

Time on task for the assignment indicated that a majority of treatment students spent more time on the lab preparation than the control group. This time included time to get the work stations, logging into the network, navigating the web to get to *Biology.com,* and reviewing the animations and simulations. The control group stayed in the classroom and worked on the text-based lab prep. An attempt was made by the instructor to time each student individually. However, the number of technical questions students had about the WEI program made individual student timing impractical. Therefore, the time recoded was for when a majority of students were finished. Students who were not finished were required to use the academic support period (ASP) to finish their lab preparation (Table 4).

Table 4 Time of task for Osmosis & Diffusion exercises		
	Treatment Group	Control Group
Average prep time (minutes)	85	65
Number of students using ASP for Prep	6	1
Students needing additional time for wet-lab	4	14

Animal Behavior

This exercise consisted of two activities (College Board, AP – Ex 11). The first was to investigate the behavior of pill bugs in a moist environment using a choice chamber. The second activity involved students testing other environmental behaviors using the same procedures. No problems were encountered with the WEI format.

The analysis of the animal behavior lab used group B (n=36) as the treatment group and group A (n=40) as the control group. Overall scores increased by 34% in the test group compared to 30% in the control (Table 5).

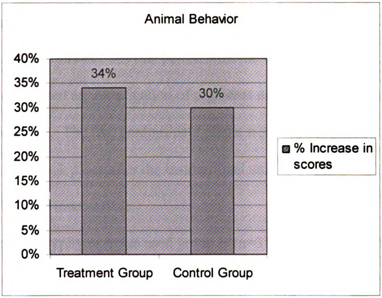


Table 5 - Test Score Improvement for Animal Behavior exercise

One period was needed for the lab prep and two periods for the wet-lab. Time in the wet-lab was longer due to the students getting used to and playing with the pill bugs. Difficulties encountered by both the control and treatment groups included bugs getting caught on tape, filter papers being too moist, and problems administering a valid control.

Some students needed extra time because it took added time for them to get accustomed to handling live materials (Table 6).

Table 6 - Time on task for animal behavior exercise		
	Treatment Group	Control Group
Average prep time (minutes)	45	40
Number of students using ASP for Prep	0	0
Students needing additional time for wet-lab	3	6

Plant Pigments – Chromatography

The purpose of the chromatography exercise (College Board, AP – Ex 4) was to have students separate plant pigments using paper chromatography and calculate their R_f values. Preparation for this lab was one period with the wet-lab requiring one period as well. Students completed an investigation of pigments using ink and one using a plant pigment of their choice. The two predominant plants were red cabbage and spinach leaves. This activity took place after the instructional unit on photosynthesis due to the network server became inaccessible.

The chromatography exercise used group B (n=35) as the treatment group and group A (n=41) the control group. Over all scores increased by 40% in the test group compared to 30% in the control (Table 7).

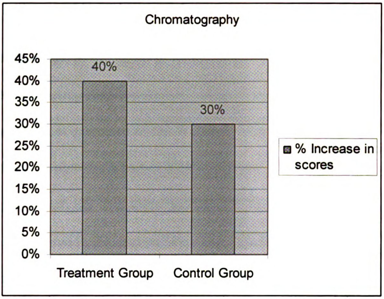


Table 7 Test Score Improvement for chromatography exercise

Both groups conducted the exercises in the classroom because the laboratory was not available. Both groups finished the labs in the allotted time. One pair of students in the treatment group had their bottle knocked over and had to finish during academic support period (Table 8). Since time was available while waiting for the pigments to separate a brief discussion of the R_f values took place while the experiments were in progress with no noticeable distraction. This helped clarify misconceptions. It was difficult for the instructor to allow students to continue with their misconceptions with an opportunity to save valuable time.

Table 8 - Time on task for chromatography exercise

	Treatment Group	Control Group
Average prep time (minutes)	45	40
Number of students using ASP for Prep	0	0
Students needing additional time for wet-lab	2	0

Cell Respiration

Students investigated the effect of temperature on cell respiration of dormant and germinating pea seeds using respirometers (College Board, AP – Ex 5). The WEI procedures were the most extensive of the WEI activities of this study. Much detail was given to students about how the lab should be conducted. However, the site lacked a relevant simulation or activity that addressed the general gas law that states: $PV = nRT$ where the temperature inside the respirometer will affect pressure and volume. The instructor assembled the respirometers prior to the lab. Students were assigned either room temperature or 10 degrees Celsius to investigate and students then shared their data with the class. To get a better understanding of how the WEI method of lab preparation was affecting the results of the test scores, a pre-lab test was administered prior to the wet-lab for this exercise.

In the wet-lab, both groups initially had difficulty identifying the water level in the pipettes. Most had difficulty reading the water level in the control respirometer because the water level remained at the tip of the pipette. Although data wasn't collected on how students did with this procedure, the instructor noted that the treatment groups' had fewer difficulties and questions regarding the readings of the pipette. Most likely this was a reflection of the simulation in the WEI activity. This inaccuracy would not have had a major impact on the results of the students' experiments as long as they were consistent in the way the pipettes were read. A number of students had difficulty in the wet-lab deciding what time to take the initial reading of the pipette. Students were not recording the initial volume. Other problems included keeping the respirometer submerged, submerging the respirometers uniformly, and remembering to monitor temperature.

During the analysis phase of the experiment, students had difficulties understanding the concept of the general gas law. The instructor led a class discussion on the concept which would have been more helpful to the students had the discussion taken place prior to the lab.

The cell respiration exercise used group A (n=41) as the treatment group and group B (n=35) as the control group. The pre-lab test scores showed an improvement of only 12% for the treatment group and 15% for the control group (Table 9).

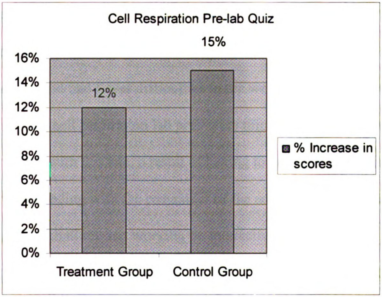


Table 9 - Test Score Improvement Cell Respiration Pre-Lab

Over all scores increased by 36% in the test group compared with 22% in the control. The data support the assumption that the wet-lab plays an important role in student knowledge and understanding of scientific concepts (Table 10).

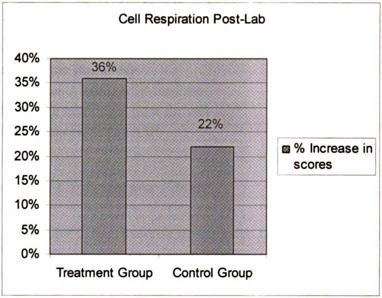


Table 10 - Test Score Improvement Cell Respiration Post-Lab

Two class periods were given to prep this lab. The treatment group spent significantly more time preparing for the lab than the control group but the treatment group spent less time and had fewer difficulties in the wet-lab than the control group. Difficulties in the WEI cell respiration lab prep were minor. However, there were a few navigational problems with this site, a result of having to activate the respirometer animation before proceeding with the remainder of the activity. Most of this time was spent reviewing the animations and working on interactive tutorials.

One class period was allotted for the wet-lab. The control group spent more time in the wet-lab with five students having to complete the lab a second time during academic support period (Table 11). The control group spent more time discovering where the water level was in pipettes and not starting the timing process.

Table 11- Time on Task for Cell Respiration Exercise		
	Treatment Group	Control Group
Average prep time (minutes)	90	55
Number of students using ASP for Prep	0	0
Students needing additional time for wet-lab*	0	5

* Wet-lab was finished during ASP.

Circulatory Physiology-Cardiovascular Fitness

The cardiovascular fitness exercise investigated the effects of different types of physical activities on people to determine physical fitness based on measurements of pulse and blood pressure. The activity provided information on how to measure blood pressure and pulse rate (College Board, 2001, AP – Lab 10A). Students took measurements of heart rates and blood pressures under different types of physical activity and then used those results to determine fitness levels. A discussion followed about using controls and then the instructor provided students with specific physical exercises (College Board, 2001, AP – Lab 10B) that could be controlled to get a more accurate assessment of cardiovascular fitness.

Students encountered difficulties learning to correctly use a sphygmomanometer. Noise in the lab area was also an initial problem.

The cardiovascular fitness exercise used group B (n=35) as the treatment group and group A (n=41) as the control group. Overall post-test scores improved 59% for the treatment group and 56% for the control group (Table 12).

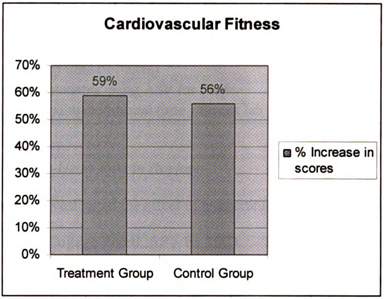


Table 12 - Test Score Improvement for Cardiovascular Fitness

The treatment groups spent more time preparing for the laboratory than the control group. The WEI included four detailed animations that were helpful in simulating methods of determining pulse rate and blood pressure. One period was used for lab prep. One period was used to show students how to find pulse rate and blood pressure. Two periods were used for the cardiovascular fitness exercises developed by the students. Both groups spent equal lab time finding pulse rate. The control group spent less time learning to accurately determine blood pressure while the treatment group spent more time and needed more assistance in finding blood pressure (Table 13). This may partially be due to the fact that students in the control group were returning from lunch and may have found it easier to find blood pressure after exercising. The treatment group was comprised predominately of non-athletes, due to advanced physical education being offered at the same time as this class.

Table 13 – Time on Task for Cardiovascular Fitness		
	Treatment Group	Control Group
Average prep time (minutes)	50	35
Number of students using ASP for Prep	4	0
Students needing additional time - fitness lab	7	3

Circulatory Physiology-Heart Rate in Daphnia

This exercise investigated the effect of temperature on the heart rate of the water flea, *Daphnia magna* (College Board, AP – Ex 10C). . This WEI lab prep activity provided students with a simulation that mirrored what would happen in the actual laboratory. This was the only animation in this study that simulated the data collection and graphed the results on the computer. This was also the only simulation that could be used in place of the actual lab. The actual laboratory itself was performed by the instructor as a classroom demonstration, therefore eliminating variables from student to student that could affect the results. This was done in an attempt to discover if the constructivist approach that allows students to make mistakes on the wet-lab had an effect on their achievement and understanding. There was no pre-lab discussion about what was being done and the exercise was carried out with students using a worksheet. (College Board, 2002, Pg 123-124) Students worked individually with no communication or interaction with other students.

The biggest obstacle for the control group was that the text-based method didn't provided any simulation activity like what the treatment group received with the WEI method. During the actual lab demonstration, the instructor gave students information regarding the heart location, the precise water temperature, and the time intervals the heartbeat counts should be taken.

Over all scores increased by 25% in the test group compared with 12% in the control group (Table 14). Students had misconceptions about the effects of temperature differences on heart rate when other variables were considered. Students didn't have the opportunity to manipulate any of the variables which may have helped them clarify those misconceptions. The data does support the supposition that the hands-on approach to conducting the wet-lab plays an important role in students' acquisition of knowledge and understanding of the scientific concepts.

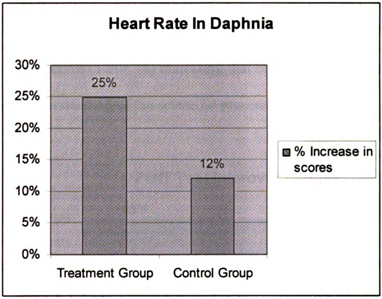


Table 14 – Test Score Improvement for Heart Rate in *Daphnia*

The only difference in the time on task for this activity was the amount of time spent on the simulations. The treatment group spent approximately 45 minutes on the activity while the control group spent only 30 (Table 15).

Table 15 - Time of Task for heart rate in *Daphnia*		
	Treatment	Control
Average prep time (minutes)	45	30
Number of students using ASP for Prep	0	0
Students needing additional time for wet-lab	0	0

PBIT

The Process of Biological Inquiry Test was used to assess students understanding of the scientific method. A number of assessments were reviewed to determine the validity and authenticity of the test. The PBIT was developed by Paul J. Germann as a tool to assess students' critical and analytical thinking in biology. The use of the PBIT was chosen in this study based on its relevance to authentic assessment. The PBIT consist of 35 test items that tested integrated process skills and logical reasoning (Appendix H). Both groups of student took the pre-test and post-test and the same time having had the experienced both the WEI and text-based constructivist method. Both groups earned similar scores (Table 16) indicating that both group A and group B have similar ability and understanding of the scientific process.

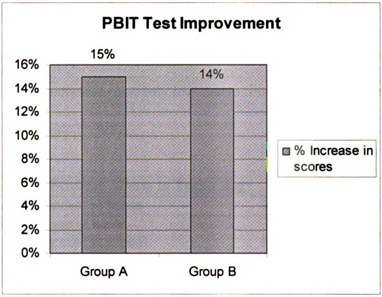


Table 16 – Test Score Improvement on PBIT

In analyzing specific sections of the PBIT there were a number of sections that showed considerable increases in understanding (Appendix H, Table 21). When considering the data gathered from the post--test and pre-test of the PBIT a comparison of specific types of questions and the level of thinking those questions would have required was used to reflect on the type of processes that the instructor could use for future instruction.

Attitude Assessment Survey

Students were given a survey (Appendix G) at the conclusion of the study to determine their attitudes and perception of using the WEI methods in this study. The survey required responses of agree/disagree/no opinion type of response. Students were also questioned about computer use and internet access as well as individual homework habits in relationship to computer use.

A large percentage of students had computers and internet access available at home (Table 17). All students have internet access at school. Although students have had access to computers at school, surprisingly only 35% of the students surveyed had previously used the internet for science. This supports studies indicating that actual web use by teachers in their instruction is relatively low due to time constraints, access to relevant software, and adequate training.

Table 17 - Student Access to Technology	
Computer access at home	81%
Internet access at home	71%
Computer access at school	100%
Used Internet in science previously	35%

Research shows that students learn better in an interactive environment (Jiang and Ting, 1998). Understanding students' perceptions of learning in an interactive environment was critical in evaluating the interactivity of this WEI (Table 18). Although students agreed that these constructivist activities were more difficult (82%) and required more organization (66%), they also agreed that the graphic simulations and interactive components of WEI were more helpful (79%, 85%) and made laboratory exercises easier to perform (76%). This supports students' comments that WEI was more difficult but they did realize the benefits.

The students' indication (Table 18) that WEI made homework and lab preparation more interesting supports research concluding that students prefer to spend more time doing homework using computers. A majority of students agreed that they preferred the WEI method to the text (58%), 30% disagreed. Students were split in agreeing (45%) and no difference (38%) with the statement that LabBench activities made the wet-lab easier. These are both indicators that teachers should consider learning styles of students when conducting WEI.

Table 18 - Attitude Towards Web-Enhanced Instruction

	Agreed	Disagreed	No Difference
More Homework Spent on Computers	80%	6%	14%
Graphic simulations were helpful	79%	2%	18%
Graphic simulations made lab easier	76%	8%	16%
Immediate feed back from WEI Helpful	85%	6%	10%
Preferred LabBench Activities to Text	58%	30%	12%
LabBench Activities made wet-lab Easier	45%	17%	38%
Help to Understand Difficult Concepts	46%	18%	36%
Made Homework and Prep Interesting	47%	14%	39%
Enjoyed Creating own Lab	40%	33%	26%
Constructionist Approach was More Difficult	82%	10%	8%
WEI Required more Organization	66%	14%	19%
Textbooks Labs Would be Easier	63%	30%	7%

Chapter 3

Findings and Discussion

This research supports the premise that WEI is an effective method of developing problem solving and critical thinking skills by promoting higher order cognitive learning. Students post-test score increases were 10% higher on average using the WEI method than the traditional text-based method (Appendix H, Table 22). A statistical analysis used the null hypothesis to determine the data's significance. There is very strong evidence against the null hypothesis on all pre-test/post-tests (p-value <.0001; Appendix K) on all data with the exception of the heart rate in *Daphnia* exercise which there was moderate evidence against the null hypothesis (p-value <.012; Appendix K)

The data (Table 16) indicate that the constructivist method, be it text-based or WEI based, improves overall understanding of the scientific process based on the increase in scores on the post-test of the PBIT when compared to the pre-test. Ninety percent of students (Table 16) improved in the post test scores which increased by14% to an 80% average score (Appendix H, Table 21). However, some areas of the test indicated that there may be gaps in this method by itself. In analyzing specific questions of the PBIT, there appears to be some areas where WEI may require supplemental instruction. More instructor led discussion of the post-lab analysis and interpretation of data would most likely have a positive impact on those areas.

The data fail to support the idea that students spend less time preparing for the lab with the WEI method. In fact, the students spent considerably more time preparing for labs due to the interactive nature of WEI. Students had the opportunity to retry interactive questions and could review animations. An average of 36% more prep time was needed for the treatment group (Appendix D, Table 19). Prep time was extended by the instructor for all labs but one. Average prep time when compared to recommendations of the AP biology lab manual indicated that prep time for labs should have been one period. (College Board, 2001) The use of the constructivist inquiry-based approach doubled the amount of time for prep and most often tripled the amount of time for the wet-lab for both the treatment and control groups when compare to the recommendations of the AP biology manual. Just like real scientific research, students would often have to start the lab over or repeat the lab when discovering that the protocol they were following was not going to be sufficient. These methods allowed for students to develop a richer experience as noted by the students' lab reports. (Appendix J)

In the future when using this approach it is recommended that even more time be used to properly "debrief" each lab activity. Little time was given for students to discuss and reflect on either the lab preparation or the post-lab. A detailed instructor-led discussion should be included and followed with repeated lab trials, especially if there were large discrepancies in data between students. Realistically the constructivist approach will always take more time. The goal is to move away from a science curriculum that is "a mile wide and inch deep" to one that strives for depth of understanding (Germann, 2002)

The prediction that students would be more efficient with the time spent in the wet-laboratory setting was not supported by the data. A valid appraisal of the student's efficiency would need to be carried out in a more controlled fashion. Use of video taping and an evaluator to make observations would produce more acceptable results. The instructor attempted to make these evaluations but student interruptions prevented this.

In the instructor's judgment, less direction was required by the treatment groups. However, there is no quantifiable data to support that assumption. This assumption is supported by research on computer simulations vs. didactic text (Chambers, 1994), simulations with electric circuits (Ronen & Eliahu, 2000), and is supported by students' perceptions (Ronen & Eliahu, 1998).

The final consideration is WEI's effect on lab technique. This research was inconclusive whether or not WEI would lead students to make fewer mistakes in lab technique. The constructivist approach created an atmosphere where students were allowed to make mistakes. The instructor initially heard comments (Appendix I) like "just tell us what to do" which was sometimes followed up with "I don't want to be wrong." The instructor's response was "it is your design, try it." Students were given responsibility for their own reasoning.

The simulation and animation activities did make a difference in some students' ability to perform certain aspects of a procedure. In the heart rate lab, the data (Table 14) indicated that more students improved in the treatment group (77%) than in the control group (49%). Since this was an instructor-led experiment, the only variable that could explain the difference was that students had practiced determining heart rate on the WEI activity.

This study does indicate a positive correlation between WEI and achievement. Individual questions may be a more reliable way to assess students' critical and analytical thinking abilities although analysis is helpful in obtaining an overall picture of students understanding.

Recommendations

Recommendations for using WEI are to take into consideration the learning styles of all students and incorporate both a text-based and WEI constructivist methods in laboratory preparations. Students initially will be resistive to undertake the constructivist approach, especially those ingrained with the notion that there is always a 'right' or 'wrong' way to do things. Once students realize that it is not the instructor's job to give answers and direction, students feel more comfortable exploring their own ideas.

The primary role of the instructor became more of a facilitator than a deliver of content. This allowed for the instructor to analyze students thinking and understanding of the topic and address misconceptions. The direction of the discussion was based on the students own understanding. The instructor was better able to monitor student progress with WEI. Students and instructor could view aspects of the WEI modules that were completed, whereas there was no efficient way to evaluate progress with the text method while students were working. Students need more time to reflect on there own practices, knowledge, and understanding. A discussion during and following each activity will help alleviate student anxiety and help them to reflect on what they are doing.

Patience is a key not only with students but with the technology. Computer equipment does not always function correctly and software programs will not always be accessible. Students need to creatively solve problems when tools are not available to them. Students do critique each other as they do the lab, which can be helpful but should be discouraged when preparing lab activities in which students are developing their own hypotheses and protocols. Having students present their work will allow time for other students to critique other lab activities in a peer review format.

Student's overall attitude to WEI was positive and supports research that attitudes toward learning improve with the use of technology when compared with traditional methods of instruction (Barron and Orwig, 1997). Keeping laboratory groups small was important. Even with the few groups that had three people in them there was a tendency for to make someone else in the group responsible. Students must take responsibility for their own learning with WEI.

To effectively utilize WEI technology to improve science learning, educators need to consider both what is being taught and how it is being taught. Students need to learn particular skills, including being able to form precise questions, search for relevant information, generate good reasons, analyze key concepts, derive reasonable inferences, recognize questionable information, and consider different points of view.

Teachers need to help by creating an environment and structure with WEI that encourages students to think both critically and creatively. Technology alone can't teach students to become competent thinkers, but combined with the best teaching practices, it can act as an empowering educational tool and a stimulus for change.

Teaching students with technology is like the Chinese proverb: "if you give a man a fish, he has food for a day; if you teach a man to fish, he has food for a lifetime." If we give our students computer technology that is just a means of presenting the same information in a different way, then our students will learn for a day. When we teach our students the skills to think creatively and critically using high-order thinking, then they will learn for a lifetime. If computer technology like WEI is utilized this way, then we will not be doing the same thing differently, we will be creating a meaningful learning environment that will help keep pace with advancements in science education.

References

Abernathy, D; (1999).Internet 2: The next generation. *Training and Development*, 53.2: 16-17..

American Association for the Advancement of Science [AAAS] (1993). The Benchmarks for Science Literacy. p. 18.

Anderson, Ronald D. (2002) Reforming Science Teaching: What Research says about Inquiry. *Journal of Science Teacher Education* 13.1: 1-12.

Awbrey, S. M. (1996) Successfully Integrating New Technologies into the Higher Education Curriculum. *Educational Technology Review*, p5

Baek, Y., & Layne, B. (1988). Color, graphics and animation in a computer-assisted learning tutorial lesson. *Journal of Computer-Based Instruction*, 15(4), 131-135.

Barron, A. E., & Orwig, G. W. (1997) New technologies for education: A beginner's guide. Englewood, CO: Libraries Unlimited..

Barron, T, (1999) Harnessing online learning. *Training and Development*, 53.9

Betz, J.A. (1996). Computer games: Increase learning in an interactive multidisciplinary environment. *Journal of Technology Systems, 24*.2, 195-205.

Bell, P. (April 1998) The knowledge integration environment: Relating debate and conceptual change through design experiments. *Paper presented at the Conference of the American Educational Research Association*, San Diego.

Boyer, E. L. (1983) High school: A report on secondary education in America. New York: Harper & Row

Brant, g., Hooper, E., &Sugrue, B. (1991) Which comes first, the sijulation or the lecture? Journal educational computing research, 7.4, 469-481

Chambers, SK, Hashellhuhn, C., Andre, T., Mayberry, C., Wellington, S. Krafka, A., Volmer, J. & Berger, J (1994) The acquisition of a scientific understanding of electricity: Hands-on versus computer simulation experience; conceptual change versus didactic text. *The annual Meeting of the American Educational Research Association*, New Orleans, LA

College Board, AP Biology Lab Manual, (2001). College Entrance Examination Board. (http://www.sc2000.net~czaremba/aplabs/)

Dewey, J. (1902). The child and the curriculum. *Chicago: The University of Chicago Press*

Engler, John (Feb. 1998). Message on Educational Technology: *Governor John Engler's Second Electronic address to the Legislature* [Online] (http://www.michigan.gov/gov/1,1431,7-103-705-1983--M_1998_2,00.html)

Ferguson, H. H., and Chapman, S. R. (1993) Computer-assisted instruction for introductory genetics. *Journal of Natural Resources and Life Sciences Education* 22: 145-152

Follansbee, S. (1998) A Role of Online Communications in Schools: A National Study [Online] Executive Summary. (http://www.cast.org/publications/stsstudy/)

Galas, Cathleen. (Dec 1997-98): From presentation to programming: doing something different, not the same thing differently. *Learning and leading with Technology* 25.4.4: 18-21.

Gallini, Joan K.; & Barron, Daniel. (2001/2002) Participants' perceptions of Web-infused environments: a survey of teaching beliefs, learning approaches, and communication. *Journal of Research on Technology in Education* 34.2: 139-56

Gardner, J,H Morrisonand R Jarman. (1993) The impact of high success to computers on learning. *Journal of Computer Assisted Learning* 9.1: 2-16.

Germann, Paul J. (1991) Developing science process skills through directed inquiry. *The American Biology Teacher*, 53.4: 243-247

Germann, Paul J. (2002) Science Making Sense, [Online] Accessed April 4, 2002 (http://www.coe.missouri.edu/~pgermann/projects/)

Goodlad, J. (1984). *A place called school: Prospects for the future.* New York: McGraw-Hill.

Hargrave, Constance P and Jeffery M Kenton. (2000) Preinstructional simulations: implication for science classroom teaching. *The Journal of computers in Mathematics and Science Teaching* 19.1 47-58.

Hall, B. (1997). *Web-based training cookbook.* New York: Wiley.

Honey, M., & Henriquez, A. (1993*). Telecommunications and K-12 educators: Findings from a national survey.* New York, NY: Bank Street College of Education.

Hughes, W. R (1974) A study of the use of computer simulated experiments in the physics classroom. *Journal of Computer-Based Instruction* 1:1-6

Jensen, Murray S.; Wilcox, Kimerly J., Hatch, J, Jay, T., (1996) A computer-assisted instruction unit on diffusion and osmosis with a conceptual change designs with a con." *The Journal of Computers in Mathematics and Science Teaching* 15.1-2: 49-64.

Jones, Trevor H.; Paolucci, Rocco. (Fall 1999) Research framework and dimensions for evaluating the effectiveness of educational technology systems on learning outcomes." *Journal of Research on Computing in Education* 32:1: 17-27

Kerr, R. (1982*). Psychomotor learning.* New York: CBS College Publishing.

Lawson, Anton E. (Nov/Dec 2000) Managing the Inquiry Classroom: Problems & Solutions. *The American Biology Teacher* 62.9: 641-648.

Levine, T. (1994) A computer-based program can make a difference: The case of the Rediscover Science program. Studies in Education Evaluation 20: 283-296.

Lu, Sasey, R, Burton E Vossand Lewis J Kleinsmith. (1997, May) The effect of a microcomputer-based biology study center on learning in high school biology students. *The American Biology Teacher* 59: 270-8

Mayton, G.B (1991, April). Learning dynamic processes from animated visuals in microcomputer-based instruction. *Proceedings of Selected Research Presentations at the Annual Convention of the Association for Educational Communications and Technology. [online]* (ERIC ED 334 999).

McLaughlin, Jacqueline S. (2001 Feb): Breaking Out of the Box: Teaching Biology with Web-Based Active Learning Modules. *The American Biology Teacher*, 63.2:110-115.

McLaughlin, M. W., & Talbert, J. W. (1993).*Introduction: New visions of teaching.* D. K. Cohen, M. W. McLaughlin, & J. E. Talbert (Eds.), *Teaching for understanding: Challenges for policy and practice.* San Francisco: Jossey-Bass Publishers.

McMasters, G. (1999). *Save money, time by using web-based training.* Austin Business Journal, 19.33: 18.

Michigan Virtual High School, 2002) [Online] (http://www.mivhs.org)

Molenda, M and Sullivan, M (2002) A watershed year for technology in education. *The Education Digest* 67.5: 4-9

National Center for Education Statistics (NCES) (2002) *The Condition of Education 2000.* [Online] (http://nces.ed.gov/programs/coe/)

National Science Education Standards. (1996).Washington, DC: National Academy Press.

National Science Teachers Association. (1990) An NSTA theme paper on the role of research in science teaching. [Online] (http://www. nsta.org/handbook/roleres.htm)
National Association of Secondary School Principals. (1996). *Breaking ranks: Changing an American institution.* Reston, VA: NASSP.

National Research Council [NRC] (1996) *National Science Education Standards* National Academy Press, Washington DC

Oates, Rita H. (2001) What works for teachers: New approaches to technology professional development *Technology Professional Development for P-12 Educators,* [Online] (http://www.electronic-school.com/2002/01/0102f2.html)

Oja, S. N., & Pine, G. J. (1989) Collaborative action research: Teachers' stages of development and school contexts. *Peabody Journal of Education*, 64.2, 96-115.

Olson, D.W. (1974, March). Interpreting a technological society. *School Shop*, 35-36.

Panel on Educational Technology. (1997) *Report to the President on Use of Technology to Strengthen K-12 Education:* [Online] (http://www.ostp.gov/PCAST/k-12ed.html)

Paolucci, Rocco. (1998) The effects of cognitive style and knowledge structure on performance using a hypermedia learning system. *Journal of Educational Multimedia and Hypermedia* 7.2-3: 123-50

Peat, Maryand: & Anne Fernandez (2000. Spring) The role of information technology in biology education: an Australian perspective. *Journal of Biological Education* 34.2: 69-73.

Peck, C.., Cuban, L. and Kirkpatrick, H. (2002. Apr) High-tech's high hopes meet student realities. *The Education Digest* 47-54

Piaget, Jean. 1973 *To Understand is To Invent.* New York: Grossman,

Powell, A. G., Farrar, E., & Cohen, D. K., (1985) *The shopping mall high school: Winners and losers in the educational marketplace.* Boston: Houghton Mifflin.

Rieber, L. (1990). Animation in computer-based instruction. *Educational Technology Research and Development*, 38.1, 77-86.

Ronen, M and Eliahu, M. (1998)Simulation as a home learning environment --Students' views. *Journal of Computer Assisted Learning* 15: 258-268.

Ronen, Mand and Eliahu, M.,. (2000) Simulation -- a bridge between theory and reality: the case of electric circuits. *Journal of computer Assisted* Learning 16. 14-26.

Salomon, G. and Almog, T. (1998) Educational psychology and technology: A matter of reciprocal relations. *Teachers College Record*, 100.1, 222-241.

Sanders, Diana W.; Morrison-Shetlar, Alison (2001, Spring) Student attitudes toward Web-enhanced instruction in an introductory biology course. *Journal of Research on Computing in Education* 33.3: 251-62

Simon, Eric J. (Feb 2001) Technology Instead of a Textbook: Alternatives for the Introductory Biology Classroom. *The American Biology Teacher* 63.2: 89-94.

Shymansky, J. A., & Kyle, W. C.. (1992) Establishing a research agenda: Critical issues of science curriculum reform. *Journal of Research in Science Teaching*, 29.8: 749-778.

Szabo, Michael.; Poohkay, Brent (1996, Spring) An experimental study of animation, mathematics achievement, and attitude toward computer-assisted instruction. *Journal of Research on Computing in Education* 28: 390-402

Tamir, P. (1986, Winter)Current and potential uses of microcomputer in science education. *Journal of computers in Mathematics and Science Teaching*. 18-28.

Thomas, Gregory P. (2001) Toward Effective Computer Use in High School Science Education: Where to from Here? *Education and Information Technologies* 6.1: 29-41.

Mikropoulos, Tassos A and Anthimos Chalkidis. (1998, June) Students' attitudes Towards Educational Virtual Environments. *Education and Information Technologies* 3.2 [Online] (http:///www.kluwer.com) Kluwer publishers.

Van den Akker, J. J. H., Keursten, P. and Plomp, T. (1992) The integration of computer use in education. *International Journal of Educational Research*, 17: 65-75.

Weller, H. G. (1996) Assessing the impact of computer-based learning in science. *Journal of Research on Computing in Education*, 28.4: 461-485

Weller, H. G. (1997, March) Computer-based learning in science: What have eight years of research shown? An analysis of research papers. *Paper presented at the Conference of the National Association for Research in Science Teaching*, Illinois

APPENDICES

Appendix A

Laboratory Pretest/Post-test

Circulatory Physiology
Cardiovascular Fitness
Pre-Test/Post-Test

1. Which of the following has the LEAST effect on blood pressure in a young adult?

   a. Temperature of the room

   b. Position of the body

   c. Level of conditioning

   d. Supplemental vitamins

Why?

2. An individual's blood pressure is reported as 110/50. Which of the following is correct?

   a. The pressure during the contraction phase of the heart is 50, and the pressure during the relaxation phase is 110.

   b. Systolic pressure is 110 and diastolic pressure is 50.

   c. The pulse is 110 during exercise and 50 when at rest.

   d. The individual shows possible borderline high blood pressure.

Why?

Refer to the following table to answer Questions 3 and 4.

	Resting Pulse	**Resting BP**	**Return to Resting Pulse After Vigorous Exercise**
a.	72	130/90	2 minutes
b.	48	110/80	30 seconds
c.	66	120/95	60 seconds
d.	84	110/75	90 seconds

3. Which of the test results would be most typical of a well-conditioned athlete? Why?

   a. b. c. d.

4. Which of the test results indicate a person with the lowest level of fitness? Why?

   a. b. c. d.

5. Why does increased physical activity raise heart rate?

6. Why is heart rate lower in an individual who does aerobic exercise regularly?

7. Why do some people feel faint when they go quickly from lying down to standing?

8. How and why does heart rate change with body position?

9. From your study of the circulatory system, how would you describe a "fit" individual?

Animal Behavior
Pre-Test/Post-Test

1. In this activity, you have been guided through the process of experimental design, and you should be able to apply these principles in other laboratory situations. Consider the following experiment:

A student wanted to study the effect of nitrogen fertilizer on plant growth, so she took two similar plants and set them on a window sill for a two-week observation period. She watered each plant the same amount, but she gave one a small dose of fertilizer with each watering. She collected data by counting the total number of new leaves on each plant and also measured the height of each plant in centimeters.

Which of the following is a significant flaw in this experimental set-up?

a. There is no variable factor.

b. There is no control.

c. There is no repetition.

d. Measurable results cannot be expected.

e. It will require too many days of data collection.

2. Students placed five pillbugs on the dry side of a choice chamber and five pillbugs on the wet side. They collected data as to the number on each side every 30 seconds for 10 minutes. After 6 minutes, eight or nine pillbugs were continually on the wet side of the chamber, and several were under the filter paper. Which of the following is NOT a reasonable conclusion from these results? Why?

a. It takes the pillbugs several minutes to explore their surroundings and select a preferred habitat.

b. Pillbugs prefer a moist environment.

c. Pillbugs prefer a dark environment.

d. Pillbugs may find chemicals in dry filter paper irritating.

e. Pillbugs demonstrate no significant habitat preference.

3. What structures do pill bugs use to respire or "breathe"?

4. If a student wanted to determine whether pillbugs prefer a moist or a dry environment, what would be the best way to analyze data from the experiment? Why?

a. Total the number of pillbugs on the dry side throughout the entire experiment and compare this with the number on the wet side throughout the experiment.

b. After waiting 5 minutes for the pillbugs to acclimate, count the number of pillbugs on the dry side every 30 seconds for 5 minutes. Total and average the results, and compare this with the number of pillbugs on the wet side during this same time interval.

c. Compare the number of pillbugs on the dry side at the end of 10 minutes with the number of pillbugs on the wet side at the end of 10 minutes.

d. Divide the number of pillbugs on the dry side throughout the experiment by the number on the wet side throughout the experiment.

5. Which of the following hypotheses is stated best? Why?

a. If pillbugs are allowed free movement, then more will be found in a moist environment than in a dry environment.

b. If pillbugs like a moist environment, then they will move to the wet side of a choice chamber.

c. If an experiment with pillbugs is run for 10 minutes, then more pillbugs will be found in the most favorable environment.

d. Pillbugs are found in moist habitats, so I predict that more will be found where it is wet.

6. How do isopods locate appropriate environments?

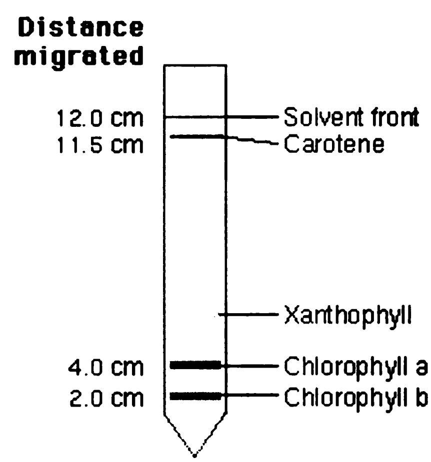
7. Is an isopods response to moisture best classified a kinesis or taxis? Why?

8. How many legs does a pillbug have?

Plant Pigments
Chromatography
Pre-Test/Post-Test

1. Look at the chromatogram below. Which of the following is true of the chromatogram?

a. The R_f for carotene can be determined by dividing the distance the yellow-orange pigment (carotene) migrated by the distance the solvent front migrated.
b. The R_f value of chlorophyll *b* will be higher than the R_f value for chlorophyll *a*.
c. The molecules of xanthophyll are not easily dissolved in this solvent, and thus are probably larger in mass than the chlorophyll *b* molecules.
d. If this same chromatogram were set up and run for twice as long, the R_f values would be twice as great for each pigment.
Explain Why.



2. If a different solvent were used for the chlorophyll chromatography described earlier, what results would you expect?

a. The distances travelled by each pigment will be different, but the R_f values will stay the same.
b. The relative position of the bands will be different.
c. The results will be the same if the time is held constant.
d. The R_f values of some pigments might exceed 1.0.
Explain Why.

3. What is the R_f value for carotene calculated from the chromatogram above?

a. 1.09
b. 0.17
c. 0.96
d. 0.33
e. 0.50
Explain Why.

Circulatory Physiology
Heart Rate
Pre-Test/Post-Test

1. Which of the following organisms would show the greatest fluctuation in body temperature hour by hour?

   a. dolphin

   b. mouse

   c. lake trout

   d. rattlesnake

Explain Why.

2. What is the relationship between metabolic rate and body temperature in *Daphnia*?

   a. As the body temperature increases, the metabolic rate decreases.

   b. An increase of 10°C results in a doubling of metabolic rate.

   c. Heart rate increases as body temperature decreases.

   d. Cellular enzymes are less active at 35°C than at 20°C, resulting in decreased metabolic rate.

Explain Why.

3. If $Q_{10} = 2$, then an enzymatic reaction that takes place at a given rate at 5°C would take place approximately how many times faster at 25°C? Show work.

   a. Twenty times

   b. Eight times

   c. Four times

   d. Three times

   e. Two times

Explain Why.

4. Which of the following experimental conditions would be most life-threatening for an ectothermic organism? Why?

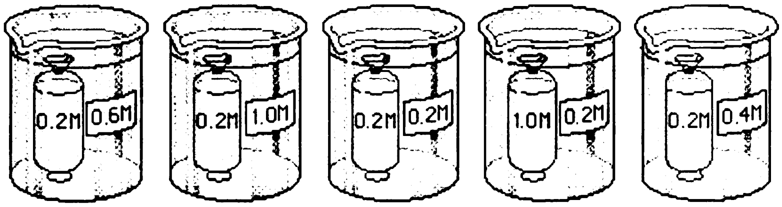
a. Temperatures that exceed 40°C b. Temperatures that are between 3°C and 8°C

Explain Why.

Diffusion & Osmosis

Pre-Test/Post-Test

Study the set of five beakers shown here to answer questions 1–3:

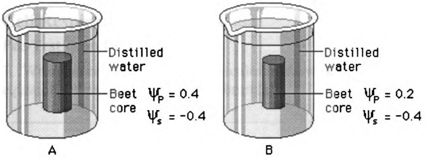


1. Which beaker(s) contain(s) a solution that is hypertonic to the bag?
a. Beaker 3
b. Beakers 2 and 4
c. Beakers 1, 2, and 5
d. Beaker 4
e. Beakers 3 and 4
Explain Why.

2. Which bag would you predict to show the least change in mass at the end of the experiment?
a. The bag in Beaker 1
b. The bag in Beaker 2
c. The bag in Beaker 3
d. The bag in Beaker 4
e. The bag in Beaker 5
Explain Why.

3. Arrange the beakers in order of the mass of the bags inside them after the experiment has run for 30 minutes. List the bag that loses the most mass first.
a. 1, 2, 3, 4, 5
b. 1, 5, 2, 3, 4
c. 4, 3, 2, 5, 1
d. 3, 2, 1, 4, 5
e. 2, 1, 5, 3, 4
Explain Why.

Refer to the figure below to answer questions 4 and 5.



4. In beaker B, what is the water potential of the distilled water in the beaker, and of the beet core?
   a. Water potential in the beaker = 0, water potential in the beet core = 0
   b. Water potential in the beaker = 0, water potential in the beet core = -0.2
   c. Water potential in the beaker = 0, water potential in the beet core = 0.2
   d. Water potential in the beaker cannot be calculated, water potential in the beet core = 0.2
   e. Water potential in the beaker cannot be calculated, water potential in the beet core = -0.2

Explain Why.

5. Which of the following statements is true for the diagrams?
   a. The beet core in beaker A is at equilibrium with the surrounding water.
   b. The beet core in beaker B will lose water to the surrounding environment.
   c. The beet core in beaker B would be more turgid than the beet core in beaker A.
   d. The beet core in beaker A is likely to gain so much water that its cells will rupture.
   e. The cells in beet core B are likely to undergo plasmolysis.

Explain Why.

6. Why don't red blood cells pop in the bloodstream?

7. The molar concentration of a sugar solution in an open beaker has been determined to be 0.3M. Calculate the solute potential at 27 degrees. Round your answer to the nearest hundredth.

8. The pressure potential of a solution open to the air is zero. Using the information from question 7 calculate the water potential if the pressure of the solution was increased to 1. Since you know the solute potential of the solution, calculate the water potential.

Cell Respiration Lab Prep Quiz

Pre-Test/Post-Test

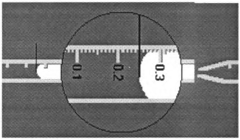
1. Write the correct names of molecules to show raw materials and products in the equation for cellular respiration. (formula)

_________ + _________ + _________ = _________ + _________ + _________

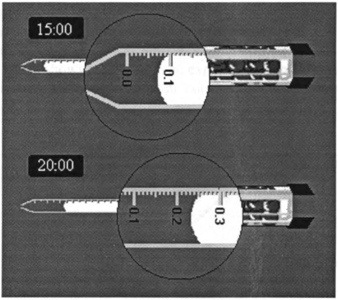
2. What are two processes in plants that require ATP?

3. How will the rate of cellular respiration be measured in this lab?
   a. Measure the amount of glucose consumed.
   b. Measure the amount of oxygen consumed.
   c. Measure the amount of carbon dioxide produced.

4. What is the reading on the pipette below?



5. What would be the rate of oxygen consumption if the respirometer readings were as shown here? *Show your work & include correct units.*

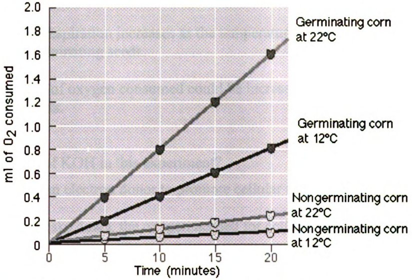


6. What is the respiration rate per hour?

Cell Respiration

Pre-Test/Post-Test

The accompanying graph shows results from an experiment done to measure cellular respiration in germinating and non-germinating corn seeds. On the basis of the graph, answer questions 1–3.



1. Which of the following is a true statement based on the data?
   a. The amount of oxygen consumed by germinating corn at 22°C is approximately twice the amount of oxygen consumed by germinating corn at 12°C.
   b. The rate of oxygen consumption is the same in both germinating and non-germinating corn during the initial time period from 0 to 5 minutes.
   c. The rate of oxygen consumption in the germinating corn at 12°C at 10 minutes is 0.4 ml O_2/minute.
   d. The rate of oxygen consumption is higher for non-germinating corn at 12°C than at 22°C.
   e. If the experiment were run for 30 minutes, the rate of oxygen consumption would decrease.

2. What is the rate of oxygen consumption in germinating corn at 12°C?

a. 0.08 ml/min
b. 0.04 ml/min
c. 0.8 ml/min
d. 0.8 ml/min
e. 1.00 ml/min

3. Which of the following conclusions is supported by the data?

a. The rate of respiration is higher in non-germinating seeds than in germinating seeds.

b. Non-germinating peas are not alive, and show no difference in rate of respiration at different temperatures.

c. The rate of respiration in the germinating seeds would have been higher if the experiment were conducted in sunlight.

d. The rate of respiration increases as the temperature increases in both germinating and non-germinating seeds.

e. The amount of oxygen consumed could be increased if pea seeds were substituted for corn seeds.

4. What is the role of KOH in this experiment?

a. It serves as an electron donor to promote cellular respiration.

b. As KOH breaks down, the oxygen needed for cellular respiration is released.

c. It serves as a temporary energy source for the respiring organism.

d. It binds with carbon dioxide to form a solid, preventing CO_2 production from affecting gas volume.

e. Its attraction for water will cause water to enter the respirometer.

5. Write the formula showing the raw materials and the products for cellular respiration.

6. If respiration in a small animal were studied at both room temperature and at 10 degrees C, what results would you predict? Explain why.

7. If you used the same experimental design to compare the rates of respiration of a 25g reptile and a 25 g mammal at 10 degrees C, what results would you expect? Explain why.

8. What would you predict the effect of germination (versus non-germination) on bean seed respiration.

Appendix B

Process Of Biological Inquiry Test (PBIT)

PARTONE: EVALUATION

The following questions refer to Bubonic Plague, or Black Death, that killed thousands of people during the Middle Ages. The Middle Ages was a time of feudalism and of kings, lords, knights, and peasants. Only the nobility and the clergy were educated. The vast majority of people had no education at all. The study of chemistry was in its infancy as the chemists of the time tried to change iron and lead into gold. Biological studies were limited to observations that could be made with the naked eye since the microscope had not been invented yet. In physics, Sir Isaac Newton had not yet described the Law of Gravity and astronomers still thought that the sun rotated around the earth.

Sanitary conditions during this period of history were very poor. For example, there was no garbage disposal. People just threw their garbage out onto the street. As a result, there must have been a tremendous number of flies, the rat population must have been very high, as well as other pests and microbes that would have lived off the garbage.

The Bubonic Plague, or Black Death, is a highly fatal disease caused by a microscopic bacterial organism called Bacillus Pestis. It is a disease found chiefly in rats and squirrels and is transmittedfrom one to another by fleas. However, man is also highly susceptible to this disease, and major outbreaks occurred in the past. The disease is spread among humans when infected fleas from rats or squirrels bite people and infect them with the Bacillus Pestis microorganism.

In 1348 there was an outbreak in Italy, and during the next two years, it killed almost half the population of Europe. In some cities, as much as two-thirds of the population was eliminated. It came back in epidemic proportions every ten years or so. In 1655, at least one-tenth the population of London was wiped out. About 80% of the people affected with this disease died within two or three days. After the epidemic, the disease more or less died out in Europe.

The plague is not a major disease at the present time but it still kills people in parts of Asia and Africa. The Bacillus Pestis is now present in the squirrel population in the Western United States.

Evaluate the possible reasons for the disease dying out in Europe.

1. Most of the people who could catch the disease easily (people who were susceptible to the disease) had already died leaving only those who were resistant to the disease. (a) a possible factor for the disease dying out; (b) an improbable factor for the disease dying out; c) a factor that cannot be judged as possible or improbable.
2. The rats were all eliminated. (a) a possible factor for the disease dying out; (b) an improbable factor for the disease dying out; (c) a factor that cannot be judged as possible or improbable.
3. In order to protect themselves, people did a variety of things, some of which were somewhat effective, some of which were not. Consulting witches and witch doctors (a) might have decreased the chances of getting the plague; (b) might have increased the chances of getting the plague (c) would not have affected the chances much one way or the other.

PART TWO: ASSUMPTIONS

A student placed some leaves of a corn plant which had been exposed to light for two hours in a test tube and added a little water. To this tube the students then added Fehling's solution. (Fehling's solution turns red when it comes in contact with a hot glucose solution.) On heating the contents of the test tube to the boiling point, the students found that the solution became red. The students then performed the same experiment on leaves which had been in the dark. These leaves did not turn the Fehling's solution red.

As a result of this experiment, the student concluded that <u>the leaves of the corn plant had produced glucose when exposed to light.</u>

To reach this conclusion, he made several assumptions listed below. An assumption is something that you take for granted as being true without actually checking or testing to find out if it is true. For example, you might say, "I'11 graduate in Junel" You take for granted or assume that you will be alive in June, that your school will judge you to be eligible for graduation in June, and similar things.

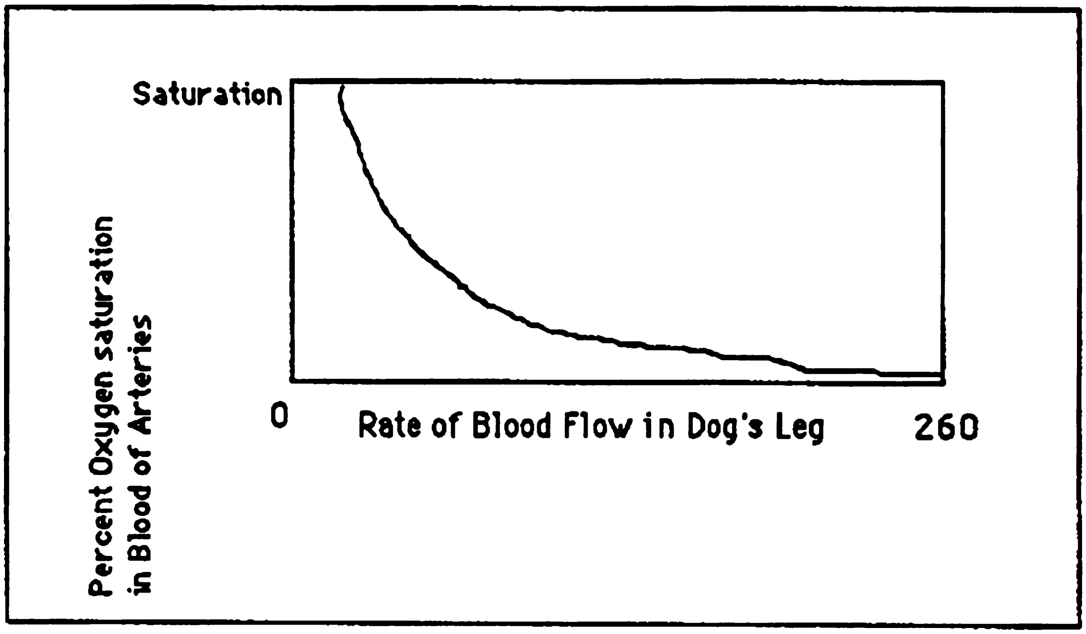
Use the following key to classify the student's assumptions

KEY: A. an assumption that is justifiable and necessary in order to do the experiment and make the conclusion.
B. an assumption that has nothing to do with this experiment or conclusion.
C. not an assumption; it is a restatement of the results.

4. The student assumed that glucose is formed more abundantly in leaves than in stems or roots.
5. The student assumed that a glucose solution will not rum red by itself.
6. The student assumed that the solution turned red after boiling.

PART THREE: DATA AND HYPOTHESIS

In this exercise you will be asked to evaluate several statements to determine if each statement is a restatement of the data presented in the graph or if the statement is hypothesis or "educated guess" as to the reason for the data.



Use the key below to classify the statements.

KEY: A. a logical hypothesis or "educated guess" to explain the data.
B. an illogical hypothesis or "educated guess" because it is actually contradicted by the data.
C. a correct restatement of the results; does not attempt to explain the results with a hypothesis.
D. an incorrect restatement of the results; does not attempt to explain the results with a hypothesis.

7. Lack of oxygen causes an increase in the size of blood vessels and this increases blood flow.
8. At near 100% blood saturation, the rate of blood flow in the dog's leg is lowest
9. Capillaries contract and reduce blood flow when the percentage of oxygen is high.

PART FOUR: INTERPRETATION OF DATA--TABLE

Photosynthesis is a chemical process which occurs in green plants. Photosynthesis uses carbon dioxide (that enters the leaf through small leaf openings), water from the soil (that gets to the leaf through conducting cells in the roots and stems), and light energy to make a sugar called glucose. The glucose is then changed into starch for storage.

Six geranium plants were treated in several experiments to test these ideas about photosynthesis.

PLANT	TREATMENT		RESULTS
Plant I	Half of each leaf was covered with aluminum foil to block light	Placed in light	Starch in half exposed to light
Plant II	Upper and lower surface of leaves covered with vaseline	Placed in light	No starch
Plant III	Placed in jar containing no carbon dioxide	Placed in light	No starch
Plant IV	Leaves removed and placed with stems immersed in glucose solution	Placed in dark	Starch, especially along veins of leaves
Plant V	No treatment	Placed in dark	No starch
Plant VI	No treatment	Placed in light	Starch

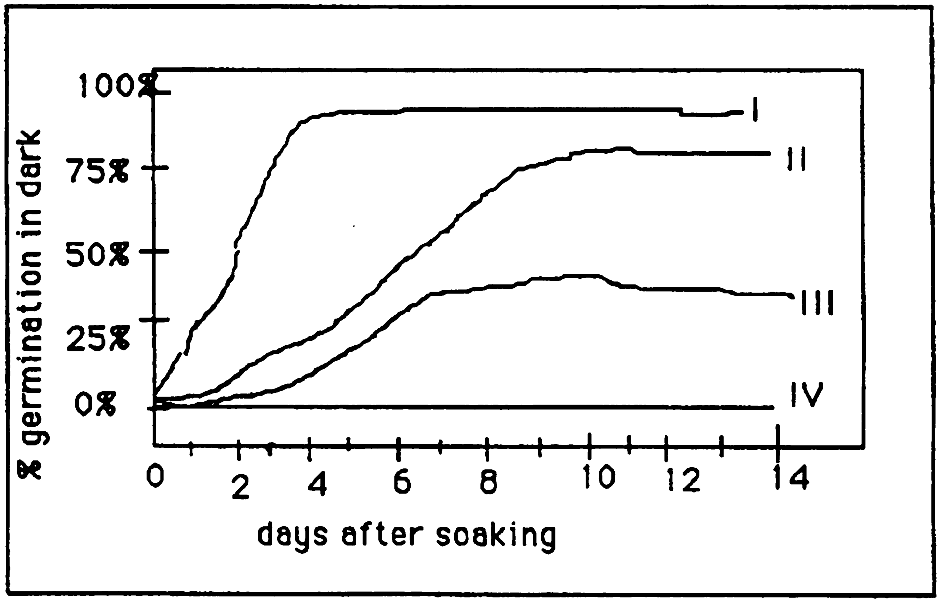
Use the following key to classify the statements below.

KEY: The interpretation of the data isA. supported by data.
B. rejected on the basis of the data presented.
C. logical, but the experiment is not designed to test it.

10. Light is necessary for starch formation in plants.
11. This experiment lacks a control.
12. The roots of a plant may store starch.

PART FIVE: INTERPRETATION OF DATA--GRAPH

The next 3 questions are based on the following graph showing the effect that soaking seeds in the dark has upon the germination of 4 species of seeds.



Use the key below to classify the following statements.
KEY: The statement is

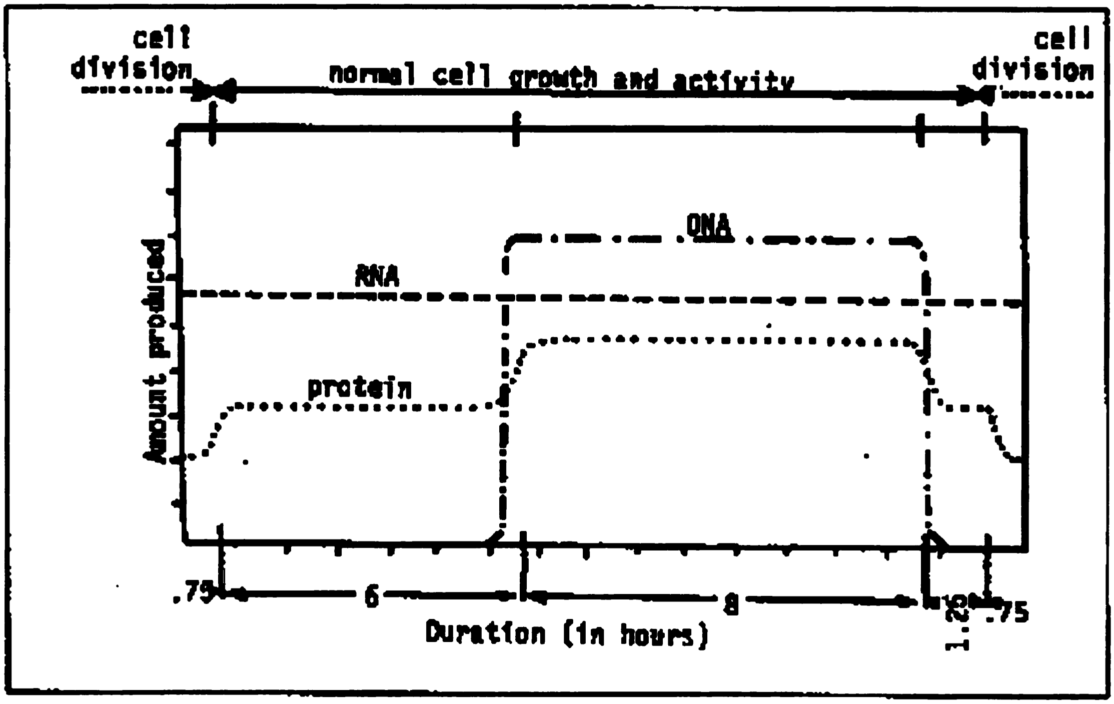
A. rejected on the basis of the evidence presented.
B. supported on the basis of the evidence presented.
C. logical, but the experiment is not designed to test it.

13. III seeds have a lower germination percentage in the dark than II seeds.
14. II seeds need light for germination.
15. Soaking makes all seed species germinate.

PART SIX: DATA AND HYPOTHESIS

A cell's life alternates between periods of normal growth and activity and cell division. When a cell division is complete, the cycle begins over again. The next 3 questions relate to the following data and key. Use the key to classify the statements.

The graph shows the production of certain chemicals in a cell for various periods before, during and after cell division.



KEY: A. a restatement of the data.
B. a statement that can be contradicted by the data.
C. insufficient evidence to evaluate this statement.

16. The amount of RNA being produced is constant.
17. Some DNA is produced at all times.
18. After cell division, the DNA formed will be equally divided between the two daughter cells.

PART SEVEN: SUPPORTING DATA

The pancreas is an organ of the human body that secretes digestive enzymes into the intestine. This enzyme is normally secreted when food is about to enter the intestine. Scientists wondered what caused the enzyme to be secreted at the right time.

The two hypotheses below are possible explanations of the control of pancreatic secretions into the intestine.

I. Nerves stimulate the pancreas to secrete its enzyme into the intestine.
II. A hormone secreted by the intestine into the blood causes the pancreas to secrete its enzyme into the intestine

Use the key below to classify each of the following experiments as they relate to the hypothesis.

KEY: A. Supports hypothesis I only
B. Supports hypothesis II only
C. Supports both hypotheses
D. Supports neither hypothesis

19. When a nerve leading to the pancreas is stimulated, the pancreas secretes enzymes.

20. If the nerves leading to the pancreas of a hungry dog are cut, no enzymes are secreted by the pancreas.

PART EIGHT: INTERPRETATION OF DATA--TABLE

During the function of kidneys, the liquid part of the blood called plasma is forced through special filtering structures. This forms a filtrate in the kidney tubules. As the filtrate passes through the kidney tubules, water and other beneficial materials are removed and reabsorbed into the plasma of the blood, leaving a solution of waste materials called urine in the kidney tubules.

The next 3 questions are based on the following data.

COMPONENT OF PLASMA, FILTRATE, AND URINE (g/100 ml fluid)			
COMPONENT	PLASMA	FILTRATE	URINE
urea	0.03	0.03	2.00
uric acid	0.004	0.004	0.05
glucose	0.10	0.10	0.00
amino acids	0.05	0.05	0.00
all salts	0.72	0.72	1.50
proteins	8.00	0.00	0.00

Use this key to classify the statements below.

KEY: A. a reasonable interpretation of the data.
B. an interpretation contradicted by the data.
C. there is insufficient evidence to make an interpretation.

21. Glucose is not found in urine.
22. The concentration of all salts is about double in the urine.
23. Uric acid is the most abundant component in the urine.

PART NINE: HYPOTHESIS

Mrs. Potter gave identical ivy plants to both Mrs. Bardimer and Mrs. Bellefleur. Both plants were the same size, had been cut from the same parent plant, and were potted in the same size pot with the same kind of soil. Despite her best efforts, Mrs. Bardimer's plant died a month later while Mrs. Bellefleur's flourished.

Use the key below to evaluate reasons for the death of Mrs. Bardimer's plant.

KEY: A. possible reason.
B. improbable or impossible reason.

24. Mrs. Bellefleur's plant was of a hardier variety than Mrs. Bardimer's.
25. Mrs. Bardimer's plant became too root bound (the pot was too small for the root system.)
26. Mrs. Bardimer's house was too cool for this kind of plant.

PART TEN: PREDICTION

The water flea is a shrimp-like organism called Daphnia. Water very low in oxygen concentration causes the Daphnia to become red, while water high in oxygen concentration causes them to become colorless.

The plasma of red Daphnia is red, while the plasma of the colorless Daphnia is colorless. Analysis shows the red pigment to be hemoglobin.

Scientists know that in humans, oxygenated hemoglobin is bright red; non-oxygenated hemoglobin is dark red; carbon monoxide-hemoglobin is bright cherry red, brighter and lighter than oxygenated hemoglobin.

Scientists also know that carbon monoxide combines with hemoglobin and prevents oxygen from being attached to the molecule.

<u>Problem: What will happen if carbon monoxide is bubbled through the water in which Daphnia are kept?</u>

Use the key below to classify the following predictions.

KEY: A. A prediction which is logical on the basis of the above data.
B. A prediction which is not logical; it is contrary to some or all of the data above.
C. A prediction which may be logical but for which there is no basis in the data above.
D. Not a prediction; it is a restatement of the given data.

27. Oxygen causes the breathing rate to get faster.
28. The plasma of the red Daphnia will appear blue.
29. Hemoglobin is the red pigment in the red Daphnia.

PART ELEVEN--INTERPRETATION

Scientists were attempting to determine what substances controlled the growth of plant tissues. Three substances were thought to be effective in promoting growth: DPU, CH, and CCM. The following table summarizes the results of their experiment.

Effect of DPU, CH, and CCM on the growth of carrot tissue cultures.		
	Fresh weight, mg	Cell number (x 1000)
Plain medium	7.2	45
Plain medium + DPU	9.4	50
Plain medium + CH	29.4	201
Plain medium + CH + DPU	56.8	508
Plain medium + CH + CCM	294	2,662

Use the key below to classify the following statements.

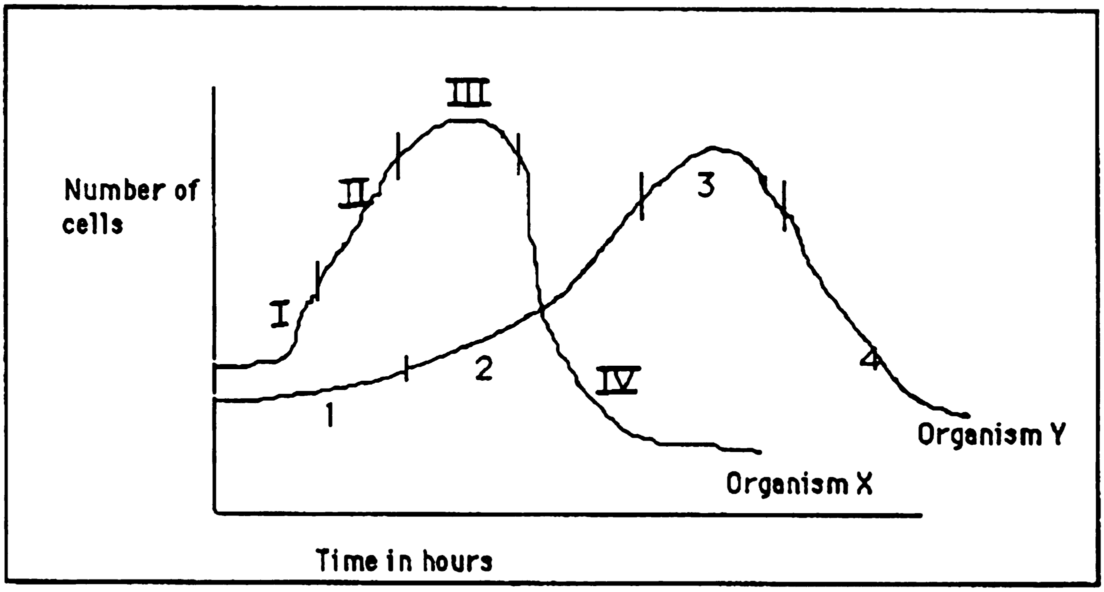
KEY: The statement is

A. a reasonable interpretation of the data.
B. an interpretation contradicted by the data.
C. There is insufficient evidence to make an interpretation.

30. DPU is slightly effective.
31. CCM is the control for this experiment.
32. CCM and DPU together are not effective in producing cell growth.

PARTTWELVE: HYPOTHESIS

The following graph plots the growth of two microorganisms, organism x and organism y. They were placed in a single flask containing food, water, and oxygen. The flask was then sealed and maintained in normal light at room temperature.



33. If the amount of food were increased at the end of phase III, what would most probably happen to the size of the population? It would probably (a) double; (b) decrease; (c) increase; (d) remain the same.
34. If only organism x were in the culture, what could account for the slowing down of the growth rate at the beginning of period III? (a) an increase in available oxygen; (b) a decrease in waste present; (c) a decrease in available food (d) an increase in available food.
35. By comparing II and 2 in the curves, it can by hypothesized that (a) organism x reproduces at a faster rate than organism y; (b) organism x is feeding on organism y; (c) both organisms are utilizing the same food in the medium; (d) organism x is controlling the y population in some way.

Appendix C

Author Developed WEI

Author Developed WEI Modules

Soil Algae Abundance	Earthworm Behavior
Fungal Culture & Abundance	Viruses/Chestnut Blight
Nitrogen Fixation Bacteria	Nematode Abundance
Species Diversity/Population Density	

ECOLABS *Teacher Module*

ESTIMATING SOIL ALGAE ABUNDANCE

Developed by:* Clarence Rudat** ***Montague High School, Montague, MI

OBJECTIVES

Given the appropriate tools the student will be able to accurately measure and calculate the occurrence of algae present in soils of different communities.

The student will be able to explain there relationships between algae abundance and abiotic factors of the specific community.

The student will be able to estimate the abundance or lack of soil algae present in a forest community.

SUGGESTED HYPOTHESIS

In analyzing the soil of a forest community there is a direct relationship between soil moisture, light and soil algae growth. Increased moisture and light will result in an increase in algae growth.

STUDENT MATERIALS (class of 30 in groups of 3)

10	10-ml pipettes
150	20-ml test tubes
10	Test tube racks
20 g	Soil (low land or creek bed forest habitat)
20 g	Soil (upland or open area habitat)

Cotton
3.5 Liters of Distilled Water
Light Source
10 wax pencils
30 Lab/Data sheets

BACKGROUND INFORMATION

Preparation of Stock Solutions
To demonstrate the occurrence, estimate abundance, and to isolate soil algae, one must use a simple salt solution devoid of organic matter. This solution is made by preparing 6 - 400 ml stock solutions, each containing one of the following salts in the concentration listed:

$NaNO_3$	10.0g
$CaCl_2$	1.0g
$MgSO_4 \cdot 7H_2O$	3.0g
K_2HPO_4	3.0g
KH_2PO_4	7.0g
NaCl	1.0g

Ten ml of each of these stock solutions is added to 940 ml of distilled water to make a liter of medium. This is supplemented with one drop of a 1.0 percent $FeCl_3$ solution. To each of a series of 15 test tubes per soil studied add 10 ml of the complete medium. Each tube is closed with a cotton plug and all are sterilized in the autoclave.

Pre–lab Activity – Have students review lab procedure On-line at www.montague.k12.mi.us/algae.htm

Day One - Collection of Soil

Soil should be collected from at least two locations, preferably an area of high soil moisture and light, and an area of either low light or low moisture. Depending on class time you may want to show students where the collections will be taken from. Do not collect soil or water directly from an aquatic environment. Soil around these areas however, would be acceptable. Have students record foliage density, soil temperature, and determine soil moisture (Moislab).

Day Two - Prep Algae Culture

Have students collect data from Moisture lab. Have students prepare the serial dilutions using 1 g soil collected on the same day and place all samples in a light source.

Three main conditions are considered when culturing algae: temperature, light, and an adequate medium. The optimal temperature for most soil algae growth is 20oC. Algae will tolerate growth above and below this optimum, but it is desirable to keep the lab at temperature as near to 20oC as possible. Generally higher temperatures are more likely to destroy algal growth than at lower temperatures. Algae should not be kept in direct sunlight that could elevate temperatures over 32oC. It is recommended that more light be provided than is provided by window light. A 40-watt florescent light a few feet from the test tubes for 16-24 hours will encourage algal growth.

Day 30 - Final Observations

Day 31 - Review calculations and classify algae.

Review example with students in calculating numbers of algae in the soil.
www.montague.k12.mi.us/aglae/probability example

QUESTIONS

1. Were there any differences in the abundance of algae in the different soils tested?

2. Can you explain these differences? Did the types of algae found in field soil differ from those that developed in the forest soil?

3. What areas of a forest community would you predict to have higher algal growth on the forest floor and why?

4. What affects do these factors have on other biotic and abiotic factors of the forest community?

5. Why might the texture of soil affect the growth of algae?

6. What is the relationship between soil moisture, light, and algal growth?

7. Why do some soils contain more algae?

FURTHER INVESTIGATIONS

Examine the algae abundance of a body of water or open field and compare results with a deciduous forest or evergreen forest.

REFERENCES

Bower, James E 1990. Field and Laboratory Methods for General Ecology. Wm. C. Brown Publishers, Dubuque, Iowa

Pramer, David 1965. Life in the Soil, Biological Sciences Curriculum Study. D. C. Heath and Company, Lexington, Massachusetts

ECOLABS

ESTIMATING SOIL ALGAE ABUNDANCE ***Student Module***

TO THE STUDENT

One of the purposes of this laboratory exercise is to develop an understanding of the scientific method and an appreciation of its practical applications to everyday problem solving. In this laboratory you will:

1. Measure the abundance of soil algae in different environments using a serial dilution.
2. Analyze the effect of varying abiotic factors on primary productivity of soil productivity.

PRE–LAB ACTIVITY http://www.montague.k12.mi.us/algae.htm

INTRODUCTION

The organisms that comprise the soil microflora are the algae, the fungi, the actinomycetes, and the bacteria. These organisms have no roots, stems, or leaves, and it is only the algae that contain chlorophyll and are green. Algae, fungi, actinomycetes, and bacteria were first studied by botanists and were classified as plants due to the fact that these organisms contained a rigid cell wall. These organisms are now classified as monera or fungi.

Algae has long been associated with aquatic habitats. The algae are numerous in habitats that are moist and exposed to light. Under appropriate moisture and light conditions they will develop on the surface of soil as green, rather slimy growth. Even in the desert algae will grow and develop either under rocks or on the surface of the soil. Some soil algae are unicellular, others develop as filaments, but those found in soil are characteristically smaller than their aquatic counterparts. As chlorophyll-bearing organisms, algae are capable of utilizing light to make energy for growth and reproduction (autotrophic). Soil algae are classified primarily on the basis of pigmentation into the Chlorophyceae (green), Cyanophyceae (blue-green), Bacillariophyceae (Diatoms), and Xanthophyceae (yellow-green).

Three main conditions are considered when culturing algae: temperature, light, and an adequate medium. The optimal temperature for most soil algae growth is 20oC and sunlight that will not raise the temperature above 32oC. Since algae have a photosynthetic metabolism and do not require preformed organic mater as food, they frequently act as pioneers and colonize barren areas that vulnerable to support high forms of life. Algae are significant also in paddy soils used for the cultivation of rice. Here they contribute significantly to the nitrogen and oxygen status of the soil, which in turn increases yield. By photosynthetic mechanisms algae convert atmospheric carbon dioxide to cell substance, increasing the total quantity of organic carbon in the soil environment. This is of particular importance in desert soils where algae act also to control erosion by forming surface crust. Recent years have witnessed an increase in interest in soil algae.

In analyzing a forest community what relationships exist between foliage densities, soil moisture and algae growth?

HYPOTHESIS

Write three or more possible hypothesis for this problem. Choose the one that you feel is the best.

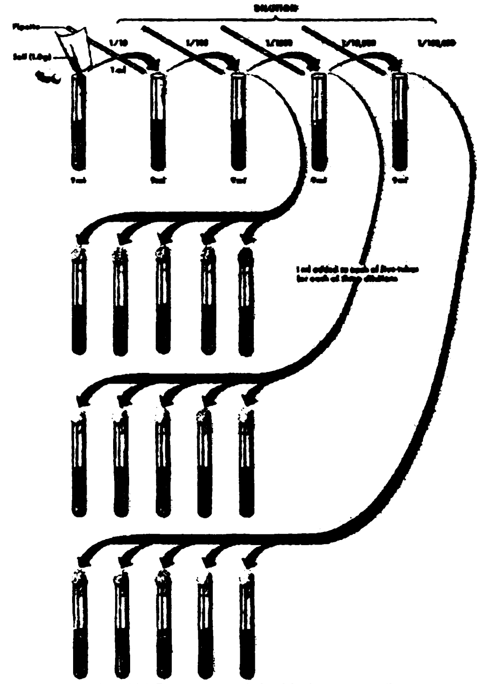
MATERIALS

15 20-ml test tubes with sterilized medium
1 wax pencil or maker
Cotton
10-ml Pipette
Soil

PROCEDURE

Obtain 15 sterilized test tubes of medium from the instructor. Label 5 tubes A (1/1,000), B (1/10,000), C (1/100,000). Perform a series of tenfold dilutions in sterilized 9-ml portions of the salt solution for the soil to be studied. The dilution series should proceed from 1/10 to 1/100,000 in the following manner:

- Place a 1.0 g sample of soil in 9ml of medium. Label this tube #1-original sample.
- Pipette 1 ml of tube 1 to a 9ml test tube of medium. Label tube #2-1/10 dilute.
- Pipette 1 ml of tube 2 to a 9ml test tube of medium. Label tube #3-1/100 dilute.
- Pipette 1 ml of tube 3 to a 9 ml test tube of medium. Label tube #4-1/1000 dilute
- Pipette 1 ml of tube 4 to a 9 ml test tube of medium. Label #5-1/10,000 dilute



One-ml quantities of the soil suspensions at each of the three highest dilutions (1/1,000, 1/10,000 1/100,000) are added as an inoculum to each of 5 tubes of medium in the following manner:

- Pipette 1ml of tube #3-1/100 to each of the 5 test tubes labeled A
- Pipette 1ml of tube #4-1/1,000 to each of the 5 test tubes labeled B
- Pipette 1ml of tube #5-1/10,000 to each of the 5 test rubes labeled C

These 15 inoculated samples are incubated in diffuse light. Examine occasionally for algae growth and make final observations after 30 days.

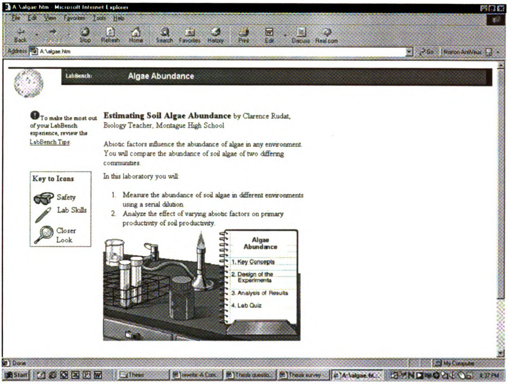
Day 30- Final Observations
To calculate the numbers of algae in the soil first record the number of tubes at each dilution in which there was growth, and then refer to table III. This table indicated the most probable number of algae per g of soil based on the number of tubes showing growth. It is applicable only when each of 10 tubes is inoculated with 1.0 ml of three dilutions. The code is the number of tubes showing growth. The first, second, and third numbers in the code refer to the number of positive tubes at dilutions of 1/1000, 1/10,000, and 1/100,000 respectively. The value located under the column designated X, and associated with the proper code, is multiplied by the reciprocal of the center dilution to obtain the most probable number of algae present per gram of the original soil. The column headed P indicates the Percentage of times that the same code would be obtained if an infinite number of analyses were performed on the sample. You employed 5 rather than 10 tubes per dilution, so results must be doubled and then evaluated using table III. The forgoing procedure may be clarified by example given by your instructor.

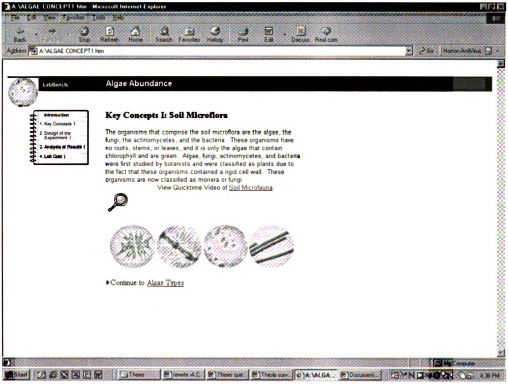
Enter your results in Table I. Now remove the cotton plug from the tubes in which there has been algae growth. Transfer some of the green material to slides. Prepare wet mounts and examine microscopically. Note and sketch the morphological characteristics of the organisms.

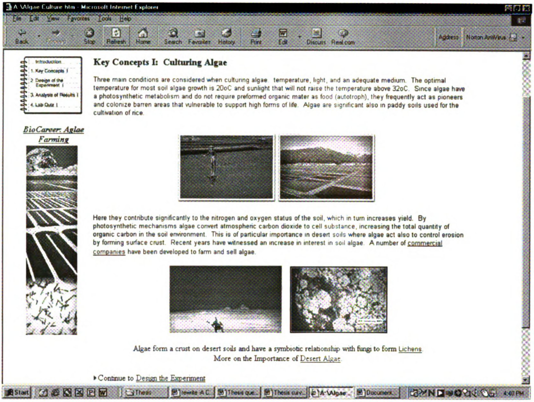
CONCLUSIONS

Carefully analyze the data collected. Accept or reject your chosen hypothesis on the basis of the data you collected. Be sure to explain your reasons for accepting or rejecting the hypothesis on the basis of observable and tabulated data.

Algae Abundance Web Pages



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Introduction
1. Key Concepts I
2. Design of the Experiment I
3. Analysis of Results I
4. Lab Quiz I
BioCareer: Aglae Farming
Key Concepts I: Culturing Algae
Three main conditions are considered when culturing algae. temperature, light, and an adequate medium. The optimal temperature for most soil algae growth is 20oC and sunlight that will not raise the temperature above 32oC. Since algae have a photosynthetic metabolism and do not require preformed organic mater as food (autotroph), they frequently act as pioneers and colonize barren areas that vulnerable to support high forms of life. Algae are significant also in paddy soils used for the cultivation of rice.
Here they contribute significantly to the nitrogen and oxygen status of the soil, which in turn increases yield. By photosynthetic mechanisms algae convert atmospheric carbon dioxide to cell substance, increasing the total quantity of organic carbon in the soil environment. This is of particular importance in desert soils where algae act also to control erosion by forming surface crust. Recent years have witnessed an increase in interest in soil algae. A number of commercial companies have been developed to farm and sell algae.
Algae form a crust on desert soils and have a symbiotic relationship with fungi to form Lichens.
More on the Importance of Desert Algae.
Continue to Design the Experiment
Start
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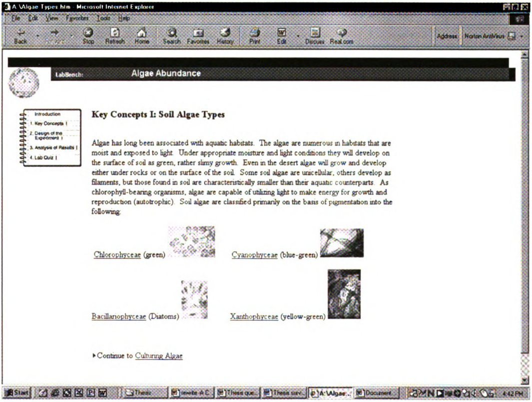
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LabBench:
Algae Abundance
Introduction
1. Key Concepts I
2. Design of the Experiment I
3. Analysis of Results I
4. Lab Quiz I
Key Concepts I: Soil Algae Types
Algae has long been associated with aquatic habitats. The algae are numerous in habitats that are moist and exposed to light. Under appropriate moisture and light conditions they will develop on the surface of soil as green, rather slimy growth. Even in the desert algae will grow and develop either under rocks or on the surface of the soil. Some soil algae are unicellular, others develop as filaments, but those found in soil are characteristically smaller than their aquatic counterparts. As chlorophyll-bearing organisms, algae are capable of utilizing light to make energy for growth and reproduction (autotrophic). Soil algae are classified primarily on the basis of pigmentation into the following:
Chlorophyceae (green)
Cyanophyceae (blue-green)
Bacillariophyceae (Diatoms)
Xanthophyceae (yellow-green)
Continue to Culturing Algae
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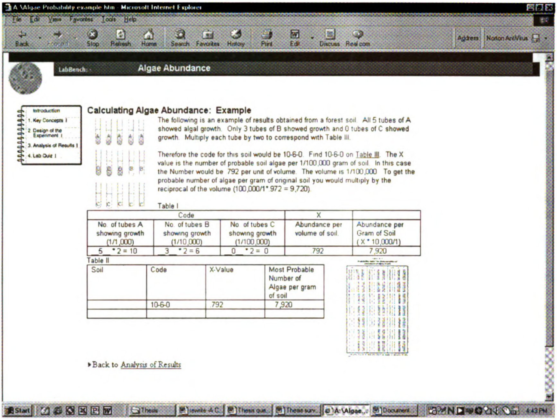


A:\Algae Probability example.htm - Microsoft Internet Explorer

LabBench: Algae Abundance

Introduction
1. Key Concepts
2. Design of the Experiment
3. Analysis of Results
4. Lab Quiz

Calculating Algae Abundance: Example

The following is an example of results obtained from a forest soil. All 5 tubes of A showed algal growth. Only 3 tubes of B showed growth and 0 tubes of C showed growth. Multiply each tube by two to correspond with Table III.

Therefore the code for this soil would be 10-6-0. Find 10-6-0 on Table III. The X value is the number of probable soil algae per 1/100,000 gram of soil. In this case the Number would be 792 per unit of volume. The volume is 1/100,000 To get the probable number of algae per gram of original soil you would multiply by the reciprocal of the volume (100,000/1*.972 = 9,720).

Table I

Code			X	
No. of tubes A showing growth (1/1,000)	No. of tubes B showing growth (1/10,000)	No. of tubes C showing growth (1/100,000)	Abundance per volume of soil.	Abundance per Gram of Soil (X * 10,000/1)
5 *2 = 10	3 *2 = 6	0 *2 = 0	.792	7,920

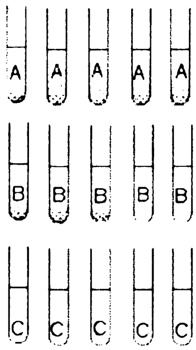
Table II

Soil	Code	X-Value	Most Probable Number of Algae per gram of soil
	10-6-0	.792	7,920

▸Back to Analysis of Results

ECOLABS

Calculating Algae Abundance: *Example*



The following is an example of results obtained from a forest soil. All 5 tubes of A showed algal growth. Only 3 tubes of B showed growth and 0 tubes of C showed growth. Multiply each tube by two to correspond with Table III.

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Table I

Code			X	
No. of tubes A showing growth (1/1,000)	No. of tubes B showing growth (1/10,000)	No. of tubes C showing growth (1/100,000)	Abundance per volume of soil.	Abundance per Gram of Soil (X * 10,000/1)
__5__ * 2 = 10	__3__ * 2 = 6	__0__ * 2 = 0	.792	7,920

Table II

Soil	Code	X-Value	Most Probable Number of Algae per gram of soil
	10-6-0	.792	7,920

ECOLABS

ESTIMATING SOIL ALGAE ABUNDANCE ***Student Module***

Observations

Most Probable Number of Algae in Soil

Soil	Tubes Showing Growth (code)	X-Value*	Most Probable Number per Gram

* Obtained from probability table I.

1. Were there any differences in the abundance of algae in the different soils tested?

2. Can you explain these differences? Did the types of algae found in field soil differ from those that developed in the forest soil?

3. What areas of a forest community would you predict to have higher algal growth on the forest floor and why?

4. What affects do these factors have on other biotic and abiotic factors of the forest community?

5. Why might the texture of soil affect the growth of algae?

6. What is the relationship between soil moisture, light, and algal growth?

7. Why do some soils contain more algae?

Conclusion:

Appendix D

Data Tables

Table 19 Average Time on Task

	Treatment Group (Minutes)	Control Group (Minutes)
Osmosis & diffusion	85	65
Chromatography	45	40
Cell Respiration	90	55
Animal Behavior	45	40
Cardio Fitness	50	35
Heart Rate in Daphnia	45	30
Total Time	360	265
Average Time	60	44

Table 20 Individual Item Analysis of PBIT

Question #	Difference	Pre--Test	Post--Test	Change in %
1	12	64%	79%	16%
2	7	51%	60%	9%
3	14	80%	98%	18%
4	19	48%	73%	25%
5	6	57%	65%	8%
6	9	74%	86%	12%
7	17	31%	53%	22%
8	20	35%	61%	26%
9	15	40%	60%	19%
10	9	58%	70%	12%
11	-5	68%	61%	-6%
12	1	81%	92%	11%
13	8	88%	98%	10%
14	14	75%	94%	18%
15	8	61%	71%	10%
16	13	79%	96%	17%
17	3	78%	82%	4%
18	7	87%	96%	9%
19	14	78%	96%	18%
20	10	42%	55%	13%
21	10	84%	97%	13%
22	6	81%	88%	8%
23	9	77%	88%	12%
24	11	74%	99%	25%
25	-3	62%	58%	-4%
26	8	88%	99%	10%
27	3	74%	78%	4%
28	7	71%	81%	9%
29	15	40%	60%	19%
30	10	86%	99%	13%
31	17	57%	79%	22%
32	14	71%	90%	18%
33	1	70%	81%	11%
34	13	71%	88%	17%
35	9	64%	75%	12%
Total	331	66%	80%	14%

Table 21 – Overall Test Score Improvement

	Treatment Group	Control Group
Osmosis & diffusion	30%	24%
Chromatography	40%	30%
Cell Respiration	36%	22%
Animal Behavior	34%	30%
Cardio Fitness	59%	56%
Heart Rate in Daphnia	25%	12%
Average Improvement	37%	29%

Table 22 - Overall Students Showing Improvement

	Treatment Group	Control Group
Osmosis & diffusion	93%	78%
Chromatography	75%	66%
Cell Respiration	95%	94%
Animal Behavior	100%	93%
Cardio Fitness	100%	100%
Heart Rate in Daphnia	77%	49%
Average Improvement	90%	80%

Appendix E:

Parent/Student Consent Form

MHS Biology

Parental/Student Consent Form

To: Parents, Legal Guardians and Students

From: Mr. Clarence Rudat

CC: Kevin Kruger

Date: 7/29/2002

Re: Data collection for Master's Thesis

Over the past four summers, I have been taking courses towards my master's degree in biology at Michigan State University. This past summer I have developed a hand-on biology unit that will use web-based pre-laboratory activities as the basis of my thesis. I have modified some lab activities that I feel will help your child better understand aspects of biology. This unit will be taught during the second semester and last for approximately nine weeks.

In order to determine the effectiveness of these new activities and the unit as a whole I will need to collect data from the biology students in my class. The data collection will be based on performance on of pre-and post--tests, homework assignments, lab activities, web based tutorials, and student reflections. All students are required to complete the same work; I am requesting permission to use your child's work, scores and reflections for my thesis. **All student work used in my thesis will remain confidential; any marks that may identify the participant will be removed from any document reproduced for my thesis.**

Please complete the attached form and return it to me by Friday, March 22, 2002. I am requesting your permission to use your child's work, scores and reflections from the molecular and behavioral ecology unit of biology for my thesis. There will be no repercussions for denying permission to use your child's data. The analysis of student data will not begin until grades for the unit are completed at the end of the marking period. Exemption of your child from data collection in no way exempts them from participating in class. They will be required to complete the same assignments as those participating in the study. Your child's privacy will be protected by every means possible.

If you have any questions about the rights of human subjects participating in research please contact the Internal Review Board chairperson, David E. Wright, at (517) 355-2180. If you have any questions or concerns about your child or this biology class please contact me at (231) 894-2661 ext. 227.

Sincerely,

Mr. Clarence Rudat

_____ I grant Mr. Rudat permission to use my data generated during the ecology unit. I am aware that Mr. Rudat will not use my name and that all student data collected will remain confidential.

_____ I do not grant Mr. Rudat permission to use my data generated during ecology unit. I am aware that I will not be penalized for choosing to withhold my data.

Student Signature: ______________________________ Date: ______________

Student Name (printed): ______________________________

Parent Signature: ______________________________ Date: ______________

Parent Name (printed): ______________________________

UCRIHS APPROVAL FOR
THIS project EXPIRES:

AUG 0 7 2002

SUBMIT RENEWAL APPLICATION
ONE MONTH PRIOR TO
ABOVE DATE TO CONTINUE

• Page 2

Appendix F

UCRIHS Approval

MICHIGAN STATE
UNIVERSITY

August 10, 2001

TO: Merle HEIDEMANN
118 North Kedzie Hall
MSU

RE: **IRB# 01-536** CATEGORY: EXEMPT 1-A, 1-B, 1-C

APPROVAL DATE: August 7, 2001

TITLE: THE ELECTRONIC LABORATORY: A COMPARISON OF PRE-LABORATORY ACTIVITIES FOR BIOLOGY STUDENTS

The University Committee on Research Involving Human Subjects' (UCRIHS) review of this project is complete and I am pleased to advise that the rights and welfare of the human subjects appear to be adequately protected and methods to obtain informed consent are appropriate. Therefore, the **UCRIHS approved this project.**

RENEWALS: UCRIHS approval is valid for one calendar year, beginning with the approval date shown above. Projects continuing beyond one year must be renewed with the green renewal form. A maximum of four such expedited renewals possible. Investigators wishing to continue a project beyond that time need to submit it again for a complete review.
REVISIONS: UCRIHS must review any changes in procedures involving human subjects, prior to initiation of the change. If this is done at the time of renewal, please use the green renewal form. To revise an approved protocol at any other time during the year, send your written request to the UCRIHS Chair, requesting revised approval and referencing the project's IRB# and title. Include in your request a description of the change and any revised instruments, consent forms or advertisements that are applicable.
PROBLEMS/CHANGES: Should either of the following arise during the course of the work, notify UCRIHS promptly: 1) problems (unexpected side effects, complaints, etc.) involving human subjects or 2) changes in the research environment or new information indicating greater risk to the human subjects than existed when the protocol was previously reviewed and approved.

If we can be of further assistance, please contact us at (517) 355-2180 or via email: UCRIHS@msu.edu. Please note that all UCRIHS forms are located on the web: http://www.msu.edu/user/ucrihs

Sincerely,

Ashir Kumar, M.D.
UCRIHS Chair

AK: kj
cc: Clarence Rudat
6392 W. Wilke Road

OFFICE OF
RESEARCH AND GRADUATE STUDIES

University Committee on Research Involving Human Subjects

Michigan State University
246 Administration Building
East Lansing, Michigan
48824-1046

517/355-2180
FAX: 517/353-2976
Web: www.msu.edu/user/ucrihs
E-Mail: ucrihs@msu.edu

Appendix G

Survey of Student Attitudes to Computer Use and WEI

Circle the response that most closely relates to you.

1. Do you have access to a computer at home? Yes No

2. 2. Do you have internet access at home? Yes No

3. Do you have internet access at school? Yes No

4. Have you used internet simulations in science before this class Yes No

5. Approximately how much time do you spend doing homework per week?

0, 1-5, 5-10, 10-15, 15-20, 20 + hrs

6. Approx. how much time do you spend doing school work on the computer?

0, 1-5, 5-10, 10-15, 15-20, 20 + hrs

SA= Strongly Agree, A=Agree, ND=No Difference, D=Disagree, SD=Strongly Disagree

7. I spent more time doing school work on the computer than before	SA	A	ND	D	SD
8. I liked using the computer better than the handouts.	SA	A	ND	D	SD
9. The graphic simulations where helpful	SA	A	ND	D	SD
10. The immediate feedback from the practice questions are helpful	SA	A	ND	D	SD
11. Labs in the textbook were easier	SA	A	ND	D	SD
12. Creating my own experiments is more fun	SA	A	ND	D	SD
13. LabBench activities were easier to do than the hard copy	SA	A	ND	D	SD
14. The moving graphics on the computer made labs easier	SA	A	ND	D	SD
15. It was hard to keep track of all the information	SA	A	ND	D	SD

I feel working on the computer:

16. made homework and Lab Prep more interesting	SA	A	ND	D	SD
17. would have been easier if labs were already written out	SA	A	ND	D	SD
18. helped me understand difficult biological concepts	SA	A	ND	D	SD
19. made me spend more time on homework	SA	A	ND	D	SD
20. An online e- textbook would make it easier to do homework	SA	A	ND	D	SD
21. I recommend computer based labs and homework	SA	A	ND	D	SD

On the reverse side list any suggestions, concerns, or comments you have about using inquiry developed labs on the internet computer.

Appendix H

Lab Report Format

Biology Lab Report Format

Experimental labs. Most of our labs will be experimental labs that involve science process skills such as hypothesis formation, manipulation of variables, gathering, tabulating, graphical display of data, data interpretation, etc.

In college, lab report requirements vary greatly. Some are quite rigorous and require that a review of the pertinent scientific literature be included in the introduction. I have simplified this requirement, by asking you to summarize this scientific information without the use of resources other than our text and online material at Biology.com.

- ***All formal lab reports that can not be read will have to be word processed!***
- ***Once you place your name on your submitted lab report, you are signing a contract that states that all the work is your own. You may work with other classmates to discuss the lab, but the wording used in your report is not to be copied from anywhere.***

Please use the following format and numbering sequence when writing up your labs: Always begin your lab with a descriptive **title** as a header.

I. Introduction:

A. Purpose/problem:
A description of the problem being investigated and/or the purpose of the lab.

B. Background Information:
The background information summarizes the relevant scientific information that allowed you to develop your hypothesis.

II. Hypothesis, Materials & Procedures:

A. Hypothesis:
State the hypothesis or hypotheses that are being investigated.
B. Materials:
List the materials used in this lab. If there is already a list written in your textbook or in a lab handout that you received, then you do not need to copy this list, you may simply reference the lab.
C. Procedures:
Describe how the procedure will allow you to confirm or reject each hypothesis. What procedures were followed, and why were these steps taken? This is not expected to be an account including minute details, but should be a *general* overview of what was done. For "experimental" labs be sure to describe how the experiment was controlled. It is a good idea to include a diagram displaying how equipment was used. This section should be written impersonally in the passive voice--not "We made a cross section of the plant, and..." but rather, "A cross section of the plant was made, and..." Please leave out the personal pronouns

III. Results, Data, Observations:

A. Observations:
You will include written observations describing what you observed. It is important to note any procedural errors that may have occurred in this section of your report. If there were any calculations involved in the lab, the work should be shown in this portion of your report.

B. **Data Tables:**
Organize your data in tabular form. All tables include appropriate descriptive titles. Most labs will require you to design at least two tables, one that has your lab group's data and the second that has the class data with class averages. DO NOT FUDGE YOUR DATA! Put only the data that your group and the class collected.

C. **Graphs:**
Students often struggle when it comes to creating an appropriate graph. All graphs must include the following:

- Descriptive title
- Labeled axes with units included
- Appropriately spaced axes with correctly placed and connected data points
- Well defined key

The data is the only part of the lab report that will be shared with your lab partner(s). Each individual, however, should create the graphs. Do not have one lab member design a computer-generated graph, which is then copied for the entire lab team. Your entire group will lose credit if this occurs.

IV. Conclusion:
Here you present a summary of the data generated by the lab. Be sure to include your actual data in this part of your lab. Do not simply say, "My data supported my hypotheses." How do you interpret the data or observations in light of your hypothesis or your own expectations? A good conclusion will have the following parts:

- An explanation of how your hypotheses and expectations reflect the data gathered. Be sure to use the data to reflect on and explain the scientific concepts explored in this lab.

- When both individual data and class average data have been gathered include a comparison of your personal data to the class average data, with an explanation for any discrepancies between the two.

- Sources of Error. You are to analyze and explain any errors that occurred during the lab. Simply stating "human error occurred" is not acceptable. Explain what the human error was. If no known human error occurred to not invent the error. For example, do not state that a mistake may have been made when measuring the solution. Only discuss errors that you know actually occurred. Was the mistake avoidable? Was the flaw in the lab itself? It is always useful to include any procedural changes that would help make the lab more useful.

- Further Research. Now that you have mastered this lab using the specific procedure and materials involved, suggest another experiment that would take you, the scientist, further. You do not actually have to do this other experiment. Use your intellect, and scientific curiosity to suggest further research and investigations that could be done.

Note:
A pre-lab includes parts II and I of this format. For most of your labs the pre-lab will be assigned for completion 2 days prior to the actual lab. You are expected to have the pre-lab neatly completed. Word-processed must be your own. It is a computer violation and cheating to use another persons lab prep. Completion of the pre-lab assignment allows you to enter our pre-lab discussion already familiar with the specific lab concepts and equipment that pertains to each lab.

A lab team that understands the procedure and knows what to expect is less likely to have to come *in during ASP or after school following lab days!*

Appendix I

Student Quotes on Using WEI

Student Quotes on Using WEI

"It is confusing at first but in the end it makes more sense."

"I like the computer things in biology . . . helps me remember stuff better."

"This is really cool."   "Just tell us what to do"   "I don't want to be wrong."

"For the first time in my life I understood this better than the smart kids."

"The computers made it easier but I really didn't like making up labs."

"Put more homework on the internet! A unique way to learn, online just as hard."

"Using the computers take more time. Would (have) liked more information about new subjects."

"Nice to have more individual freedom in the class – you don't have to stick right along with the class, you can go ahead if you understand, but bad for the slackers. Graphics weren't always helpful . . . not always sure what was going on."

"I didn't like using the computer because I don't think I learned much."

"It was hard to keep track of stuff on the computer."

"Working on the computers the second semester was great, sooo (sic) much more interesting than reading out of a boring textbook. All hard work though."

I didn't like the computer (could be that my computer is slow) it was 'more hard' for me to concentrate because of, well, it's the net. But I guess I learned some things."

"Difficulties occur when there are technical problems with the school computers."

"School computers were too slow and would sometimes freeze."

"I don't think the computer helped because I have trouble reading something off a computer screen."

"Less labs – Explain what we should be doing more"   "Just tell us the answer!"

"More class time for discussion after prep." "I wish (the instructor) would help us more."

"I think more class discussion would have helped people to do better on their labs."

Appendix J

Student Sample of Lab Protocol

Sample of Student Lab Protocol

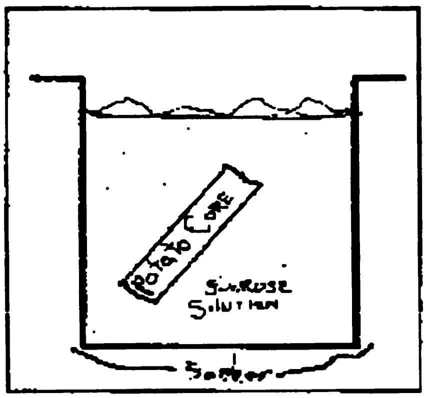
Lab Report – Exercise Three: Potato Cores

Problem: What is the water potential of potato cores? How can we find it with sucrose solution concentrations and potato cores gaining weight? **Response:** I think these can be solved by finding the changing mass of potato cores and using these to find the equilibrium.

Background Information : Diffusion in the process of molecules moving from a place of high concentration to a place of low concentration. Potato cores are thin rods taken from the center of a potato.

Hypothesis: If (and when!) a potato core is placed in increasing concentrations of sucrose solution, then the **mass of the potato core will increase**. This is because the sucrose solutions are hypertonic when compared to the potato.

Controls
- -Scale
- -Temperature
- -Pressure
- -Potato Source



Materials: Beakers, Potato Cores, Scale, Graduated Cylinders, Sucrose

Procedures: Six potato cores were measured for mass and placed in six different prepared solutions of water and sucrose in a beaker (0, .2, .4, .6, .8, 1.0). They were left in there for five hours, and then removed and measured for mass again. Multiple trials should be conducted for accuracy, but we didn't.

Observations: In observing, data was collected on the mass of the potato cores. Before, they weighted, respectively, 4.0, 4.0, 4.1, 4.1, 4.0 and 4.1 grams. After five hours of soaking in a sucrose solution, they had changed to the following, respectively: 5.5, 4.9, 4.5, 4.0, 3.8 and 3.9 grams. The difference and percent of change is recorded below.

Data Table Exercise 3

	0 M	.2 M	.4 M	.6 M	.8 M	1.0 M
Mass Before (g)	4.0 G	4.0 G	4.1 G	4.1 G	4.0 G	4.1 G
Mass After (g)	5.5 G	4.9 G	4.5 G	4.0 G	3.8 G	3.9 G
Difference	1.5 G	.9 G	.4 G	-.1 G	-.2 G	-.2 G
Percent Increase	38 %	23 %	10 %	-2 %	-5 %	-4.2 %

From the graph and the points plotted on it from the data table, I was able to determine the point of equilibrium, which was a molar concentration of .648 (This is an approximation). With this, I was able to multiply the particle amount of sucrose (1), the concentration, or equilibrium (.648), the pressure constant (.0831), and the Kelvin temperature of the room (300), which would yield the solute potential of the potato core:

$$- (iCRT) = \text{Solute Potential}$$
$$- \quad (1 \times .648 \times .0831 \times 300) = -16.15$$

When added to the pressure potential, which is zero, we get the same answer for water potential. –16.15. This means that the amount of water and mass a potato core can hold when fully saturated, is 16 times the amount of water and mass when compared to it when it has no water. In other observations, at the beginning of the experiment, the potato was kind of dry and thin, but by the middle and end of the experiment it had changed and was a little different in size, and of course, moisture.

Graph/Data Analysis: The data from the table and the graph is a representation of the percent change in mass in relation to the molar concentration of sucrose in each solution. And what it means, in the formation it is in, is that as sucrose increases, solution absorption decreases (see conclusions). The data point at 23% is quite off though, as it lies quite out of the way of the trend. Perhaps this can be attributed to an error in the solution or procedure. Overall, the trend of water absorption moves downward as sucrose increases.

Conclusions: My hypothesis was proven incorrect, because the data proved it wrong. I stated that as sucrose increased, so would the amount of water absorbed, but as sucrose increased, it absorbed less (the potato) and actually began to lose water, beginning at a change of 23% in zero sucrose, but by the highest concentration of sucrose, a negative change had taken place. I think this is because the solution became more and more hypertonic, and therefore the potato needed to balance things out and create equilibrium. Although my hypothesis was proven wrong, I did manage to solve the problem of the hypothesis: the water potential of potato cores. As for **sources of error** I do remember (in my procedure) that I laid the potato cores on the table for a moment once, and it most likely picked up something during that time which would have interfered with the data by altering the make-up of the solution. It is unclear what effect this had on the data.

Further Research: I think to further investigate this lab, we could test the level of equilibrium (.648) and see if this is actually correct. In other experiments we could try to find the equilibrium of potatoes in different solutions. I think this would tell us a lot about the permeability and absorbency of potatoes. Which we all know, is vital to the affairs of both ourselves and our posterity. I think, is solutions of less hypertonic-ness, the equilibrium would prove to be lower. A practical application of this is in the construction of bridges, which rely on the knowledge of the expansion and shrinking of materials according to temperature and weather fluctuations.

Appendix K

Statistical Analysis

analysed with: Analyse-it + General 1.62

Test	**Paired samples t-test**
	Group A Treatment
	Osmosis Post-Test ≠ Osmosis Pre-Test - R1
Performed by	Clarence Rudat
Date	28 July 2002

n 41

	n	Mean	SD	SE
Osmosis Post-Test	41	4.8	1.8	0.28
Osmosis Pre-Test	41	2.4	1.3	0.20
Difference	41	2.3	1.8	0.28

Difference between means	2.3
95% CI	1.7 to 2.9

t statistic	8.20
2-tailed p	<0.0001

	Group B Control
	Osmosis Post-Test ≠ Osmosis Pre-Test - R1
Performed by	Clarence Rudat
Date	28 July 2002

n 36

	n	Mean	SD	SE
Osmosis Post-Test	36	4.6	2.4	0.40
Osmosis Pre-Test	36	2.7	1.3	0.21
Difference	36	1.9	2.1	0.35

Difference between means	1.9
95% CI	1.2 to 2.6

t statistic	5.50
2-tailed p	<0.0001

analysed with: Analyse-it + General 1.62

Test	**Paired samples t-test**
	Group A Control
	Chromatography Pre-Test ≠ Chromatograhpy Post-Test - R1
Performed by	Clarence Rudat
Date	28 July 2002

n 41

	n	Mean	SD	SE
Chromatography Pre-Test	41	1.2	1.2	0.19
Chromatography Post-Test	41	2.3	0.7	0.11
Difference	41	-1.2	1.1	0.17

Difference between means	-1.2
95% CI	-1.5 to -0.8

t statistic	-6.72
2-tailed p	<0.0001

analysed with: Analyse-it + General 1.62

Test	**Paired samples t-test**
	Group B Treatment
	Chromatography Post-Test - R1 ≠ Chromo Pre-Test
Performed by	Clarence Rudat
Date	28 July 2002

n 35 (cases excluded: 1 due to missing values)

	n	Mean	SD	SE
Chromatography Post-Test	35	2.4	1.0	0.16
Chromatography Pre-Test	35	1.5	1.1	0.18
Difference	35	0.9	1.3	0.22

Difference between means	0.9
95% CI	0.5 to 1.4

t statistic	4.12
2-tailed p	0.0002

analysed with: Analyse-it + General 1.62

Test	**Paired samples t-test**
	Group A Control
	Animal Behavior Pre-Test ≠ Animal Behavior Pos-Testt - R1
Performed by	Clarence Rudat

Date 28 July 2002

n 37 (cases excluded: 5 due to missing values)

	n	Mean	SD	SE
Animal Behavior Pre-Test	37	1.162	0.866	0.1424
Animal Behavior Post-Test	37	2.811	1.450	0.2384
Difference	37	-1.649	1.703	0.2800

Difference between means	-1.649
95% CI	-2.217 to -1.081

t statistic	-5.89
2-tailed p	<0.0001

analysed with: Analyse-it + Ge

Test	**Paired samples t-test**
	Group B Treatment
	Animal Behavior Post ≠ Animal Behavior Pre
Performed by	Clarence Rudat

Date 28 July 2

n 33 (cases excluded: 3 due to missing values)

	n	Mean	SD	SE
Animal Behavior Post-Test	33	3.2	1.5	0.26
Animal Behavior Pre-Test	33	1.3	1.0	0.17
Difference	33	1.8	1.6	0.28

Difference between means	1.8
95% CI	1.3 to 2.4

t statistic	6.57
2-tailed p	<0.0001

analysed with: Analyse-it + General 1.62

Test	**Paired samples t-test**
	Group A Treatment
	Cell Respiration Pre-Test ≠ Cell Respiration Pre-Lab
Performed by	Clarence Rudat
Date	28 July 2002

n 41

	n	Mean	SD	SE
Cell Respiration Pre-Test	41	2.561	1.361	0.2126
Cell Respiration Pre-Lab Test	41	3.488	1.434	0.2239
Difference	41	-0.927	1.649	0.2575

Difference between means	-0.927
95% CI	-1.447 to -0.406

t statistic	-3.60
2-tailed p	0.0009

analysed with: Analyse-it + Ge

Test	**Paired samples t-test**
	Group B Control
	Cell Respiration Pre Lab ≠ Cell Respiration Pre-Test
Performed by	Clarence Rudat
Date	28 July 2

n 35 (cases excluded: 1 due to missing values)

	n	Mean	SD	SE
Cell Respiration Pre-Lab Test	35	3.9	1.8	0.30
Cell Respiration Pre-Test	35	2.6	1.3	0.22
Difference	35	1.3	1.7	0.29

Difference between means	1.3
95% CI	0.7 to 1.9

t statistic	4.50
2-tailed p	<0.0001

analysed with: Analyse-it + Ge

Test	**Paired samples t-test**
	Group A Treatment
	Cell Respiration Pre-Test ≠ Cell Respiration Post-Test - R1
Performed by	Clarence Rudat
Date	28 July 2

n	41

	n	Mean	SD	SE
Cell Respiration Pre-Test	41	2.561	1.361	0.2126
Cell Respiration Post-Test	41	5.366	1.639	0.2560
Difference	41	-2.805	1.569	0.2450

Difference between means	-2.805
95% CI	-3.300 to -2.310

t statistic	-11.45
2-tailed p	<0.0001

Test	**Paired samples t-test**
	Group B Control
	Cell Respiration Post-Test ≠ Cell Respiration Pre-Test
Performed by	Clarence Rudat
Date	28 July 2002

n	32 A(cases excluded 4 due to missing values)

	n	Mean	SD	SE
Cell Respiration Post-Test	32	4.9	1.6	0.29
Cell Respiration Pre-Test	32	2.5	1.2	0.22
Difference	32	2.4	1.7	0.30

Difference between means	2.4
95% CI	1.8 to 3.0

t statistic	7.91
2-tailed p	<0.0001

analysed with: Analyse-it + General 1.62

Test	**Paired samples t-test**
	Group A Control
	Cardio Fitness Pre-Test ≠ Cardio Fitness Post-Test
Performed by	Clarence Rudat
Date	28 July 2002

n	40 (cases excluded: 1 due to missing values)

	n	Mean	SD	SE
Cardio Fitness Pre-Test	40	1.625	1.005	0.1589
Cardio Fitness Post-Test	40	6.525	1.552	0.2454
Difference	40	-4.900	1.614	0.2552

Difference between means	-4.900
95% CI	-5.416 to -4.384

t statistic	-19.20
2-tailed p	<0.0001

analysed with: Analyse-it + General 1.62

Test	**Paired samples t-test**
	Group B Treatment
	Cardio Fitness Post-Test ≠ Cardio Fitness Pre-Test
Performed by	Clarence Rudat
Date	28 July 2002

n	36

	n	Mean	SD	SE
Cardio Fitness Post-Test	36	6.5	1.7	0.28
Cardio Fitness Pre-Test	36	1.3	1.2	0.20
Difference	36	5.2	2.1	0.35

Difference between means	5.2
95% CI	4.5 to 5.9

t statistic	14.73
2-tailed p	<0.0001

analysed with: Analyse-it + Ge

Test	**Paired samples t-test**
	Group A Treatment
	Heart Rate Pre-Test ≠ Heart Rate Post-Test
Performed by	Clarence Rudat

Date 28 July 2

n	41

	n	Mean	SD	SE
Heart Rate Pre-Test	41	1.707	1.101	0.1719
Heart Rate Post-Test	41	2.195	1.100	0.1719
Difference	41	-0.488	1.186	0.1852

Difference between means	-0.488
95% CI	-0.862 to -0.114

t statistic	-2.63
2-tailed p	0.0119

analysed with: Analyse-it + General 1.62

Test	**Paired samples t-test**
	Group B Control
	Heart Rate Post-Test ≠ Heart Rate Pre-Test
Performed by	Clarence Rudat

Date 28 July 2002

n	36

	n	Mean	SD	SE
Heart Rate Post-Test	36	2.1	1.1	0.19
Heart Rate Pre-Test	36	1.1	1.0	0.17
Difference	36	1.0	1.5	0.25

Difference between means	1.0
95% CI	0.5 to 1.5

t statistic	4.02
2-tailed p	0.0003

analysed with: Analyse-it + General 1.62

Test	**Paired samples t-test** Group A Process of Biological Inquiry Test Post Test ≠ PBIT Pre-Test
Performed by	Clarence Rudat
Date	28 July 2002

n 40 (cases excluded: 2 due to missing values)

	n	Mean	SD	SE
PBIT Post Test	40	27.4	5.5	0.86
PBIT Pre-Test	40	22.0	5.2	0.82
Difference	40	5.4	4.4	0.70

Difference between means	5.4
95% CI	4.0 to 6.8

t statistic	7.74
2-tailed p	<0.0001

analysed with: Analyse-it + Ge

Test	**Paired samples t-test** Group B Process of Biological Iinquiry Test Post-Test ≠ PBIT Pre-Test
Performed by	Clarence Rudat
Date	28 July 2

n 35 (cases excluded: 1 due to missing values)

	n	Mean	SD	SE
PBIT Post-Test	35	27.9	5.0	0.85
PBIT Pre-Test	35	22.2	5.9	1.00
Difference	35	5.8	3.7	0.62

Difference between means	5.8
95% CI	4.5 to 7.0

t statistic	9.24
2-tailed p	<0.0001

Appendix L

Definition of Terms

Active Learning: Process of learning that engages students in exploring ideas and constructing knowledge based on their own observations and experiences as opposed to passive learning in which students experience such classroom activities as: listening to the teacher lecture, watching the teacher demonstrate a science experiment, and copying a teacher's notes.

The Biology Place: A web site used for web-based instructional activities used to enhance biology instruction. The site is written and maintained by Peregrine Publishers. *The Biology Place* was created by teams of leading educators in partnership with Peregrine Publishers to offer students, educators, and anyone with a desire to learn about biology the chance to explore some of its many facets. [i]

Cognitive: Pertaining to knowledge acquisition. Knowledge can be as simple as recall of information or as complex as synthesizing information and deriving conclusions.

Computer-Assisted Instruction (CAI): A method of instruction delivery that uses a computer to deliver instructional programs according to the pace and characteristics of the student. The program software is either on the computer hard drive or is accessed through CD-ROM. This method of instruction is also referred as Computer-based instruction (CBI) and computer-aided instruction.

Constructivism,: A conceptualization of how human beings learn. Understanding is greater and new learning more lasting if learners are active builders of knowledge structures and constructors of meaning, rather than passive recipients of information transmitted to them by teachers. A constructivist approach to staff development models constructivist teaching, learners are active builders of knowledge structures and constructors of meaning, rather than passive recipients of information where teachers guide and facilitate rather than tell or dictate. (Oates, 2001)

Experimental design: A design used to measure the effects of a treatment on the dependent variable by comparing it to a control group.

Experimental group (Treatment Group): A group of selected students who received web-enhanced instruction (WEI).

Control group: A group of selected students who do not receive web-enhanced instruction (WEI). In this study it is the group that is exposed to text-based instruction.

iText: A web-based electronic textbook available from Prentice Hall

LabBench Activities: A set of activities from the web site *Biology.com* that coordinates with the Advanced Placement biology laboratory program. The activities contain animations and interactive questions that help students connect laboratory procedures to the biological principles they are studying.

Learning: A relatively permanent change in performance resulting from practice or past experience. (Kerr, 1982, p.5). Students in this study showed a change in their performance regarding the scientific process.

Performance: A periodic occurrence fluctuating from time to time. It is transitory (Kerr, 1982). Students in this research were assessed by their performance on the pre-test/post--test specific to a particular concepts and/or processes.

Telecommunications: Any method used to communicate or deliver information by electronic means to another location.

Web-based instruction (WBI): This term describes broad methods of delivery in which instructions are delivered over the internet. Web-Based Instruction is interactive and utilizes available multimedia to enhance the level of delivery of instruction (Hall, 1997). Web-based instruction is referred to as web-based learning, interactive distance learning, or internet based instruction (IBI) (McMasters, 1999). They all share the same concept, which is delivering learning to students using the internet.

Web-enhanced instruction (WEI): Web-enhanced instruction is a narrow term for the use of computers and web-based courseware that is used to enhance the traditional face-to-face classroom environment by exposing students to content-specific information delivered over the internet (Sanders 2001). Although these terms are often used interchangeably, it is important to distinguish WEI from WBI. Both are web-based, but WBI often times offers little face-to-face interaction whereas with WEI the majority of instruction is face-to-face interaction. For the purpose of this study WEI is the method used with the treatment group.