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A Comparison of an Integrated, Project-Based Unit and a Traditional Teaching Unit in Content Acquisition and Attitudinal Changes

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Ranae Ikerd

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A COMPARISON OF AN INTEGRATED, PROJECT-BASED UNIT AND A TRADITIONAL TEACHING UNIT IN CONTENT ACQUISITION AND ATTITUDINAL CHANGES

By

Ranae Ikerd

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ABSTRACT

A COMPARISON OF AN INTEGRATED, PROJECT-BASED UNIT AND A TRADITIONAL TEACHING UNIT IN CONTENT ACQUISITION AND ATTITUDINAL CHANGES

By

Ranae Ikerd

Teachers struggle with the issues of student motivation and the most effective methods of teaching content and processes in science. In this investigation a unit designed to balance content and process acquisition and increase student motivation by focusing on the central question: "What are the energy transformations occurring in Lake St. Clair?" was compared to a Biological Sciences Curriculum Study (BSCS) unit in a controlled study of 46 high school biology students. The experimental unit integrated the content topics of photosynthesis, respiration, classification and the lake ecosystem with the process of doing a science project. In an item analysis, significant differences were seen in 4 content questions and 5 attitude items but there were no significant differences in content acquisition or attitude between the means of the two groups.. Fifty-five % of the students in the experimental group reported their favorite experience in the course was the lake study unit.

This is dedicated to future and former students in hopes that they will come to know their world and all its living things.

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Introduction

Several questions are continuously debated among practicing teachers. What is the most effective method of teaching content? Is it more efficient to stress content or process? How can students best be engaged in studying topics of rigorous abstract detail like biosynthetic pathways? Are there any differences in learning by gender in various teaching methods? Must content be sacrificed to teach process?

It was the intent of this thesis to address some of those questions. In this study, the central question was: "What are the attitudinal and learning differences between a traditional Biological Sciences Curriculum Study (BSCS, 1990) unit and an experimental integrated, project-based unit designed during the course of this study?" The experimental integrated, project-based unit included a lake (field) study component at the shores of Lake St. Clair, a student-designed research project and a lecture and reading component in integrated content. There were two areas of integration in the experimental unit as shown in Table 1. Content that would normally be taught separately in a traditional unit was integrated into the experimental unit. In addition, rather than emphasize process or content, it was hoped they could be merged in the design of the experimental unit which revolved around the central question of "What are the energy changes that occur in a lake ecosystem?".

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Table 1. Comparison of Sections

Control	**Experimental**
BSCS text and labs	BSCS text only
2 separate units • photosynthesis and respiration • classification and ecology	**1 integrated unit** • photosynthesis, respiration, classification and ecology
student-designed, directed labs	student-designed research project
NO lake study	lake study
NOT project-based	project-based with a central question

Table 1. These are the fundamental differences between the experimental and control groups in the study.

The integrated experimental content was taught as two or more separate units in previous years and concurrently in the control group in this study. Two separate units consisting of photosynthesis and respiration in one unit and classification and ecology in the second unit were taught to the control group for the analysis of the effectiveness of the unit design. It was anticipated that the experimental group would show increased learning of the desired content and more favorable attitudinal changes based on the results of a pre- and post-test and a pre- and post-attitudinal survey. These expectations were based on a pedagogical literature search and will be supported in that section of this introduction.

Coincidentally in the final year of this study, Lake St. Clair experienced an ecological problem which will be discussed in detail in the historical section of the introduction. The impact of the timing of the disaster was to give the students in the experimental group a sense of relevancy and immediacy for the unit and for their research project. This sense of relevancy and immediacy was lacking in the control group since their research investigation was prescribed in the BSCS format. It was expected that the relevancy and immediacy of the ecological disaster would manifest itself in the topics of investigation the students in the experimental group would choose. If the lake study was meaningful to the students, they would probably select ecologically-oriented research projects to investigate and suggest possible solutions to the ecological probem occurring.

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Pedagogical Background

The design of the experimental unit considered three broadly defined pedagogical concepts: content, motivation and process which is a subset of both domains of content and motivation. If content is defined as the body of information and process is defined as the method by which one acquires or obtains the body of information, motivation would be seen as the desire of the student to acquire the information. The information might be facts in a book or answers to a question the student has. The content might be something the teacher thinks is important or something the student thinks is important. The process might be looking up something in a book or designing an experiment to investigate a hypothesis. It is the contention of this paper that all three are components which are essential to the design of a successful teaching unit.

Whether to emphasize content or process or whether to include student-designed research projects in the curriculum design depends on the philosophy of the teacher and perhaps to some extent upon the amount of experimentation a teacher has done with various teaching methods. Klopfer(1990) breaks down science educators into two categories: those that he calls "professionalists" and those that he "visionaries." According to Klopfer, the professionalist believes that science courses should prepare the students for a professional career in science. A curriculum designed by a professionalist should supply the student with sufficient background in foundation courses, an in depth study of mathematics and an exploration of some application of the principles learned in these courses. Conversely, those who advocate the visionary approach emphasize application of the scientific principles and worry less about a rigorous foundation. Concepts, as the visionary sees it, should be presented on a need-to know basis. It is the attempt of this study to merge these two dichotomous philosophies into the experimental unit so that it provides both the necessary foundation for the professionalist and the application necessary for the visionary.

In preparation for becoming a scientist or an engineer, it has been suggested that students experience mathematics preparation, laboratory and field experience, research projects and teachers with high expectations (US Congress, OTA, 1988). Schools should emphasize participatory versus passive acquisition of content, the various science fields, and various scientific investigatory techniques rather than science as a whole and "The Scientific Method" as the only way for one to be actually doing science.

In current science education, it is held that science should have meaning for students, studying a few topics in depth (less is more) is better than the converse (Rossing, 1988). Science should be integrated with other subjects and instruction should present a balance of content and process (Landes, 1988). It is the intent of this study to address these suggestions with the exception of one. In deference to the professionalists mentioned earlier, to eliminate any content areas might slight the students in the formation of their content base in an area that may be essential to understanding later concepts. In this experimental design, no content or topic areas of curriculum were eliminated, only integrated.

As the unit was being developed, backmapping (AAAS, 1992) was used as a method to determine what content was relevant for the lake study. Backmapping involves looking at the desired outcomes or the desired content acquisition and then proceeding backward to see what prerequisite knowledge needs to be acquired before the desired learning can occur. In this study backmapping was used to determine that understanding photosynthesis and respiration were prerequisite to understanding how energy transformations occurred within an ecosystem.

If "learning is active, not a purely receptive, process in which people construct their own meanings" as Richard White (1988) asserts, then by involving the students in a research project in which they investigate a concrete and meaningful ecosystem to them, they will engage in the learning process. White further suggests that science instruction should include experiences which facilitate learning. In order to do so, the content needs to be sequenced in such a way that prerequisite learning occurs at the proper time. To make learning relevant, the lake unit had to revolve around the content students needed to understand the ecosystem rather than the usual sequencing of separate prescribed topics of textbook units. This would then be in agreement with White's contention that science

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education should assist in maintaining eagerness and provide an opportunity to investigate the natural world.

When discussing the conditions of learning, Gagne (1985) states that the motivation to learn is tied to task mastery and achievement and is intrinsic to the task of learning itself. Rather than postpone learning activities until the student is motivated, he contends that learning activities need to be structured in such a way to promote a feeling of mastery from environmental interaction and the motivation will follow. He suggests informing the learner of the anticipated outcomes, stimulating recall of prior learning and providing learning guidance and feedback in addition to other things. In Outcomes-Based Education, knowing what is expected at the culmination of the unit serves as an intrinsic motivator to the students (Spady, 1992). In the design of the experimental and control units in this study, these considerations were made to the extent that both the experimental and control groups received the anticipated outcomes prior to beginning the unit.

According to Glass (1976), educational research has to be "meta-analyzed", meaning the results of many different but similar studies must be compared to one another. In the past researchers would either attempt to refute the studies that conflicted with their hypotheses or ignore them. Glass recommends reviewing the literature on all studies of related topics. Previously, Kransi (1992) did a similar study where students were involved in a water quality study and found significant attitudinal changes. In the current study, her attitudinal survey was modified so that the responses of the students were qualified as to the

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direction of the attitudinal changes. It was expected that students in the experimental group would have more positive attitudinal changes than the control group if the lake study was indeed a motivator as hypothesized.

Many studies have been done with the BSCS program. Contrary to Saadeh (1973) which showed no advantage to the BSCS program, Leonard (1983) showed that the BSCS program was superior to a highly-directive, well-established "traditional" commercial program. Because of this and because of several successful years of teaching with BSCS, this experimental unit was designed to promote inquiry and discovery in a way that was similar to the BSCS format. Both the experimental and control groups were required to design, conduct and present a report on their research topics.

Because BSCS has been in practice for over twenty years (Besvenick, 1988 and Yager, 1988), perhaps it could be said to be traditional even though there are other curricula that have been used even longer. Hall and McCurdy (1990) compared BSCS to a more traditional curriculum at the post-secondary level in the cognitive and affective domains and found there were no significant differences in attitude or reasoning. In this study both treatment groups showed an increase in formal reasoning but the BSCS group had significantly higher scores in achievement in lab content as measured by their 63-item instrument. It is the intention of the current study to compare a "traditional" BSCS-style program to a more "modern" version of an inquiry-based integrated unit that maintains the integrity of the BSCS. The experimental unit here is a project-based, integrated unit designed for this study.

A great deal of attention has been given in the literature to the premise of hands-on, activity-based teaching strategies being superior to more passive learning modes (Shymansy, 1989). Because of this, hands-on, activity-based teaching strategies were included in both groups of this study. The difference in the project-based, integrated unit's activities is that they are open-ended student-designed which is expected to be a motivating factor in contrast to the control group's directed student-designed lab.

Perhaps a solution to some of the dichotomies in science education like content vs. process or the professionalist vs. the visionary, for examples, would be a merger between some opposing philosophies. Usually the units of photosynthesis, respiration, ecology and taxonomy would be taught separately and independent of one another. In extreme cases, a Biology course or curriculum may even exclude any one of the topics. A basic level course may completely omit the molecular aspect of photosynthesis and respiration while an advanced course may omit taxonomy or ecological relationships. Often the ecology units are at the end of the textbook or curricular guide and get omitted in the event of a time constraint. In any case, no current high school textbooks integrate the topics.

In the traditional laboratory treatment of these topics, again, there is a distinct lack of integration. An additional fundamental difference between the experimental and control groups was the attempt to integrate all of the topics of photosynthesis, respiration and ecology into one cohesive unit including lab work, lecture, discussion and field work in the experimental group. A similar approach was used in The Illinois Rivers Project (Williams, 1990). Further integration occurred in the rivers project when other disciplines, such as English, were assimilated into the experimental design. Williams recommends continued study on the idea of project-driven learning. Similar projects occur in Michigan with the Huron Rouge and Clinton Rivers. To determine the effects of this integration on learning and attitudes about science, a study was undertaken involving students in an accelerated introductory biology course in Grosse Pointe, Michigan.

A Description of the School Setting

The Grosse Pointe Public School System is located in a middle to upper income suburban community which consists of 5 separate cities of Grosse Pointe Park, Grosse Pointe Farms, Grosse Pointe Woods, Grosse Pointe City and Grosse Pointe Shores. The community is located east of Detroit, Michigan, west and south of Lake St. Clair. This investigation occurred at Grosse Pointe South High School, one of two public high schools in the district. South serves approximately 1200 students grades 9-12. The community is rich with resources and the school district has received numerous awards in various areas of distinction.

At South High School, successful completion of one year of each biological and physical science is required for graduation. Although most students at South take Biology (which uses the BSCS Blue, 1990 text) as sophomores, the students in the last two years of this investigation were in special sections of a course called BSCS reserved for freshmen who were in an accelerated science program. These students typically finish in the top 30 % of their class, are in advanced math classes and take advanced placement science courses as upper classmen. Taking the course at the freshman year is an option for students and requires a recommendation from a previous science instructor which is occasionally waived upon the insistence of the parent.

A Historical Perspective of Lake St. Clair

Lake St. Clair is a beautiful member of the Great Lakes chain although it is not considered to be one of the great lakes. It is a mesotrophic lake connected to Lake Huron by the St. Clair River in the north and to Lake Erie via the Detroit River in the south (Mason, 1993). With over 100 square miles of coastal marshes, Lake St. Clair and Lake Erie wetlands support an abundance of wildlife, producing more furbearers than the rest of the lakes combined and a greater diversity of fish stocks with a higher biomass of fish per unit area than any of the other Great Lakes (Mason, 1993). At the northeastern part of the lake, the largest delta system in the great lakes region offers exceptional opportunities for observing waterfowl and marsh birds (Mason, 1993). Much of the original wetlands have been drained for recreational, residential, marine or agricultural purposes and the wetlands that do remain are often diked to prevent seasonal flooding (Mason, 1993).

Even though or perhaps because the total area of the lake is only 28, 400 square miles (1,114 km^2), the lake can experience extreme water level changes when winds gust, causing shoreline property damage (Mason, 1993). Because of this, most of the US lakeside residences have constructed breakwalls which may contribute to the changing ecosystem in the lake. The lake's mean depth is only 10 feet (3 m). The deepest part of the lake is the dredged shipping channel at 27 feet (8 m) but the maximum natural depth is 21 feet (6.4m) (Mason, 1993). Perhaps because it has the largest drainage basin-to-lake surface ratio (11:1 for Lake St. Clair compared to an average of 2:1 in the combined other great lakes) (Mason, 1993), it had been able to sustain the sewage effluent without previous problems prior to 1994. In winter, the lake usually freezes over although ice cutters keep a shipping lane open (Mason, 1993). Ice fishing shanties dot the lake until the first major thaw. Many people in the community use the lake for recreational purposes and all people enjoy its majestic sunrises. The lake is located two blocks due east of South High School. Access to the lake was granted to the experimental group students by the Grosse Pointe War Memorial.

While a great many studies have concentrated on other lakes in the Great Lakes Basin (Davis, 1966; Davis, 1979; El-Shaarawi, 1978; Henson, 1966; Munawar, 1978, Watson, 1978), very few plankton studies have been conducted in Lake St. Clair (Sprules, 1991). Sprules and Munawar (1991) indicate the previous studies on the lake had been done in the early seventies. They showed that the lake in 1984 had low size diversity and hypothesized that indicated a perturbed system. They attributed this to a high flushing rate and contaminant loading from the St. Clair River, resulting in a reduced assemblage of zooplankton. A reduced diversity is often thought of as being indicative of an ecologically stressed environment (USDA, 1988). One of Sprules's sampling sites was an offshore location very close to the site used by the students in this study.

Two major problems occurred in Lake St. Clair in the summer before the final phase of this study (1994). Some public beaches were closed from June 22 through September 3 because of high fecal coliform counts (Fornoff, 1994). The local papers abounded with articles and various media regularly held interviews with various locals and officials who primarily attributed the problems to the upstream release of untreated sewage (White, 1994).

The second problem was the unusual growth of various algal species. This problem was attributed to the presence of an exotic species, the zebra mussel, which first began to appear in the great lakes some years earlier (Mehan, 1995). The various lake communities purchased or rented weed harvesters which were regularly seen near the shore churning up mountains of weeds at a total expense to the state of over $1 million (Mleczko, 1994). The local businessmen complained of lost revenue (Schabath, 1994). Property owners complained of the stench and of the problems associated with boating and other recreational activities in weed infested waters (Schabath, 1995). Joint committees between citizens and officials were formed to study the problem (Puls, 1994). The most predominant theory was that the zebra mussels were filtering the water making it more clear so the sunlight could reach to greater depths and promote plant growth (St. Clair Shores Sentinel, July, 1995).

On occasion the inefficiency of the antiquated storm sewer systems of the local and up river communities was cited as a possible source of the problem (Stealth, 1995). Because of alleged budget constraints, the fecal wastes mixed with storm runoff and were released into the lake by many communities to avoid flooding virtually every time it rained extensively (Stealth, 1995). Another often cited cause of the problem was the use of gutter downspout connections emptying directly into storm drains (Stealth, 1994). Eight hundred out-dated septic tanks and drainage ditches were cited as being contributors to the problems (Stealth, 1994). Almost no one mentioned a correlation between the growth of chemical lawn-care industry and the increased fertile runoff to the lake (Puls, 1994). Community forums were held where citizens were allowed to voice their opinions and question the authorities (Stealth, 1995). People worried their property values would plummet and there was some evidence that lakefront values did dip (Mleczko, 1994). The conditions were expected to worsen (Puls, 1994). Canadian officials warned that the E. coli bacteria could over-winter and create a problem in the following summer (Stealth, 1995).

The ecosystem of the lake was definitely changing (Discovery, 1994). The zebra mussels began to appear in 1986, shortly after Sprules's study (1991). Their effects were first noticed when they began to clog the water intake pipes which caused the shut down of the Monroe municipal water treatment plant (Stealth, 1995). The plankton were supposed to have decreased by 85 percent since 1984 (Discovery, 1994). Each zebra mussel filtered about one liter of water a day each, changing the food chain from a pelagic to a benthic type (Discovery, 1994). The aquatic plants increased from 37 percent to 80 to 90 percent coverage of the lake's bottom (Discovery, 1994).

How would these events affect the students of Grosse Pointe? The students, as residents of the five Grosse Pointe cities have access to beautiful lakeside parks with swimming pools, beaches, boat slips, tennis courts and other amenities. Some students have access to the lake from their yacht club memberships. Would the students in this study be able to assimilate the information, formulate hypotheses and suggest solutions to the problems effecting the lake ecosystem?

This described Lake St. Clair situation provided an opportunity to involve students in an engaging, real-world, authentic problem, defining a vision-driven outcome of significance that would increase the successful learning of the experimental students (Spady, 1992). It was the type of activity that would create students who were perceptive thinkers, collaborative contributors, innovative producers, self-directed achievers and adaptable problem solvers (Rogers, 1992).

Exemplary teachers expect their students to be scientifically literate, to see science as it relates to a variety of situations and problems, to apply their knowledge and to take action to solve problems (Penick, 1986). In a course description of an exemplary Biology program at Shawnee Mission South in Shawnee Mission, Kansas, the teachers use an adjoining 24-acre multihabitat to emphasize the nature of scientific research and environmental sciences. The school joined with local resources to develop a program which facilitates both short-term, open-ended and long-term, individual experimental investigation (Yager, 1983). If exemplary programs utilize the community resources, the time was ripe for involving the students of South High School in helping to research and resolve a community problem; that is the degradation of Lake St. Clair.

Methods

The entire sequence of investigations was run over a course of three years from the fall of 1992 through the spring of 1995. For clarification, Table 2 summarizes the progression of the research over this period.

Table 2. Progress of Research

Year	Label	Summary of Research	Composition of Unit(s)	
1992	**Baseline**	While the units were taught in the traditional fashion, activities, lecture notes, and the units' organization were developed.	• energy • photosynthesis • respiration • classification • biomes	
1993	**Pilot**	The lake study was incorporated as part of the unit as a trial run for the experimental group. Pre- and post-content tests and attitudinal surveys were developed, tested and refined.	• energy, photosynthesis and respiration • classification and ecology	
1994	**Experi-mental**	**Experimental** • data collection **Control** • data collection	**Experimental Unit** • photosynthesis, respiration, energy, classification and ecology	**Control Units** • energy, photosynthesis and respiration • classification and ecology

Table 2. An evolution of the experimental and control units over time.

During the first year, 80 students in sophomore level biological science were taught the unit(s) in a traditional format using the BSCS Blue Version (1990) text, teacher-generated lecture and accompanying laboratory exercises in addition to some teacher-generated supplemental activities. Because it was the first year the instructor taught the course, corresponding tests were developed for each of the separate units of taxonomy, energy, photosynthesis and respiration. The district's prescribed BSCS curriculum was strictly followed. The department chairperson provided guidance and suggested lesson plans. No separate ecology unit as such was taught that year but students prepared group projects on individual biomes at the end of the course.

During the first year of the study beginning in the fall of 1992, the sequence of instruction began with a biochemistry unit which consisted of an introduction to the molecular structure of the biologically significant macromolecules and some of their most common reactions including dehydration synthesis. The biochemistry unit also included an introduction to simple acid/base chemistry and the concept of catalysis. A short energy unit followed, describing ecological relationships in food chains. A brief introduction to evolutionary theory was next and then taxonomy was introduced stressing evolutionary lineages. Photosynthesis and respiration were taught as separate units after a cell biology unit. The cell biology unit included a brief review of cell structure but primarily focused on the specific functions of the organelles and the structures which enabled them. By the time photosynthesis was introduced, the Michigan winter was in its full throes. It was during this year that the instructor sensed an affective detachment on the part of the students in this very important content area of energy transformation. Especially in the areas of the photosynthetic and respiration pathways, low test scores indicated the students struggled cognitively. It appeared there was a genuine need for a restructuring of the units.

During the second year, a pilot program was run in which the energy-related units of photosynthesis, respiration, and ecology were reorganized into a more cogent unit with a more unifying theme. Like Project-Based Instruction (Scott, 1994), the unit revolved around a central question, "What are the energy transformations that occur in organisms in Lake St. Clair?" As a pilot program prior to the actual experimental trial, two sections of freshmen level BSCS courses were taught the reconstructed unit which included several trips to the lake for investigatory purposes. It was the first time the instructor had taken students to a field site for research purposes. At that time, it was thought that a later comparison between the test scores of the students in the second year to those of the first year might be done but because the revamping of the unit was so extensive, it was decided there was no basis for comparison between the measurement instruments on a quantitative level. The students were given a pre- and post-test to evaluate the content acquisition they had learned during the unit. The tests were cumbersome to assess and very subjective and so were completely reconstructed for the actual experimental trial in the third year.

The second year of the study served as a very important lesson for the instructor to practice an entirely different teaching style.

In the second year of the study, during the fall of 1993, two sections of 25 BSCS freshmen students each were taken to the lake on two separate occasions. The students were excused from one additional class period and so were at the lake site for approximately 90 minutes on two separate occasions for sampling, testing and collecting. Prior to going to the lake, students received copies of the instructions for using the LaMotte water quality testing kits. Various water sampling techniques were demonstrated and the students were briefed on the sequence of events occurring through the unit. They were told to report directly to the field site in the morning where they would meet their instructor and begin sampling. The students then walked two blocks to the school for their next class.

Students were randomly appointed to research teams of 4-5 students and were verbally instructed to design, complete and present reports on research projects involving but not limited to the assigned data they were collecting at the site. Each project was required to have a testable hypothesis. At a prescribed due date the team was required to submit one formal paper describing the relevant background information pertaining to the team's proposed hypothesis, a procedural description, the results and a conclusion. The project was presented by the team to the class. The team's presentation was required to be at least 5 minutes in length and needed some sort of audio-visual aid to communicate the results of the study in a graphic mode.

Each team selected a member to fulfill the obligations of the following assigned roles: the communicator, who conferred regularly with the instructor on the group's progress in their research; task master, who monitored the activities of the group to ensure the assigned tasks were being done; resource manager, who obtained and distributed materials for the procedures to the members of the group; secretary, who recorded the progress of the group, passed in papers with verified signatures of all the members; and the data manager who assisted the other members and was primarily concerned that the required data was collected. Each team was responsible for conducting tests on the Water Analysis Report Form (Appendix A) including reporting temperature, odor, observations, turbidity, color, alkalinity, pH, calcium, carbon dioxide, dissolved oxygen, hardness, iron, nitrates, silica and a list of all organisms collected with drift nets or in dredged samples.

In the pilot year, students experienced a great deal of difficulty identifying the various organisms. The identification keys were too complicated for the students' limited patience and available time. It was decided at that time to include taxonomy as part of the experimental unit in the following year. Over the summer, a protocol was designed which included a simplified identification method for their use. The students indicated three limitations with the design of the field study. They requested more time at the site for conducting tests and collecting samples. They were distressed to miss one of their classes in order to do the field study and indicated they would prefer to be on site only during their regularly scheduled class time. Finally, they indicated a need for more test kits.

These feelings were accommodated in the design for the experimental trial which followed the pilot.

During the third year, in the fall of 1994, students from two freshman BSCS sections were included in the final phase of the research study. One section was randomly assigned as the control group. That section's unit was treated in the "traditional" BSCS fashion as described for the first year of the study, being divided into smaller units. These students designed, conducted and presented their experiments without using organisms collected from the lake. Their "unit" consisted of two smaller units of photosynthesis with respiration and taxonomy with ecology. All their experiments were contained in the room and consisted of the prescribed BSCS curriculum including the respiration lab (Appendix B) and the photosynthesis lab (BSCS Blue, 1990).

On the other hand, the experimental group spent five 45-minute periods at the lake during class time collecting organisms, testing for the previously mentioned various abiotic components of the water and setting up any research projects the teams elected to perform. These students were given the same verbal instructions as the previous year's pilot group in regards to the designated roles of the team members and the requirements for the research project.

As much as possible, both sections were taught the same topics and had the same number of days of lecture. Both sections were appointed to the same size working teams for all lab

activities and subsequent reports. All students in both sections were assessed in two areas for their academic record. They were required to take unit tests on the material after the completion of their units. Each team in both sections was required to submit and present a formal report on the nature of its investigations as previously described for the pilot study. For analysis for research purposes, all students were required to complete a pre- and post-experimental attitudinal survey(Appendix C) and multiple choice content test in Appendix D (Kransi, 1992) which were machine-scored. A summary of the experimental design components is included in Table 3.

Table 3. Experimental Design Components in 1994

Group	**Controls** (Similarities between control and experimental groups)	**Variables Tested** (Differences between control and experimental groups)
Control	• unit outcomes • content areas • pre- and post-content test • attitudinal survey • collaborative teaming • free-response exit attitudinal survey • respiration lab • lecture notes and supplementary materials	• NO lake study • BSCS text and labs • 2 separate units • student-designed and directed labs
Experimental	same as control	• lake study • BSCS text only • 1 integrated unit • student-designed research project

Table 3. A comparison between experimental and control groups in design of the respective units.

Both sections of students were informed they were part of a research study and the parents of the experimental group received a letter describing the lake collecting site (see Appendix E). Permission slips were also required for participation in the lake study. Both sections of students and most of the parents (those who attended the Open House evening session) were told that the two sections would not necessarily be doing the same activities. The parents and students were assured at several times that the basis of their academic evaluation would be independent of the research assessment. At no time during the final experimental trial were any of the students informed as to whether they were in the experimental or control group. Students from both sections were interviewed and were presented with several occasions to verbalize any concerns. At the completion of the academic year, students were presented with a free-response attitudinal survey (Appendix F) described later.

The unit under investigation consisted of an integration of photosynthesis, respiration, ecology and taxonomy. The course year began with an introductory biochemistry unit and was immediately followed by the experimental unit. This unit lasted approximately 4 weeks in duration in the experimental year. A comparison of lesson plans of the experimental and control groups is included as Appendix G. As is consistent with most accelerated students in science (DiGisi, 1995), the students of both the control and experimental groups were expected to read corresponding material in the text outside of the class. Both groups received the same supplementary reading materials, lecture notes (see Appendix H), and course outcomes (see Appendix I). The experimental group received copies of the protocols for LaMotte sampling kits in addition to some instructor-designed protocols for lake ecosystem studies (Appendices J, K and L). The control group performed one BSCS photosynthesis laboratory exercise included in their text with some additional requirements prescribed by the instructor as described earlier. Both the experimental and control groups performed a modified an older BSCS respiration experiment with a supplemental worksheet used in the pilot and baseline years.

Both the experimental and control teams were required to design, conduct and present a report on their research topics. One difference between the two groups was that the control group was supplied with materials from a Biological supply company but the experimental group was allowed to manipulate variables in the environment like light or pH to conduct their research.

During the final year of the study, the experimental group students reported to the site 15 minutes prior to the start of the regular school day but were dismissed from the site with 15 minutes of travel time anticipated walking back to the school. Students needed time to deposit any organisms collected at the site in the lab and to get cleaned up before going to their next class. Lake water quality tests were conducted on site. Organism counts were conducted at the lab on the day following the site visit in accordance with the procedures described in the lab protocols. For the same duration of time that the experimental group was collecting, the control group was given time to interact in teams preparing their photosynthesis lab reports.

Students in the experimental group returned to the site on their own time in the evening to do further sampling because of some evidence suggesting diel variations in plankton numbers (Bhattacharya, 1988). One instructor-generated protocol required the students to set out a chemical lightstick at night to see if there was a difference in the numbers and kinds of organisms collected in containers with and without lightsticks. An empirical method (Horn, 1993) was adapted for determining the biodiversity of the collected samples. Each experimental team was required to submit a list of the numbers and the kinds of collected organisms segregated by taxonomic groupings as instructed in the protocol. An additional instructor-generated protocol on the effects of pH on the viability of plankton was distributed to students as an example. The basis for academic evaluation for both control and experimental groups was the final project and the unit test(s) which were separately administered because of the design of the unit. The control group received two separate unit tests at the completion of each of the two separate units and the experimental group received one unit test at the end of the experimental study. In the normal structure of a course at this level, units are generally smaller, shorter and more concise and testing occurs at one to two week intervals. There was no statistical comparison made between the results of the two groups on these sets of tests because they were different assessments and were used for academic assessment purposes only.

In both the experimental and control groups, the final academic assessments consisted of a paper and pencil test and a team presentation of its research investigation. The control

group used the BSCS photosynthesis laboratory exercise which directed the students to design and implement a series of experiments to show which ingredients were necessary for photosynthesis. Each team in the experimental group generated its own investigation at the site which required including a testable hypothesis. The project assessments for the experimental group consisted of a combination teacher, self and peer Rubric (an assessment checklist) which evolved over the two years of using the lake study as a research project (See Appendix M). This assessment was given the same weight as a test. The team projects in the control group were graded in the normal fashion, being weighted equivalent to normal labs or homework assignment grades. All students were provided with a copy of the Rubric several days prior to the presentation of the project so that they were fully aware of the evaluation process.

Prior to beginning the unit, both groups were given a 40-item pre-test which consisted of multiple-choice questions on classification, photosynthesis and respiration. At the same time, the pre-experimental attitudinal survey was administered to both treatment groups. At the completion of the unit, the same two tests were administered as post-tests to both control and experimental groups.

The tests were machine-scored and the data were hand entered onto an SPSS/PC+ file where the means were analyzed for the .05 level of significance using the student's t-test. For the attitudinal survey, the responses were scored in such a way to show no change in attitude, an improvement in attitude or a decrease in attitude for each question. The pre-attitudinal survey was used as a baseline score for each student. If the attitude changed, the direction but not the magnitude of the change was recorded. If for example, on pre-attitudinal survey opinion question number 16, the student rated working in teams as a 2 closer to "strange" and after the unit, scored it as 3, moving the attitude closer to "familiar", which would be the desired outcome, this would have been scored as an attitudinal improvement. A movement in the opposite direction would have been scored as a negative attitude. See Appendix C for a listing of the directions in which effected the attitudinal direction scoring. The mean scores were then separated by gender for pre-test and post-test scores. An student's t-test item analysis was then performed on the test scores. Finally, a chi square analysis was also performed on each item in the attitudinal survey.

The research topics of the pilot teams of 1993 were compared with the topics selected by 1994's experimental group to see if the ecological problem in the lake would have any effect on the interest or motivation of the students to investigate ecological issues. The proposed topics of 1994 were used as a basis of comparison because they would be more reflective of the students' naive perception of the lake ecology before their experience at the sampling site impacted their thinking.

At the completion of the final year of the investigation, students were given a survey (see Appendix F) in which they were asked to rate the course in a variety of areas and then asked to respond to several open-ended questions. The survey was distributed on the last day of class. The students were assured the survey was completely anonymous and were instructed to leave the survey in a brown paper envelope upon exiting the room. While no statistical analyses were done of these responses, the results are summarized in the following section. Only two of the questions on the exit survey directly related to the topic of this study. Only the questions asking the student to describe his or her most favorite unit and the question asking the student to give the most challenging topic were tallied. Since this was a free-response type survey, related categories were grouped in the same response. For example, one student said the nervous system was the most challenging unit and another indicated the endocrine system. Both of these were grouped in the human body category. If a student listed a sub-topic of a unit, it was also scored as a main unit. For example, responses indicating the Kreb's cycle or the Calvin cycle were grouped with the photosynthesis and respiration unit.

Results

It was expected that students in the experimental group of the 1994 study would design some ecologically related, controlled studies. Although students in the experimental group could have elected to do simple diel comparative studies and probably observe results in oxygen concentrations (Khillare, 1987), for example, none of them did so. During the pilot program, some of these types of studies were done and it was evident the students were capable of designing complex research studies. In contrast to the pilot program, in the third year, students appeared to have difficulty adapting previously collected samples and data to design and conduct a simple experiment. In general, the project presentations in the experimental group of 1994 were disappointing. The project presentations of the control group were of consistently higher quality but because the parameters of the assessments were different, no quantitative comparisons were made. The project grades for the experimental group are listed in Appendix N. The mean score for the projects was 78.3 (out of 100 possible points) and the standard deviation was 6.55. See Table 4 for the hypotheses for each of the teams' projects in the Pilot and Experimental years.

Table 4. Team Research Project by Year

1993 Pilot Teams	1993 Completed Topics	1994 Experimental Teams	1994 Proposed Topics
Team 1	Is the concentration of iron greater near the shore or farther from the shore?	Freaks of Nature (Team 1) consisting of students numbered 14,11,5,12 and 18	Fecal Bacteria
Team 2	Does the DO change over time?	High Energy Team (Team 2) consisting of students numbered 7,9,17,4 and 19	Test and observe pond life and seaweed
Team 3	How long can organisms survive without oxygen?	Team 3 consisting of students numbered 20,1,2,6 and 3	Test for pollution in different parts of the lake. We think there will be more pollution closer to shore.
Team 4	The kinds of organisms that eat each other	Team 4 consisting of students numbered 23,10,16 and 22	The amount of pollution and how it causes the decline of living organisms.
Team 5	Are DO and CO_2 related?	Team 5 consisting of students numbered 21,8,13 and 15	Something with pollution and how it affects marine life.

Table 4. The topics selected by various teams in the pilot and experimental years.

Most projects in the experimental group later evolved to a more testable design. Freaks of Nature (Team 1, 1994) varied the pH of the collected organisms and recorded viability counts. Team 5 of 1994 constructed an experiment where one fish lived in lake water and one fish lived in tap water in separate bowls and watched to see which fish would die first. The equipment for fecal or coliform bacteria counts was not available but the Team 4 of 1994 did not subsequently prepare a substantive project. Team 3 of 1994 did not follow through experimentally and later changed their design to comparing the abiotic factors in tap water to those in lake water. Team 2 of 1994 compared counts of organisms in the lagoon to counts collected from the lake.

The pre-test, post-test, and gain scores for the experimental group are shown in Appendix N along with the numbers of unchanged, and positive and negative attitudinal changes. Appendix O gives the same data set for the control group. The analysis of data from the Pre-test and Post-test and the attitudinal surveys are summarized in the following tables for 1994. Table 5 shows the descriptive data for the pre-test, post-test, gain scores (showing the increase in number of correct responses from the pre- to post-test), and the results of the analysis of the attitudinal surveys.

Table 5. Descriptive data for the pre-test, post-test, gain scores and attitudinal surveys in 1994

	Experimental N=22			Control N=24		
Measurement Type	**Mean**	**Standard Deviation**	**Standard Error of the Mean**	**Mean**	**Standard Deviation**	**Standard Error of the Mean**
Pre-test	16.6	3.80	.810	16.3	4.88	.997
Post-test	27.2	6.11	1.30	27.6	4.48	.914
Gain Scores	10.5	5.66	1.21	11.4	5.52	1.13
Unchanged Attitudes	49.1	9.19	1.96	50.7	9.69	1.98
Positive Attitudinal Changes	18.1	5.91	1.26	17.8	7.56	1.54
Negative Attitudinal Changes	17.7	5.73	1.22	16.5	8.36	1.71

Table 5. The means, standard deviations, and standard errors of the mean of the pre-test, post-test, gain scores, unchanged attitudes, positive attitude changes, and negative attitude changes of the experimental and control groups of 1994.

The Student's T-test shows that the difference between the variances of the experimental and control groups are not statistically significant in any of the measured areas. In other words, statistically speaking, there is a 99.9% probability that the scores come from students within the same population sample. Table 6 summarizes the analysis of variance for the measurements.

Table 6. Analysis of variance for the pre-test, post-test, gain scores and attitudinal surveys in 1994

Measurement Type	T	df	2 Tail Sig.	SED	95% CI
Pre-test	.30	44	.77	1.3	(2.2 - 3.0)
Post-test	.28	44	.78	1.6	(3.6 - 2.7)
Gain Scores	.50	44	.62	1.6	(4.2 - 2.5)
Unchanged Attitudes	.55	44	.59	2.8	(7.2 - 4.1)
Positive Attitudinal Changes	.17	44	.87	2.0	(3.7 - 4.4)
Negative Attitudinal Changes	.17	44	.58	2.1	(3.1 - 5.5)

Table 6. An analysis of variance of the means of the pre-test, post-test, gain scores, unchanged attitudes, positive attitude changes, and negative attitude changes of the experimental and control groups of 1994 shows there are no significant differences between the experimental and control groups.

In an item analysis only 4 of the 40 multiple choice content acquisitions as measured on the post test showed a significant difference between the control and the experimental group at the .05 level. Those were numbers 7, 11, 24 and 40 (Appendix B) as shown in Table 7 below. Questions 7, 11 and 40 favored the experimental while the experimental group significantly outscored the control group on question 24. Although not significant, the experimental group was very close to outscoring the control group on questions 22, 31 and 32.

Table 7. Significant Differences in Scoring by Item on the Post-test by Group in 1994

Item Number	Test Item	Group Favored	T Value	Significance
7	Which of the following would be examples of homologous structures?	control	3.46	yes
11	A family includes closely related...	control	2.96	yes
22	The net yield of ATP's in glycolysis is...	experimental	1.77	not
24	The part of cellular respiration that involves the use of oxygen is...	experimental	2.60	yes
31	The process by which organisms produce energy from metabolizing glucose or other macromolecules would be...	experimental	1.65	not
32	The process by which organisms use light energy to produce glucose and other sugars is called...	experimental	1.73	not
40	Which of the following is true with regards to ATP? C. energy is given off when a phosphate is removed.	control	2.10	yes

Table 7. Significantly different content post-test questions between the experimental and control groups of 1994 show both experimental and control groups favored on various items.

In a chi square analysis by item of the change in responses between the pre- and post-attitudinal surveys, 5 of the 80 items showed a significant difference at the 0.05 level. Those differences were on items numbered 14, 18, 29, 61, and 63 on the survey (Appendix C) as summarized in Table 8 below.

Table 8. Significant Differences in Attitudinal Changes by Item in 1994

Item No.	Item	Chi Square	Same E	Same C	Pos E	Pos C	Neg E	Neg C
14	Laboratory Activities (Dangerous...Safe)	9.27	9	20	7	3	6	1
18	Working in Teams to Solve Problems in Class (Dull...Fun)	7.76	8	6	12	7	2	11
29	Waste Recycling (Strange...Familiar)	6.65	18	15	2	9	2	0
61	Our Local Rivers and Lakes (Polluted...Clean)	6.33	10	17	7	1	5	6
63	Our Local Rivers and Lakes (Important...Unimportant)	6.33	22	18	0	2	0	4

Table 8. Significantly different attitude changes between the experimental and control groups of 1994 show the experimental group changing more favorably in the areas of the cleanliness of the lake and working in teams than the control group.

There were no significant differences between the genders in either group in pre-test, post-test, or gain scores. The gain scores are tabulated by gender for the control and experimental groups in Table 6 below. There were also no detectable differences in attitudinal responses.

Table 9. Average Gain Scores by Gender in 1994

Gender	Experimental N=22	Control N=24
Male **N=22 Total** **N=12 E, N=10 C**	8.4	11.1
Female **N=24 Total** **N=10 E, N=14 C**	13.1	11.6

Table 9. This table shows the mean scores for experimental and control groups separated by gender.

The analysis of variance for the gain scores for each group segregated by gender is summarized in Table 10.

Table 10. Analysis of Variance of Gain Scores by Group and by Gender in 1994

Source of Variation	Sum of Squares	Degrees of Freedom	Mean Square	F	Significance of F
Main Effects	78.8	2	39.4	1.32	.277
Group	2.90	1	2.90	.097	.757
Gender	70.9	1	70.9	2.38	.130
2-Way Interactions	50.0	1	50.1	1.68	.202
Explained	129	3	42.9	1.44	.244

Table 10. The analysis of variance of the gain scores by group and gender shows no significant differences between the mean scores of the males and females in the experimental group or between the mean scores of the males and females in the control group. There is no difference between the control and experimental group mean scores of either sex.

The results of the student exit survey are tallied in Tables 11 and 12 below. In the experimental group, there were twenty-two respondents and in the control group, 24 surveys were recorded. Not all students answered all questions. The percentages were based on the number of responses in that group for that particular question rather than based on the total number of respondents.

Table 11. Results of the Student Exit Survey:
Favorite Experience in the Course in 1994

	Experimental Group N=22	**Control Group N=24**
Lake Study Unit	55%	0%
Fetal Pig Dissection	23%	46%
Laboratory Work/ Microscope	9%	25%
Plants	9%	4%
Anthropology/Human Evolution	5%	0%
Cell Biology	0%	4%
Grading System/ Getting a Good Grade	0%	16%
Mid-term Review Game	0%	4%

Table 11. In the student exit survey, 55% of the respondents in the experimental group mentioned the lake study unit followed by the dissection. In the control, most respondents selected the dissection, followed by laboratory work.

Table 12. Results of the Student Exit Survey
Most Challenging Material or Topic in the Course

	Experimental Group N=22	**Control Group N=24**
Photosynthesis and Respiration	33%	32%
Human Systems	15%	4%
Modern Genetics/ Genetics	33%	44%
Plants	10%	0%
Evolution	5%	0%
Biochemistry	5%	16%
Taxonomy	0%	4%

Table 12. The experimental and the control groups are similar in rating photosynthesis and respiration unit as being the most material or topic along with genetics.

Discussion

Since the experimental group's research projects and the photosynthesis projects of the control group were assessed differently, no comparison between the two group's project grades would be valid. Although attempts were made to guide the experimental group students to design an experiment that was simple and contained a testable hypothesis, students resisted and generally performed immature work. While the original proposed hypotheses were initially exciting, most of the teams did not bring the project to completion in the desired state of acceptability. The designs were severely limited which was not the case in the pilot study. Considering these students were supposedly an elite group of high school freshman and there have been more sophisticated grade school science projects, it was disappointing. After introducing experimental design, rather than veto the ideas outright, the students were informed that a valid experiment could be designed and several suggestions were made but many students in the experimental groups stuck with the original limited designs or fashioned something trivial. What is clear is the choice of proposed hypotheses in the experimental reflect the relevancy of the problems with the lake ecosystem to the students.

Science instructors have continued to struggle with the best methods for teaching students to solve complex problems (Shaw, 1983). The results of this study show a difficulty in getting students to design a viable project. Shaw (1983) included observations, predictions, measurements, classification, inference, and collecting and recording data as basic processes that are needed in order to be able to use the integrated processes of interpreting data, controlling variables, operational definitions, formulating hypotheses and experimental designing which are necessary for problem-solving. His studies at the middle school level show that there is a hierarchical relationship between these processes. The learning of the basic processes precludes the integrated processes. The implications for the results of the experimental unit are that either not enough teaching occurred at the basic level prior to the inception of the experimental research project or not enough learning occurred on the part of the experimental students. This also lends further support to the concept of Constructivism (Prawat, 1992) which suggests a teacher find where the students are and construct a lesson to take them from that place to where the teacher wants the students to be. If this experimental study had begun with an attempt to determine at what process level the students were, scaffolding (Berkheimer, 1993) would have helped to bring them to the level necessary for the desired amount of sophistication in their research design. More teacher input as the project was developed would probably have resulted in better project designs (Kimbrough, 1995) but too much may have resulted in a lack of relevance to the student. Teachers struggle with maintaining a balance in this area. In the future, a pre-survey of the presence of basic process skills would show whether scaffolding is necessary.

While it is disconcerting that the evidence does not suggest a significant learning increase for the experimental group, it helps to know that at least no harm is being done in the area of content acquisition by engaging the students in a field study project. In the item analysis, the control group outscored the experimental group on only 3 of 40 questions in a variety of content areas. The 3 questions came from classification and energy content. The experimental group outscored the control group on one question in cellular respiration but came close to outscoring them in an energy question and a photosynthesis question. The variety in the types of items which differ indicate there is not any clear distinction between the types of content that were acquired in either group. More studies would have to be done to get more data in content acquisition in integrated, project-based units.

In the Science Department at Grosse Pointe South High School, only two of the teachers regularly take students on field studies. In anecdotal accounts, there are two reasons cited for this distinct lack of field trips and field studies. One reason is the amount of time it takes from the learning of the content. This study shows the students don't appear to be losing any content by doing a field study.

The second reason teachers don't have field studies is the mechanics of arranging the study. Many districts do not provide transportation for any trips, for example. The amount of effort required to make arrangements for a field study is almost overwhelming, including getting approval from the building administrators; issuing, recording and collecting parental permission slips; contacting the field site and making appropriate arrangements; organizing, transferring and maintaining equipment; soliciting and communicating with adult chaperones; making transportation arrangements, if needed; and supervising and instructing students at the site. One might ask, if the same amount of learning occurs without the field studies, why bother?

When the responses to the exit survey are examined, the answer to this question is clear. Overwhelmingly, the students liked the field study. They liked being at the lake, collecting samples and bringing them back to the lab for further investigation. It was hoped that by integrating the complicated issues of photosynthesis and respiration into an ecology unit, the students would respond more favorably to the abstract concepts on cognitive and affective levels. This doesn't seem to be supported by the results of the survey since both groups responded similarly in the question about the most challenging topic and there was no significant increase in content acquisition in the experimental group.

Both the visionary and the professionalist mentioned in the pedagogical background would agree the process of doing the science is of value. The students experienced first hand the pleasures of sampling in the morning sun, the frustration of watching the sampling syringe sinking away in the clear water, the excitement of seeing microscopic creatures swimming across the slide. In the future, there will be more students from Grosse Pointe South High School doing lake studies. Chemistry students will begin analyzing water samples and next year's students in this class will continue to experience a more refined lake study project.

Constructivists would have it that "good" science teachers help students connect with real world experiences and encourage students to solve problems by taking risks and assuming responsibility for their own learning (Wildy, 1995). If the results of this study are not an isolated event, why would a teacher who uses these techniques be considered "good" and another, who remains in the classroom be considered "bad" even though the same learning demonstrated by students has occurred in both situations? The idea of categorizing teachers as good or bad or as exemplary or mundane because of their teaching style or pedagogical preferences is not supported by the results of this study. It seems that some of the papers that tend to classify instructors and their preferred style are a bit elitist and perhaps judgmental and rarely substantiate their qualifications with solid experimental data. If more learning consistently, not theoretically, occurs in one type of classroom setting, then "good" teachers need to be taught the technique(s). More studies continue to need to be done to determine what conditions foster learning in the science class.

Teachers historically feel compelled to "cover" a certain body of content (Ladewski et al, 1994). Perhaps this is because after entering into a new teaching position, some supervisory or administrative-type person or a colleague or a department chair hands the beginning teacher a curriculum guide that specifies certain areas of required instruction. It may be implied at the time that if the teacher doesn't perform the prescribed job description that he or she may be in jeopardy of losing the new job. In the interest of job security and some semblance of interest in best preparing the students for their future endeavors, science teachers are reticent about deviating from the prescribed curriculum. While they may agree that philosophically, science is investigatory, collaborative and teaches responsibility, teachers are interested in more pragmatic concerns like classroom control, having familiarity and comfort with the processes and content in the course (Ladewski *et al*, 1994) and in ensuring the paycheck will continue.

The means of the attitude improvements and the negative attitudinal changes are very close in both groups. The attitudes of the students in general neither worsened nor improved overall as a result of the study in either group.

In the chi square item analysis, the significant differences occur in several areas. Significant improvements were anticipated in the area of attitudes about the lake, doing lab work, and perhaps about science in general. Items which had nothing to do with either the control or experimental unit like hunting or clearcutting should not have shown any difference in changes. This expectation was consistent with the results. It is interesting to examine the numbers of the students whose groups showed significant attitude changes on the items in Table 5. Thirteen out of 22 experimental students had an attitude change about the safety of laboratory activities. Doing field studies definitely impacted them. It is interesting to note the changes were equally distributed between thinking the activities more safe or more dangerous.

Another significant attitudinal difference worth noting is the pleasure students from the two groups experienced from working in their respective teams. The experimental students overwhelmingly responded more favorably to their experience while the control students mostly became less favorable toward working in teams.

In the area of waste recycling, for some inexplicable reason the control group became more favorable toward it while the experimental group remained fairly consistent with its attitudes toward it. Since this was not one of the content or process study topics in either group, no change was anticipated.

Finally, in analyzing the data for the statistically significant items concerned with the lake's pollution, the experimental group improved its attitude after testing the water but the only attitudes that changed in regards to the importance of the water were in the control group. These numbers were small but statistically significant because none changed in the experimental group.

In this study, the teacher was excited about undertaking a study in which students might get motivated to learn content that was rated by students as challenging. Initially, it appeared their parents were not so excited nor supportive. Within the first few days of the study, a group of parents became quite vocal about their misgivings of the study. While no concerns were raised at the Open House when parents were informed their students were part of a study, phone calls ensued during the entire four weeks of the study. The first parent who called was concerned that the students had been talking and thought that since they were part of the study, less learning would occur in one group and their grades would be consequently or incidentally be affected by this. All parents were reassured that this was not the case.

The experimental group had several major behavioral problems during the remaining year which may relate to the results of the study. The unusual nature of these occurrences merits mentioning. In 16 years of teaching, these types of behaviors have not been seen in a course of this type to the extent that they were seen in the experimental group. Several of the girls blatantly plagiarized from a teacher's manual which was evidently provided to the girls by one of their parents. A group of boys were banned from working together in the laboratory because of repeated attempts to copy answers from other students and for improper use of laboratory equipment. Several students were disrespectful toward the teacher and were issued counselor referrals.

Another occurrence involved a different student who misrepresented a classroom discussion. During an ensuing conference, the parents commented unfavorably about the teacher and stated these opinions were formed at the first Open House meeting when the idea of the study was introduced to the parents. It was clear they had formed their opinion based on rumors that were circulating in regards to the assessment of the students in the study. The implications of these occurrences for the results of this study are that if the students in this group were for some reason behaviorally different from their counterparts in the control group, this may have made them more or less likely to learn or change their opinions as a result of the study.

Although not statistically analyzed, the quarter grades of the students in the experimental group were consistently lower than those of the control group. For example, in the fourth quarter (purposely selected because it wasn't part of the study), 68% of the control group got A's for the marking period but the experimental group only had 24%. As the results show there is no distinguishable difference statistically between the variance of the experimental students pre-test scores and that of the control group, it was assumed they were from the same population sample. With mathematics course placement and the students' quarter grades in mind, it might be suggested that perhaps the were not the same and the experimental group had some cognitive or attitudinal limitations not shown in the control group. If this was the case, repeated studies might show significant differences in favor of the experimental group.

The limitations of a controlled study in a high school setting include small samples and the samples are often biased because of scheduling. Most of the students in the control group were placed in a super-accelerated math course while most of the students in the experimental group were in an "ordinary" accelerated math class. Some of the students in both groups were not in an accelerated math class at all. If the study group samples were biased and the control group learned more because of some intrinsic or innate increased learning capacity (as possibly indicated in their mathematics placement), the insignificant difference in the change in scores between groups might have manifested itself as significant in favor of the experimental condition with an unbiased sample with more similar groups.

Further investigatory work in this area needs to be undertaken. The results of this study, while interesting, may not be consistent with other studies. Despite the limitations of doing research on learning and attitudes in high school settings, long-term investigations need to continue. More research needs to be done to examine the cognitive pathways connecting processing and knowledge base to problem-solving (Lavoie 1993). How else can one objectively analyze the learning and attitudinal consequences of the different pedagogical concerns? Krajcik *et al* (1994) recommend experiencing project-based instruction in a collaborative setting but offer no experimental evidence to support increased learning with this method of instruction. From this researcher's perspective, collaboration would have been helpful but simply talking about why the method was favorable may not be sufficient to persuade others to engage in this demanding teaching practice. Solid evidence supporting increased learning or at least attitudinal changes in conjunction with collaborative work would do so.

While there were no statistically significant differences between genders in the experimental and control groups, there appears to be a trend worth noting for further research. It appears that females tend to do better than males with the field study as part of their curriculum. This is consistent with the Office of Technology report (US Congress, 1988) which suggests that certain teaching methods including field studies and group projects encourage girls in science. With a larger sample size, such as $N > 150$, the reported difference in scores could take on statistical significance. This provides support to the idea of replication in learning studies. While it was not the intent of this study to examine the effects of integration of curriculum with project-based instruction on gender-differentiated learning, these results are interesting to note.

In conclusion, one of the benefits of field studies was evidenced in the responses on the exit surveys of the experiment students. They were able to learn the same content as the control students even while spending 5 of the days of the unit at the lake. They enjoyed the unit even while experiencing challenging subject matter. In the future, more emphasis will be made on teaching the students to design testable hypotheses with data collected at the field site. Better interaction with the group communicators and the instructor will help improve the teams' experimental designs. Doing a field study serves a valuable function in science education. It allows the students to do what many scientists do, interact with variables in the environment, collect and observe various life forms, design and conduct experiments, and study a relevant ecosystem. Field studies should be encouraged in science education and supported by all educators.

Appendices

Appendix A.

Water Analysis Report Form

Water Analysis Report Form

Team Name: Site:	Team Number: Weather:	Team Members 1. 2. 3. 4. 5.	Period___ Date:
Characteristic/ Test	**Result/ Observation**	**Characteristic/ Test**	**Result/ Observation**
Odor		**Alkalinity**	
Turbidity		**pH**	
Color		**Calcium**	
Temperature		**Carbon Dioxide**	
Silica		**Nitrates**	
Dissolved Oxygen		**Hardness**	
Iron		**Observed Organisms**	

Appendix B.

Respiration Lab: Do Living Things Produce a Common Substance?

Do Living Things Produce a Common Substance?

Name____________________________

Period___

PROCEDURE: For tubes 1-7, add 5 drops of phenol red and a screw to each tube, then as your teacher directs, add a screw to each tube with the head of the tube facing up in such a way that when the other items are added, they will not be in the solution. To the appropriate tube, add each of the substances listed. Cap each tube. For tubes 8-10, add 10 drops of phenol red to each tube, then add the indicated substance. For tubes 11-13, use limewater instead of phenol red. For tubes 10 and 13, use a straw to gently blow bubbles through the solution until a change is observed. **CAUTION!** Do not inhale or ingest the substances. Record your observations in the data table and answer the discussion questions.

Tube	Contents	Observation	Tube	Contents	Observation
1	Nothing		8	5 drops acid	
2	Yeast		9	15 drops soda	
3	Boiled Yeast		10	Bubbles	
4	Dry Seeds		11	5 drops acid	
5	Sprouted Seeds		12	15 drops soda	
6	Live Insect		13	Bubbles	
7	Dead Insect				

DISCUSSION QUESTIONS: Answer the following using complete responses. Be sure to use complete sentences in your responses. Remember to elaborate, explain and give examples.

1. Soda contains carbon dioxide (CO_2) dissolved in water. According to your results from tubes 8 and 9, what kind of substance (acid or base) does CO_2 form when it is dissolved in water?

2. If a certain substance causes a color change in phenol red like that in tube 9, can you conclude the substance contains an acid? Can you be certain it contains CO_2 ? Justify your responses.

3. What evidence supports that your breath forms an acid when mixed with the water of the phenol red solution?

4. Judging from your results in tubes 10 and 13, does your breath contain CO_2? Explain.

5. In what way(s) did the substances that produced change(s) in tubes 2-7 differ from those that did not? How does this relate to a definition of life?

6. What hypotheses can you give to account for the color change(s) in some of the first seven tubes?

7. What is the function of tubes 8-13 in explaining the changes that occurred in tubes 1-7?

8. You may have heard people say that plants consume CO_2 and produce O_2. Describe how the data in this lab do not support this idea.

Appendix C.

Attitudinal Survey

Pre- and Post-Attitudinal Survey
Student Copy
Opinion Survey About Science

Darken the number of the response which best corresponds to your feelings in each category at the appropriate number on your answer sheet.

Science

1.	Strange	1	2	3	4	5	Familiar
2.	Good	1	2	3	4	5	Bad
3.	Dull	1	2	3	4	5	Fun
4.	Interesting	1	2	3	4	5	Boring
5.	Easy	1	2	3	4	5	Difficult
6.	Unimportant	1	2	3	4	5	Important
7.	Career	1	2	3	4	5	Hobby

Laboratory Activities

8.	Strange	1	2	3	4	5	Familiar
9.	Good	1	2	3	4	5	Bad
10.	Dull	1	2	3	4	5	Fun
11.	Interesting	1	2	3	4	5	Boring
12.	Easy	1	2	3	4	5	Difficult
13.	Unimportant	1	2	3	4	5	Important
14.	Dangerous	1	2	3	4	5	Safe

Working in Teams to Solve Problems in Class

15.	Good	1	2	3	4	5	Bad
16.	Strange	1	2	3	4	5	Familiar
17.	Unimportant	1	2	3	4	5	Important
18.	Dull	1	2	3	4	5	Fun
19.	Useful	1	2	3	4	5	Wasteful
20.	Busy	1	2	3	4	5	Quiet
21.	Difficult	1	2	3	4	5	Easy

Scientific Method

22.	Strange	1	2	3	4	5	Familiar
23.	Good	1	2	3	4	5	Bad
24.	Dull	1	2	3	4	5	Fun
25.	Interesting	1	2	3	4	5	Boring
26.	Easy	1	2	3	4	5	Difficult
27.	Unimportant	1	2	3	4	5	Important
28.	Useful	1	2	3	4	5	Unnecessary

Waste Recycling

29.	Strange	1	2	3	4	5	Familiar
30.	Good	1	2	3	4	5	Bad
31.	Important	1	2	3	4	5	Unimportant
32.	Easy	1	2	3	4	5	Difficult
33.	Necessary	1	2	3	4	5	Unnecessary

Lawn Fertilizing

34.	Strange	1	2	3	4	5	Familiar
35.	Good	1	2	3	4	5	Bad
36.	Permanent	1	2	3	4	5	Temporary
37.	Easy	1	2	3	4	5	Difficult
38.	Necessary	1	2	3	4	5	Unnecessary
39.	Dangerous	1	2	3	4	5	Safe

Hunting

40.	Strange	1	2	3	4	5	Familiar
41.	Good	1	2	3	4	5	Bad
42.	Dull	1	2	3	4	5	Fun
43.	Interesting	1	2	3	4	5	Boring
44.	Easy	1	2	3	4	5	Difficult
45.	Unimportant	1	2	3	4	5	Important
46.	Career	1	2	3	4	5	Hobby

Wildlife Management

47.	Strange	1	2	3	4	5	Familiar
48.	Good	1	2	3	4	5	Bad
49.	Dull	1	2	3	4	5	Fun
50.	Interesting	1	2	3	4	5	Boring
51.	Easy	1	2	3	4	5	Difficult
52.	Unimportant	1	2	3	4	5	Important
53.	Career	1	2	3	4	5	Hobby

Clearcutting Forests (this means clearing part of a forest by cutting all the trees down)

54.	Good	1	2	3	4	5	Bad
55.	Strange	1	2	3	4	5	Familiar
56.	Unnecessary	1	2	3	4	5	Necessary
57.	Ugly	1	2	3	4	5	Beautiful
58.	Useful	1	2	3	4	5	Wasteful
59.	Permanent	1	2	3	4	5	Temporary
60.	Safe	1	2	3	4	5	Dangerous

Our Local Rivers and Lakes

61.	Polluted	1	2	3	4	5	Clean
62.	Beautiful	1	2	3	4	5	Ugly
63.	Important	1	2	3	4	5	Unimportant
64.	Drinkable	1	2	3	4	5	Undrinkable
65.	Uninhabited	1	2	3	4	5	Inhabited

Read each of the following statements carefully. Darken the corresponding mark on your answer sheet which best describes your feelings about the statement.

66. Most people can leave science to the experts and do not need to understand how science works.

67. In order to solve a problem scientifically, scientists should not use information (data) unless they have collected it through their OWN research.

68. Careful observation is less important in modern science since the development of new instruments like the electron microscope.

69. Science deals with all problems and it can provide answers to all questions.

70. The knowledge of science is final.

71. A good scientist must have the ability to ask the right questions.

72. A scientist should only do research on those projects that will provide something useful.

73. Since a measurement involves the of numbers, it rarely can be wrong.

74. Scientists assume that if events A and B occur at the same time, then one must be the cause of the other.

75. Good science does not require that scientists share their findings with other scientists.

76. A good scientist always defends fellow scientists and their scientific ideas when others say they are wrong.

77. Scientists do not make errors in their conclusions if they follow scientific processes.

78. To make good decisions about how to use our natural resources (land, forests, wildlife, etc.), we all need to consider is the scientific information.

79. The observations a person makes are influenced by his past experience.

80. If a scientists carefully reports his or her experiment, other scientists will accept the experimental conclusions without question.

81. Hunters today are the cause for most of the decline in wildlife populations.

82. If a scientist measures two variables (such as water temperature and growth of fish) and finds they both increase or decrease together, it proves changes in water temperature causes changes in fish growth.

83. I would like a career working as some type of scientist.

84. I would like a career working with wildlife, forests, rivers, lakes or other natural resources.

85. Big industries lie UpJohn and Dow Chemical are the Michigan polluters and should pay for the clean-up.

Key for Positive Direction Change

A positive sign is placed at the end of each continuum to indicate the direction in which an attitudinal change needed to move in order to be scored as a positive attitudinal change. A move in the opposite direction for that question was scored as a negative change.

Science

1.	Strange	1	2	3	4	5	Familiar +
2.	+Good	1	2	3	4	5	Bad
3.	Dull	1	2	3	4	5	Fun+
4.	+ Interesting	1	2	3	4	5	Boring
5.	+ Easy	1	2	3	4	5	Difficult
6.	Unimportant	1	2	3	4	5	Important +
7.	+Career	1	2	3	4	5	Hobby

Laboratory Activities

8.	Strange	1	2	3	4	5	Familiar+
9.	+ Good	1	2	3	4	5	Bad
10.	Dull	1	2	3	4	5	Fun +
11.	+ Interesting	1	2	3	4	5	Boring
12.	+Easy	1	2	3	4	5	Difficult
13.	Unimportant	1	2	3	4	5	Important+
14.	Dangerous	1	2	3	4	5	Safe+

Working in Teams to Solve Problems in Class

15.	+ Good	1	2	3	4	5	Bad
16.	Strange	1	2	3	4	5	Familiar+
17.	Unimportant	1	2	3	4	5	Important+
18.	Dull	1	2	3	4	5	Fun+
19.	+ Useful	1	2	3	4	5	Wasteful
20.	+ Busy	1	2	3	4	5	Quiet
21.	Difficult	1	2	3	4	5	Easy+

Scientific Method

22.	Strange	1	2	3	4	5	Familiar+
23.	+Good	1	2	3	4	5	Bad
24.	Dull	1	2	3	4	5	Fun+
25.	+ Interesting	1	2	3	4	5	Boring
26.	+ Easy	1	2	3	4	5	Difficult
27.	Unimportant	1	2	3	4	5	Important+
28.	+Useful	1	2	3	4	5	Unnecessary

Waste Recycling

29.	Strange	1	2	3	4	5	Familiar+
30.	+ Good	1	2	3	4	5	Bad
31.	+ Important	1	2	3	4	5	Unimportant
32.	+ Easy	1	2	3	4	5	Difficult
33.	+ Necessary	1	2	3	4	5	Unnecessary

Lawn Fertilizing

34.	Strange	1	2	3	4	5	Familiar+
35.	Good	1	2	3	4	5	Bad+
36.	+ Permanent	1	2	3	4	5	Temporary
37.	+ Easy	1	2	3	4	5	Difficult
38.	Necessary	1	2	3	4	5	Unnecessary+
39.	+ Dangerous	1	2	3	4	5	Safe

Hunting

40.	Strange	1	2	3	4	5	Familiar+
41.	+ Good	1	2	3	4	5	Bad
42.	Dull	1	2	3	4	5	Fun+
43.	+ Interesting	1	2	3	4	5	Boring
44.	+ Easy	1	2	3	4	5	Difficult
45.	Unimportant	1	2	3	4	5	Important+
46.	+ Career	1	2	3	4	5	Hobby

Wildlife Management

47.	Strange	1	2	3	4	5	Familiar+
48.	+Good	1	2	3	4	5	Bad
49.	Dull	1	2	3	4	5	Fun+
50.	+ Interesting	1	2	3	4	5	Boring
51.	Easy	1	2	3	4	5	Difficult+
52.	Unimportant	1	2	3	4	5	Important+
53.	+ Career	1	2	3	4	5	Hobby

Clearcutting Forests (this means clearing part of a forest by cutting all the trees down)

54.	Good	1	2	3	4	5	Bad+
55.	+Strange	1	2	3	4	5	Familiar
56.	+Unnecessary	1	2	3	4	5	Necessary
57.	+Ugly	1	2	3	4	5	Beautiful
58.	Useful	1	2	3	4	5	Wasteful+
59.	+Permanent	1	2	3	4	5	Temporary
60.	Safe	1	2	3	4	5	Dangerous+

Our Local Rivers and Lakes

61.	Polluted	1	2	3	4	5	Clean+
62.	+Beautiful	1	2	3	4	5	Ugly
63.	+Important	1	2	3	4	5	Unimportant
64.	+Drinkable	1	2	3	4	5	Undrinkable
65.	Uninhabited	1	2	3	4	5	Inhabited+

For the True/False section, the "positive" attitudinal response is given. If a student whose attitude changed gave the response not listed, it was scored as a negative change.

66. Most people can leave science to the experts and do not need to understand how science works.
F
67. In order to solve a problem scientifically, scientists should not use information (data) unless they have collected it through their OWN research.
F
68. Careful observation is less important in modern science since the development of new instruments like the electron microscope.
F
69. Science deals with all problems and it can provide answers to all questions.
F
70. The knowledge of science is final.
F
71. A good scientist must have the ability to ask the right questions.
T
72. A scientist should only do research on those projects that will provide something useful.
F
73. Since a measurement involves the of numbers, it rarely can be wrong.
F
74. Scientists assume that if events A and B occur at the same time, then one must be the cause of the other.
F
75. Good science does not require that scientists share their findings with other scientists.
F
76. A good scientist always defends fellow scientists and their scientific ideas when others say they are wrong.
F
77. Scientists do not make errors in their conclusions if they follow scientific processes.
F
78. To make good decisions about how to use our natural resources (land, forests, wildlife, etc.), we all need to consider is the scientific information.
F
79. The observations a person makes are influenced by his past experience.
T

80. If a scientists carefully reports his or her experiment, other scientists will accept the experimental conclusions without question.

F

81. Hunters today are the cause for most of the decline in wildlife populations.

F

82. If a scientist measures two variables (such as water temperature and growth of fish) and finds they both increase or decrease together, it proves changes in water temperature causes changes in fish growth.

F

83. I would like a career working as some type of scientist.

T

84. I would like a career working with wildlife, forests, rivers, lakes or other natural resources.

T

85. Big industries lie UpJohn and Dow Chemical are the Michigan polluters and should pay for the clean-up. F

Appendix D.

Multiple Choice Content Test

Multiple Choice Pre- and Post-Test

Biology Pre-test for Energy Unit
Please place your responses on the scan-tron sheet

1. A group of interrelated organisms that can breed and produce viable offspring would be called
   A. species B. prokaryote C. coacervate D. eukaryote.
2. Which of the following consists of DNA and a protein coat?
   A. species B. prokaryote C. coacervate D. eukaryote
3. Which of the following has organisms whose cells contain membrane-bound organelles like a nucleus
   A. protenoid B. prokaryote C. virus D. eukaryote
4. Structures which have the same evolutionary and embryological origin but may have differing functions are called A. protenoid B. homologous C. virus D. species
5. Cells that lack a membrane surrounding the nucleus are called
   A. species B. prokaryotes C. coacervates D. eukaryotes.
6. According to the Linnean system of classification, the organisms *Acetabularia mediterranea* is most closely related to A. *Mediterranea crassa* B. *Mediterranea crenulata* C. *Cremulata acetabularia* D. *Acetabularia crenulata.*
7. Which of the following would be examples of homologous structures? A. tentacles of a jellyfish and arms of a starfish B. wings of a bat and flipper of a whale C. wings of a bat and wings of a bee D. cilia of a paramecium and hair of a mammal.
8. An organism which has a segmented body, jointed appendages and an exoskeleton made of chitin would belong to which phylum? A. chordata B. porifera C. mollusca D. arthropoda.
9. An organism which has two cell layers and a middle layer of mesoglea, has a life cycle which has a polyp and medusa stages and has tentacles with nematocysts would belong to which phylum? A. Porifera B. Nematoda C. Coelenterata or Cnidaria D. Annelida.
10. The class of Arthropods in which the members have 8 legs, no wings or antennae, spinnarettes, and two body regions would be the A. Insecta B. Arachnid
    C. Crustacean D. none of the above.
11. A family includes closely related A. orders B. classes C. phyla D. genera.
12. The name of the organelles where aerobic respiration occur is the
    A. stroma B. chlorophyll C. mitochondrion D. PGAL
13. The liquid solution in the chloroplast where the dark reaction occurs is called the
    A. stroma B. chlorophyll C. mitochondrion D. PGAL
14. A 3-carbon compound that can be removed to the Calvin cycle or other cellular functions such as synthesis or respiration would be A. stroma B. chlorophyll
    C. mitochondrion D. PGAL
15. The green pigment found in plants would be called
    A. stroma B. chlorophyll C. mitochondrion D. PGAL
16. A type of anaerobic respiration that occurs in yeast would be called
    A. fermentation B. thylakoid C. mitochondrion D. PGAL
17. Which of the following events occur in Photosystem II?
    A. water is split B. hydrogen is produced C. electrons are energized
    D. all of the above.
18. Which of the following events occur in Photosystem I?
    A. water is split B. hydrogen is produced C. electrons are energized
    D. all of the above.
19. Which of the following statements best describes the events occurring in the light reaction?
    A. water is split, electrons are energized and hydrogen is attached to carriers
    B. water is split and carbon dioxide is produced C. electrons are energized and carbon dioxide is fixed D. all of the above.
20. Which of the following best describes what happens in the dark reaction of photosynthesis?
    A. water is split B. hydrogen is attached to carriers C. electrons are energized
    D. carbon dioxide is fixed

21. Which of the following best describes what happens in the Calvin cycle?
A. water is split B. hydrogen is attached to carriers C. electrons are energized
D. carbon dioxide is fixed
22. The net yield of ATP's in glycolysis is A. 2 ATP's B. 4 ATP's C. 8 ATP's
D. 36 ATP's E. 38 ATP's
23. Which of the following statements best summarizes the net result of the Kreb's cycle?
A. oxygen is metabolized B. 1 ATP and 2 CO_2's are produced
C. 38 ATP's and 6 CO_2's are produced D. none of the above.
24. The part of respiration that involves the use of oxygen is A. glycolysis
B. the Kreb's cycle C. the electron transport chain D. all of the above.
25. The raw materials an organism takes in would be called
A. nutrients B. autotrophs B. heterotrophs D. kilocalories
26. Organisms which obtain energy and nutrients from nonliving things would be called
A. nutrients B. autotrophs B. heterotrophs D. kilocalories
27. ATP is an example of where organisms store energy in organic molecules. This kind of energy is known as A. chemical energy B. free energy C. respiration
D. none of the above.
28. Organisms which obtain energy and nutrients from other living things whether living or dead would be A. nutrients B. autotrophs B. heterotrophs D. kilocalories.
29. Which of the following consists of the living things and the nonliving components of a particular area? A. cellular respiration B. photosynthesis C. ATP D. ecosystem
30. The amount of energy required to raise the temperature of a kilogram of water through 1°C is a(n)
A. kilocalorie B. autotroph C. ATP D. ecosystem
31. The process by which organisms produce energy from metabolizing glucose or other macromolecules would be called A. cellular respiration B. photosynthesis C. ATP D. ecosystem
32. The process by which organisms use light energy to produce glucose and other sugars is called
A. cellular respiration B. photosynthesis C. ATP D. ecosystem
33. Organisms that break down and use dead plants and animals for food are said to be
A. producers B. consumers C. decomposers D. none of the above.
34. How organisms change compounds into energy is called their
A. aerobic B. anaerobic C. metabolism D. none of the above.
35. Nonliving components of an ecosystem would be called A. biotic factors B. abiotic factors
C. consumers D. decomposers
36. Reactions that take a more complex compound and break it down into simpler compounds are known as A. aerobic B. anaerobic C. catabolism D. anabolism
37. Organisms such as bacteria and yeast which produce energy from glucose without using oxygen respire in which fashion? A. aerobically B. anaerobically C. catabolically
D. none of the above.
38. In general, which of the following best represents an energy-producing reaction in living things?
A. simple substances join together to make complex substances
B. complex substances break apart to make simpler substances
C. simple substances remain simple D. complex substances remain complex
39. Which of the following is true with regards to the relationship between free energy and entropy in energy-producing reactions in living things?
A. the free energy increases and the entropy decreases
B. the free energy increases and the entropy increases
C. the free energy decreases and the entropy increases
D. the free energy decreases and the entropy decreases
40. Which of the following is true with regards to ATP? A. energy is required to remove one of its phosphates B. energy is released when a phosphate is added C. energy is given off when a phosphate is removed D. none of the above.

Appendix E.

Letter to Parents

Ikerd 94
Biology
Memo to Parents
October 4, 1994

Dear parents,

This is to let you know we will be making a research trip to the lake on Thursday, October 6, and the following dates: Friday, Oct. 7; Wednesday, Oct. 12, Wednesday, Oct. 19 and Wednesday, Oct. 26.

We will meet in the parking lot in the War Memorial by 8:00 AM. The students will walk back to school at 8:47. This arrangement will allow them to spend the normal amount of time in Biology class and still make it to their second period on time. I appreciate your cooperation on this and apologize in advance for any inconvenience for you or your family. If there are any extenuating circumstances which preclude this arrangement, please call or send a note.

After our session at the lake, students will be expected to report directly to the school and so must have their necessary items with them. They will not be excused for being tardy to their second period class. If other arrangements are necessary, please notify me and take care of them through the attendance office.

Students need to be aware of the weather when preparing to dress for the occasion. We will be at the edge of the lake taking samples so boots or sneakers would be appropriate. Stress head covering, layers for warmth and waterproof slickers in the event of rain. Yes, we will collect in the rain, sleet or snow. if it is raining, umbrellas will help, preventing the data sheets from saturation. if the family owns waders and the student knows how to walk in water without wetting themselves, please bring them. I would also advise a change of clothes in the event of inclement weather.

One reason that collecting might be postponed would be if the lake is too rough to safely collect samples. In that event, I will be in the parking lot from 7:50 until 8:05 to tell students to report to my classroom instead. It is possible that we may need to reschedule at that time.

I could use some help at the site. If you are available, please feel free to stop by and stick around. You won't have any duties except morally supporting me. I would appreciate your company. I promise you won't get wet and if you dress warmly, you won't get cold.

Thanks for your indulgence. If you have any questions, don't hesitate to ask.

Respectfully,

Ranae Ikerd

Appendix F.

End of the Year Survey

End of the Year Survey

Name of course__________________ Year _____ Period ____

Please respond to this survey as honestly as you can. I will use these responses to help me plan for future years.

Please rate the course in the following areas by circling the appropriate response:

1. Rate of presentation..too fast 1 2 3 4 5 too slow

2. Difficulty of the material..too easy 1 2 3 4 5 too hard

3. The extent to which the teacher helps you................too much 1 2 3 4 5 not enough

4. Interest level of the course..................................not interesting 1 2 3 4 5 very interesting

5. Application of this course in your life.......................applicable 1 2 3 4 5 not applicable

6. Fairness of the grading system used in this course.............fair 1 2 3 4 5 not fair

7. Consistency of the teacher...consistent 1 2 3 4 5 inconsistent

8. Professionalism of the teacher...pro 1 2 3 4 5 unpro

Please answer the following questions with complete candor:

1. Please describe your most favorite experience in this class. Why would you consider it to be your most favorite?

2. List one or two things that you did not like about this class. How would you change things to make this a better course in the future?

3. What was the most challenging material or topic in the course curriculum? Why do you think that particular subject was challenging?

4. Which unit was the least challenging or the most boring? What changes could be made to make sure that it would be more interesting next year?

Appendix G.

Unit Lesson Notes

Unit Lesson Notes

Date	Experimental	Control
9-28-94	Completed electrophoresis post-lab, introduced idea of control vs. experimental groups; tried to stress concept of reach your own conclusion rather than someone else's	same
9-29-94	Took science opinion survey and pre-test	same
9-30-94	Ecuador: slide presentation	same
10-3-94	Returned and discussed lab papers, formed research groups, met and choose roles, wrote first idea for research; it was reiterated that the results of the surveys and the pre-tests would have no reflection on their grades	same except no research topic written
10-4-94	Respiration products lab (students worked in group)	same
10-5-94	Brief discussion of respiration labs, brief introduction to collection equipment and testing kits; brief group meeting to discuss lab results, dispense keys, refine research idea Handouts given- instructions for kits, keys	same except more elongated discussion and demonstration of respiration labs
10-6-94	on site: Survey of site, chemical testing, pH meters non-functioning	lecture on Anaerobic respiration; overheads of organisms and their donors group work: prepare lab for collection and questions
10-7-94	on site: collecting of organisms in lake and lagoon using dip net, drift plankton net, bottom dredged, samples returned to room, opened over the weekend	lecture on respiration and team work

10-10-94	students were directed to read chpts 7,8,5 More handouts: Simple keys, cartoons, outcomes and worksheets for ps and resp., sample lab-What is the effect of pH on plankton? students worked I lab: identifying organisms	lecture on anaerobic and aerobic pathways for respiration hand-outs: ps and resp
10-11-94	Lecture: parts of a formal paper Group; meeting to decide on research topic	Photosynthesis Lab BSCS Blue 7B
10-12-94	Michigan Math Test-13 students present worked in groups, looked at organisms, sent 8 students to library for research	Michigan Math Test-students straddled in during the period, checked results, conferred in groups, interviewed students
10-13-94	Lake: Continuing chemical tests, put pop bottles in for collecting; some samples collected; much exploring; use of a fishing pole (not ours); students interviewed, some enjoyed the lake and the beauty of it, starting the day there was serene.	Demos: decamp of H2O2 with KI and dish soap to demonstrate use of splint for oxygen gas, set up fermentation demo with grape juice and yeast; group work, dispensed Formal lab rubric
10-14-94	Lab work: identifying collected organisms	Lecture on photosynthesis and respiration; discussion of upcoming reports.
10-17-94	Lecture on photosynthesis and respiration.	Class presentations on photosynthesis lab results
10-18-94	Shortened schedule: Pre-lab on lake, reminder of report requirements, discussion of assessment rubric..	Finished presentations; continuation of notes on photosynthesis.
10-19-94	Lake: Bottles collected and taken to the lab	Completed notes on photosynthesis and respiration
10-20-94	Samples examined in lab	Test Review
10-21-94	Lecture on Photosynthesis and Respiration and continued examination of organisms in the lab	Test: Chapters 3,7 & 8: energy, Photosynthesis and Respiration
10-24-94	21 minutes of class Worked in lab	Review Test
10-25-94	Shortened Schedule Notes on PS and Resp	Diversity Lecture
10-26-94	Lake site: beautiful collection	Lecture on diversity

10-27-94	Class lab work and discussion; lecture	Lecture
10-28-94	Class lab work and discussion	Lecture
10-31-94	Presentations of projects	Library visit for Diversity project
11-1-94	Shortened Schedule Computer room-students worked on taxonomy tutorial and learned how to use f(g) scholar	Finished notes on taxonomy
11-2-94	Library for research on taxonomy	Library
11-3-94	review for test	review
11-4-94	Test-Energy/Diversity/ Photosynthesis/ Respiration	Test: Diversity
11-7-94	Return tests; review	
11-8-94	Administer post-test and opinion survey	

Appendix H.

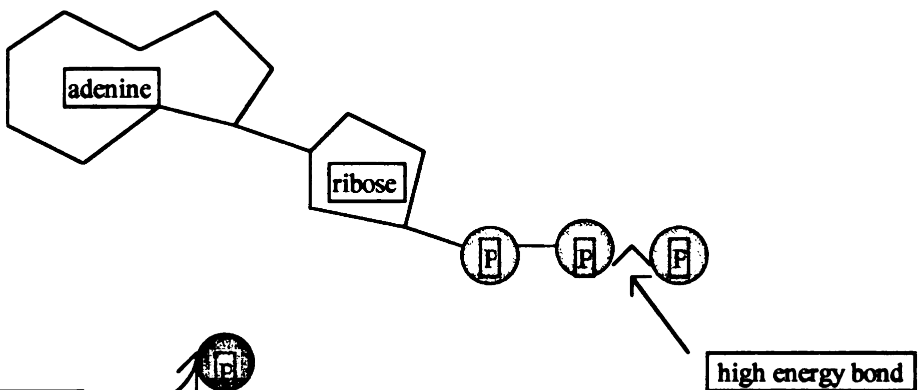
Supplementary Materials for Teaching Unit

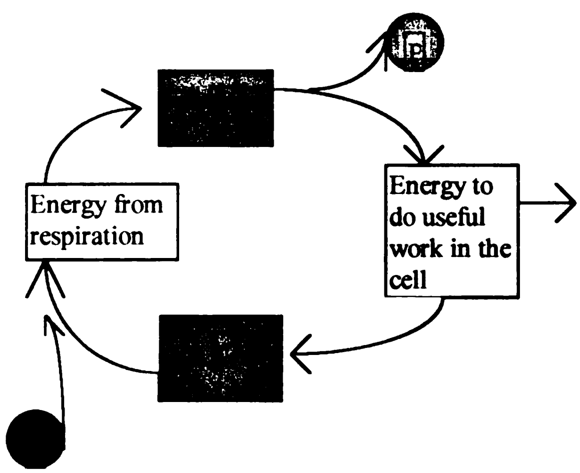
Energy Transfer

fuel (hydrocarbon) + $O_2 \Rightarrow CO_2 + H_2O$ + energy

Chemical energy is stored in the bonds of the molecule:

Adenosine triphosphate (ATP)→
Adenosine diphosphate + P_i + energy





Photosynthesis

Steps:

A. THE LIGHT REACTION

1. Photosystem II

- water is split
    1. produces protons in the thylakoid lumen
    2. releases electrons
    3. oxygen is released to the atmosphere
- light absorbed by P680 (chlorophyll)
- electrons energized by light
- ATP's generated by protons

2. Electron transport system

- electrons release energy in a series of reactions in the thylakoid membrane
- uses pigments and proteins (cytachromes)
- more protons are produced

3. Photosystem I

- light absorbed by P700
- electrons energized, then stepped down in another electron transport system (ferridoxin)
- NADPH's produced

B. THE DARK REACTION

1. Calvin Cycle

- **CO_2 is "fixed" by combining it with RuBP**
- **ATP drives the dark reaction**
- **PGAL is produced**

2. Cytoplasm

- **PGAL combines to make glucose or is used in respiration**

Metabolisms of Various Organisms

	Energy	
Carbon Source	Chemical	Light
Organic	Chemoheterotroph	Photoheterotroph
Inorganic	Chemoautotroph	Photoautotroph

Aerobic Respiration

Steps

1. Glycolysis

- glucose is split
- 2 ATP's required, 4 ATP's produced, 2 ATP's netted
- 2 pyruvic acids produced

2. Kreb's Cycle (Citric Acid Cycle)

- pyruvic acid releases CO_2 and forms acetic acid
- acetate combines with CoA and then oxalacetic acid to make citric acid
- loss of 2 CO_2's, molecules rearranged
- production of ATP
- production of NADH
- production of FADH

3. Electron Transport Chain

- hydrogens combined with oxygen to make water
- energy tokens (NADH, FADH) cashed in to
- produce ATP

ATP Produced per Molecule of Glucose

Phase	ATP Produced	Reduced Coenzymes	ATP from Oxidation in electron transport chain	Total ATP Produced
glycolysis	2 ATP	2 NADH + H^+	6 ATP	8 ATP
pyruvate to acetyl CoA	-	1 NADH + H^+	3 ATP	3 ATP
pyruvate to acetyl CoA	-	1 NADH + H^+	3 ATP	3 ATP
Kreb's cycle	1 ATP	3 NADH + H^+ 1 $FADH_2$	9 ATP 2 ATP	12 ATP
Kreb's cycle	1 ATP	3 NADH + H^+ 1 $FADH_2$	9 ATP 2 ATP	12 ATP

Classification Study Guide

1. Fill out the missing characteristics of the members of each kingdom in the following chart :

	Moneran	Protista	Fungi	Plantae	Animalia
Cellular Organization	one-celled or colonial				
Prokaryotic or Eukaryotic				eukaryotic	
Form of Nutrition		mostly heterotrophic			
Special Features					nervous system, motility
2 or More Examples			yeast Morels		

2. Give the kingdom to which each of the following organisms belong:

spider______________ sponge_________________ E. coli__________________

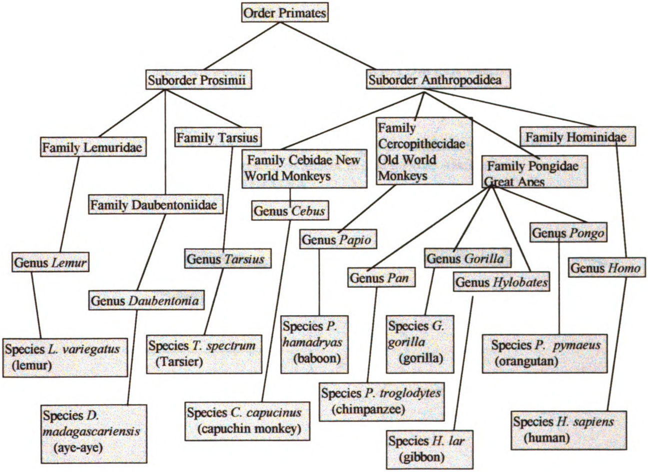
kelp________________ maple_________________ moss___________________

diatom______________ toadstool_______________ Amoeba_________________

squid________________ bread mold______________ snake___________________

3. Primate Classification. Use this branching Key to classify the primates listed below.

Primate	Suborder	Family	Genus	Species
human				
gibbon				
aye-aye				
gorilla				
chimpanzee				
tarsier				



4. Classify each of the following three organisms with this dichotomous key for some of the Protista members:

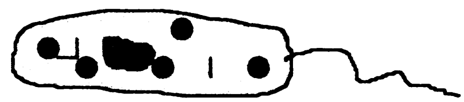
Step 1. a. single-celled with flagella and chloroplasts with chlorophyll→Phylum **EUGLENOPHYTA**
b. single-celled, moves by pseudopods, cilia or flagella, chloroplasts absent→Phylum **PROTOZOA**, go to Step 2

Step 2. a. with pseudopods, without cilia or flagella→Class **SARCODINA**
b. with cilia or flagella, without pseudopods→go to step 3

Step 3. a. with flagella, without cilia→Class **MASTIGOPHORA**
b. with cilia, without flagella→Class **CILIATA**, go to Step 4

Step 4. a. cilia all similar size, no obvious membranelles around the oral groove→Order HOLOTRICHIDA, go to Step 5
b. cilia of different lengths, membranelles around the oral groove are present→orders **PERITRICHIDA**, **CHONOTRICHIDA**, or **SPIROTRICHIDA**

Step 5. a. oral groove lined with cilia, no obvious membranelles→Suborder **TRICHOSTOMINA** which has 14 families divided into genera, Paramecium genus is one of them (there are 9 possible species of Paramcium, *P. caudatum* is one them).
b. oral groove or mouth opening with membranes moving in waves, cilia present or absent in oral groove→Suborder **HYMENOSTOMINA**



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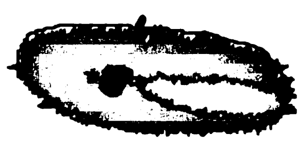

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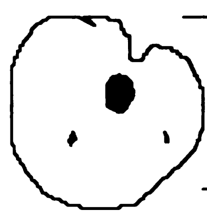

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Classification and Habitat Project

Outcomes:

At the completion of this unit, students will demonstrate that they can classify and categorize organisms based on characteristics of the organism and the classification criteria. In addition, students will be able to give examples of organisms and characteristics of those organisms which place them in the major classification categories of kingdom, phylum, class (for chordates and insects), and some orders of mammals.

Assignment:

Each student will select (an) organism(s) from each of the following categories:

> *1 mammal, 1 fish, 1 amphibian or reptile, 1 bird, 1 Moneran, 1 Protist and 2 invertebrates from different phyla*

For each organism selected, the student will prepare a formal report wherein the following information will appear:

> *Complete classification including: kingdom, phylum, class, order, family genus, and species,*
>
> *A description of the habitat where the organism is found,*
>
> *Behavioral description including method(s) of reproduction; mating habits if known; location in the food web, dietary habits and predators; and general normal types of behavioral characteristics exhibited by members of the species,*
>
> *And a complete bibliography including at least 4 references, one of which may be your text, and at least one of which must be something other than an encyclopedia.*

You may <u>**NOT**</u> use organisms which are classified as examples in your text. The completed project is due ________________ at the beginning of class period. Any late papers will be penalized. This paper will comprise _____% of your unit assessment.

Energy Unit Study Guide

Make sentences using all of the following terms listed at one number in a sentence.

1. create destroy energy form
2. system entropy input energy output entropy
3. entropy disorder increase
4. energy stored compounds reactions work
5. free energy decrease entropy increase
6. metabolism anabolism catabolism biosynthesis degradation
7. catabolism large simple anabolism large simple
8. ATP glucose ADP
9. free energy catabolic anabolic

Use the following terms to construct a concept map for the unit:

living things	ATP	free energy
energy	entropy	metabolism
chemical energy	anabolism	catabolism
ecosystem	food webs	abiotic factors
biotic factors	producers	consumers
heterotrophs	autotrophs	decomposers

Appendix I.

Unit Outcomes

Outcomes for the Lake Study Unit

1. Discuss why organisms need energy and how they obtain it.
2. Analyze energy flow through an ecosystem.
3. Relate the first and second laws of bioenergetics to their implications for living things.
4. Evaluate anabolic and catabolic reactions in metabolisms.
5. Create a concept map showing the relationships between concepts in the unit.
6. Diagram ATP's role in energy transfer.
7. Explain homology and analogy and give examples of both types of structures.
8. Describe the classification hierarchies used to categorize organisms and how they are related to one another.
9. Recognize the significance of using binomial nomenclature.
10. Classify organisms on the basis of a bilateral key.
11. Classify organisms into the five kingdoms based on characteristics of the organisms and the kingdoms.
12. Classify organisms completely using references and additional resources.
13. Discuss the difficulty in defining a species and explain the biological meaning of species.
14. State the importance of photosynthesis and identify the plant structures that are involved in photosynthesis.
15. Identify the steps by which light energy is converted to chemical energy during the light reactions.
16. Discuss the importance of the Calvin cycle while accounting for the units of carbon and energy involved.
17. Describe how environmental factors affect the rate of photosynthesis.
18. Relate the processes of metabolism and cellular respiration.

19. Distinguish among the three hydrogen-carrier molecules and their functions.

20. Describe how the three stages of cellular respiration are related.

21. Identify the products of glycolysis.

22. Compare the ATP production of aerobic respiration and fermentation.

23. Discuss the importance of oxygen to the electron transport chain.

24. Explain the central role of the Krebs cycle in metabolism, accounting for the carbons, ATP's in the cycle.

Appendix J.

Which Organisms are Attracted to Light?

Which Organisms are Attracted to Light?

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 implications to everyday problem solving.

INTRODUCTION: Light can be a limiting factor for the growth and development of some organisms. Photosynthetic organisms need to have a sufficient amount of light to drive the photosynthesis reaction. Other organisms which feed on photosynthetic organisms may have evolved light-sensitive devices to enable them to move to an area where light is available so that they can be near their source of food. For example, snails that consume algae may move toward a light to locate food.

In order to be attracted to light, organisms must have some sort of sensory device which is sensitive to light. There are many devices which organisms have developed for the sensation of light. Then they must have some sort of motility to be able to move to the light source. Your light detecting devices are your eyes. There are pigments in the special cells in the rod and cone cells in the retina (located in the back of your eyeball) which become stimulated by light and send messages to the brain which are interpreted as vision. Other organisms may have different pigments in different kinds of cells which perform the same function. You may have seen the eyespot on a planarian or the dark skin on the upper surface of an earthworm. Both of these structures enable the organisms to detect light. The ability of the earthworm to detect and move away from light is a survival mechanism for an earthworm. Direct sun on the earthworm would dry it up and kill it. Other organisms will move toward light for survival reasons.

To be attracted to light, organisms must have some sort of motility to be able to move to the light source. You can move because of the muscles and bones in your arms and legs. Other organisms may move in different ways. Many simple organisms may have flagella or cilia which help them move through water. Perhaps you have seen a Paramecium move with the beating of its hair-like cilia or an Euglena move with the waving of its whip-like flagellum. Worms may move with muscles controlling the slinky motion of their tubular body.

In this exercise, you will be collecting organisms from a lake which seem to be attracted to light and comparing them to organisms which don't appear to be attracted to light. By using keys and observations, you will determine which organisms have the ability to move to light and the ability to sense light.

HYPOTHESIS: Write two hypotheses about the kinds of organisms which will or will not be attracted to light.

MATERIALS: two 2-liter bottles of the same color, one lightstick, 2 one-meter rope or string with an attached weight, plankton net

CAUTION: Make sure your bottles are secured with the rope and the weight.

Make sure you label your specimen jars as to whether the sample comes from the bottle with or without the lightstick.

Be careful not to bend the lightstick too far to break the plastic stick. If you do, you must immediately wash your hands because the hydrogen peroxide inside is a skin irritant.

PROCEDURE: DAY 1

1. Peel off the label and the bottom black plastic from the 2L bottles. Carefully cut off the top of the bottle about 10 cm down from the top with sharp scissors.

2. Punch holes at the top or side through which string can be tied Loop the string through the holes and secure it with a knot.

3. Establish a biofilm on each of the 2L bottles by tying a weight to the free end of each string and completely submerging the bottle in the lake or stream by filling them with water. Secure the bottle by attaching it to a permanent fixture such as a large tree or fence pole. Leave the bottle there for at least 2 days.

3. Submerge both bottles by filling them with lake water. Ensure that the bottles remain submerged. Make the opening of the mouth of the bottles face the same direction. Place the bottles as far apart as the length of the string allows.

DAY 3,4, or 5

1. At night, carefully break the lightstick according to the directions on the wrapper. Insert the lightstick into one of the 2-liter bottles. Make sure the light stick will not drift out of the collecting bottle. You can tape it or tie it in the bottle with a string.

2. Submerge both bottles by filling them with lake or stream water. Ensure that the bottle remain submerged. Make the mouths of both your bottles face the same direction.

EARLY THE FOLLOWING MORNING

1. Label two buckets with your group and period. Carefully lift one collecting bottle from the collecting site and immediately place the bottle and its contents into one collecting bucket. Place the other bottle and its contents in the other bucket. Do not mix the samples. Leave the lightstick in its collecting bottle or label its bucket. Try to keep as much of the collected water in the bottles as possible. Take them back to the lab.

IN CLASS THAT DAY

1. Compare the samples from the two buckets, recording your visual observations. Do the containers seem to have the same kinds of organisms?

2. Take a random sample from your collection by dipping a small beaker or jar into the sample. Measure 50 mL into a clear glass container and place it under a dissecting microscope. With the use of your macroscopic data tables, scan the container and make hash marks next to the corresponding organisms, counting only the first 25 organisms you see. Try to be random about your counting. In other words, don't just count one particular type of organism because it is easy to spot. Repeat this procedure four times with four different samples.

3. Take one drop of your collected sample and prepare a wet mount with a cover slip. Using medium power (100X), count the first 10 organisms and record them on the microscopic data sheet in the same fashion as listed above. Move the slide to a different field of view and repeat the counting of 10 organisms until you have counted a total of 50 microscopic organisms with this slide. Be random about your counting and moving the slide to different locations. Be sure to count some organisms near the edge of the coverslip. Clean the slide and coverslip and repeat this procedure with another sample taken from a different location in the collecting bucket.

4. When your group is finished, you should have counted and recorded a total of 100 macroscopic and 100 microscopic organisms. Your teacher will instruct you to pool the class data in a specified place. Clean up your work area and follow instructions with regards to disposal of the samples.

CONCLUSIONS: Carefully examine the class data. Accept or reject your hypothesis on the basis of this data. Be sure to explain the acceptance or the rejection of the hypothesis on the basis of the observed lists of organisms.

QUESTIONS :1 . Construct a chart with a list of all the organisms found in each of the two bottles. List each organism's method of locomotion. For the organism which were found in the bottle with the light stick, on the chart describe the structure that enables them to detect the presence of light.

2. Choose one of the organisms you collected. Describe a trap that you would design to collect that organism.

3. Which organisms seem to be attracted to light? For each organism listed, give a reason why its attraction would benefit their survival.

4. Is it possible to conclude that all organisms found in the 2L bottle with the lightstick are attracted to light? Explain your answer.

Teacher's Guide to Which Organisms are Attracted to Light?

developed by Ranae Ikerd and Bob Brill 1993 NSF-KBS

OBJECTIVES: The student will determine which small lake organisms are attracted to light.

The student will analyze the structures of these organisms in regards to their methods of motility and sensation to electromagnetic radiation.

SUGGESTED HYPOTHESES: 1. The bottle containing the light stick will have different organisms from the empty collecting bottle

2. The bottle containing the light stick will have the same organisms as the empty collecting bottle.

BACKGROUND INFORMATION: This method of collection was used by a graduate assistant at the Kellogg Biological Station of Michigan State University. The researcher reported that the organisms collected consisted of mostly pollywogs. The researcher was trying to get fish larva.

Students might find Euglena and other motile photosynthetic organisms, Planaria, Hydra, Daphnia and some fly larva such as midges. The photosynthetic organisms have chlorophyll to sense the light and Euglena have flagella to move to the light. Planaria have an eye spot which can detect the presence of light and move by muscle contraction to the light source. They are generally only attracted to dim light and would be found in productive lakes. Planaria eat animal tissues. Hydra eat Daphnia and other zoo plankton and can move three ways. They move by somersaulting, by amoeboid movement at base and they can move by contracting their tentacles and pushing their base through the water. Daphnia and fly larva are Arthropods which eat zoo plankton and algae. Arthropods move by contraction of the muscles of their jointed legs. The larva are worm-like and can propel themselves by an undulating motion. All arthropods have an exoskeleton for muscle attachment to increase leverage.

Keep the organisms refrigerated after the students have collected them. They will store for a couple days but they should be aerated for any longer length of storage time.

In the reference section are some materials available from the Department of Agriculture which contain some discussion about organisms found in various places. Contact your local or state government agencies for more specific lists of organisms which would be found in your area. It would save time in the lab if your students have a simple key with organisms which are found in your area at that time of year.

Lightsticks can be purchased at your local SCUBA shop or at a place that sells camping equipment. Purchase 12-hour sticks so that the entire evening the stick will be lit. The light emitted by the stick is due to a phenomenon called chemiluminescence. The lightstick contains a phenyl oxalate ester with a fluorescent dye and a small glass vial of hydrogen peroxide. When the vial is broken, the peroxide and ester react forming an intermediate. This process causes an excitation of the dye molecule and a glowing results from its electrons moving back to the ground state. This reaction is temperature sensitive. You could demonstrate this to your students by placing each of two or three lightsticks in hot water (boiling is fine but ensure the stick does not rest on the bottom of the beaker or it may melt), ice water and room temperature water. Dim the lights. You can use smaller, shorter-timed sticks for the demonstration.

You could include this activity in a unit on ecology, water, nervous systems or transport.

QUESTIONS: If your students are not accustomed to writing conclusions as the lab directs, you may want to lead them to the proper method for this by using the following questions. It is recommended, however, that students learn to write their own conclusions without this type of help.

1. Which organisms are attracted to light?

2. If organisms are found in both the lit and empty collecting bottles, what is your explanation for this?

3. What other methods could you use to attract organisms to your collecting bottles in the water?

FURTHER INVESTIGATIONS: You might want to try this experiment at another time of the year and compare the organism found in different seasons. Your students will be amazed to see that there are organisms in winter water.

Different colors of lightsticks might be compared at their effectiveness for attracting organisms.

Students might suggest different forms of bait to set in their bottles collect other organisms.

This activity could be used as an introduction to taxonomy and diversity. The students could then classify their organisms into various classification categories if sufficient reference material is available for them to easily do so.

Using the reference from the Department of Agriculture, the students could make hypotheses about their water quality based on the types of organisms found.

REFERENCES:

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Van Meet, Luc. *Animal behavior*. 43(4): 696 (1992)

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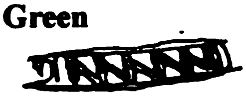
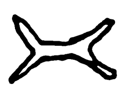
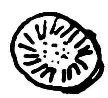
Appendix K.

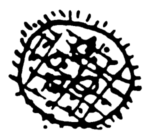
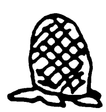
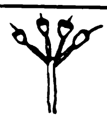
Student Data Tables for Micro- and Macroorganisms

Student Data Tables for Micro- and Macroorganisms

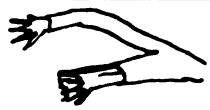
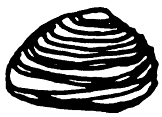
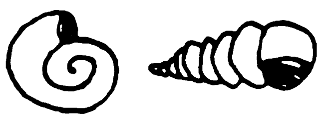
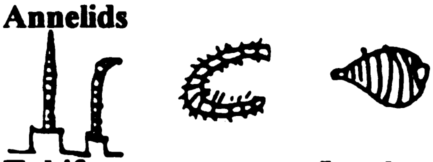
Freshwater Microorganisms

Team Name: **Period:** **Date:**	**Collection Site:**
Team Members: 1. 2. 3. 4. 5.	**Site Description**
Organisms	**Data**
Algae	
Blue-green or Cyanobacteria   **Anabaena** **Nostoc**	
Green   **Spirogyra**	
Desmids   **Closterium**	
Diatoms   	
Others **Sketch**	

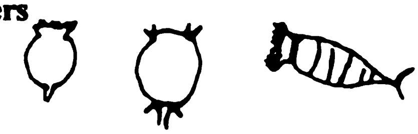
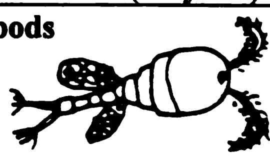
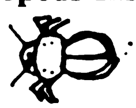
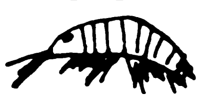
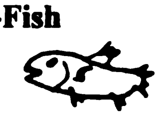
Freshwater Microorganisms

Team Name: **Period:** **Date:**	**Collection Site:**
Team Members: 1. 2. 3. 4. 5.	**Site Description**
Organisms	**Data**
Protozoans	
Euglena 	
Ciliophora  **Paramecium**	
Mastigophora  **Volvox**	
Sarcodina  **Amoeba**	
 **Difflugia**	
 **Codosiga**	
Others **Sketch**	

Freshwater Macroorganisms (page 1)

Team Name: **Period:** **Date:**	**Collection Site:**
Team Members: 1. 2. 3. 4. 5.	**Site Description**
Organisms	**Data**
Cnidarian  **Hydra**	
Bryozoan 	
Mollusks  **Bivalves-clams and mussels**	
Mollusks  **Snails**	
Nematodes 	
Annelids  **Tubifex** **Leech**	
Others **Sketch**	

Freshwater Macroorganisms (Page 2)

Team Name: **Period:** **Date:**	**Collection Site:**
Team Members: 1. 2. 3. 4. 5.	**Site Description**
Organisms	**Data**
Rotifers 	
Arthropods   **Daphnia** **Crustaceans (crayfish)**	
Arthropods-Copepods 	
Arthropods-Insects   **Adult** **Larva**	
Arthropods-Amphipoda 	
Vertebrates-Fish 	
Vertebrates-Amphibian 	

Appendix L.

What are the Effects of Acids and Bases on Plankton?

What are the Effects of Acids and Bases on Plankton?

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 implications to everyday problem solving.

INTRODUCTION: In order to survive, organisms must be able to maintain a stable internal environment even in stressful conditions. This ability is called homeostasis. As an example, sometimes the aquatic protozoan *Paramecium* must actively pump out water so as not to rupture its cell membrane and die.

The acidity of a solution can be measured by the pH scale. The pH ranges from 0 to 14 and if the pH is at 7, the solution is called neutral. A pH below 7 is considered acidic while a pH greater than 7 is basic.

Most organisms live in a narrow range of pH or they exhibit a low tolerance for any change in pH. One of the reasons for this is that a change in pH may change the shape of important enzymes that are needed by the organism to catalyze important reactions. Enzymes can not perform their function if their shape is changed. This is one of the reasons why conditions like acid rain can be so devastating to an environment.

Buffering is an important mechanism which helps maintain a constant pH. A buffer helps regulate the pH of a system in such a way that reduces the change in pH as compared to an unbuffered system.

Because of this, organisms have evolved an elaborate internal buffering system to help regulate the pH in order to run biochemical reactions at optimal conditions of pH. In this activity, we will be studying the effects of changing pH on organisms.

This activity will consist of three parts. In the first part, you will investigate the effects of changing the concentrations of an acid and a base on buffered and unbuffered solutions. In the second part of the lab, you will investigate tissue homogenates (parts of organisms that have been placed in a blender to release cellular substances) in different concentrations of the acid and base to determine if cells have a natural internal buffering system. Finally, you will set up a controlled experiment to test the effects that changing the pH has on the viability of plankton. The viability is the how well or how many organisms survive.

HYPOTHESES:

Part I: Write two hypotheses on the effects of buffering on pH changes in the acidic and basic solutions.

Part II: Write two hypotheses on the effects of homogenates on pH changes in the acidic and basic solutions.

Part III: Write two hypotheses on the effects of changing the pH on the viability of plankton.

MATERIALS:

pH meter or paper	tap water
dropping pipettes	graduated cylinder
egg white (fresh)	0.1M Hydrochloric Acid (HCl)

liver or potato homogenate or warm gelatin
0.1M sodium hydroxide, a base (NaOH)
pH 7 buffer solution
"wild" culture sample of local plankton
small beakers, 50 or 100 mL or plastic (not paper) cups
graduated pipettes

CAUTION: HCl and NaOH are strong chemicals so goggles and aprons MUST be worn at all times. If you spill some, dilute it with water and notify your teacher immediately. Keep rinsing until your teacher tells you to stop.

PROCEDURE: PART I

1. Measure 11.0 mL of 0.1M HCl into a test tube or small beaker. In each of seven other labeled containers, measure 9.0 mL of distilled water. With a measuring pipette, remove 1.0 mL of the 0.1M HCl from the first container and add it to the water in the second container and mix it. Then take 1.0 mL of the mixed, diluted solution in the second container and mix it with the water in the third container as you did with the second container. Then take 1.0 mL from the third container and mix it with the water in the fourth. Continue in this fashion until all solutions are finished. What you have done is called a serial dilution and each subsequent dilution is one tenth the concentration of the previous solution. If you have done your dilutions correctly, all of the solutions should contain the same amount of liquid. Record the pH each of the solutions. Save the solutions for Step 3 of Part I.

2. Repeat Step 1, substituting 0.1M NaOH for the HCl. Record the pH of each of the solutions. Save the solutions for Step 3.

3. Add 10 mL of buffer to each of the previous containers and record the pH.

PART II: 1. Obtain your team's assigned blended homogenate. Place it in a graduated cylinder and add distilled water until it measures 126 mL. Repeat Steps 1 and 2 from Part I, substituting the diluted homogenate for the distilled water. Record the pH of each solution.

PART III: 1. Repeat Steps 1 and 2 from Part I of this procedure, using distilled water to dilute the NaOH and HCl. To each of the 14 labeled containers, add 1 or 2 droppers full of plankton. Be sure to use clean glass containers for this step. Record the pH of each container.

2. Examine your samples daily for viability by placing each under the dissecting microscope. Scan the container for the numbers of living and dead organisms, counting only the first 30 organisms you see. Record the number of dead and living organisms. Try to be random about your counting. In other words, don't just count one particular type of organism because it is easy to spot.

3. Take one drop of each sample and prepare a wet mount with a cover slip. Using medium power (100X), count the first 10 organisms and record them as living or dead on the data sheet in the same fashion as described above. Move the slide to a different field of view and repeat the counting of 10 organisms until you have counted a total of 30 microscopic organisms with this slide. Again, be random about counting and moving the slide to different locations. Be sure to count some organisms near the edge of the coverslip. Record the pH daily for each container.

4. Repeat this procedure daily for one week or until your instructor indicates.

DATA: For Parts I and II, make a line graph using two data lines (one each for HCl and NaOH). Plot pH on the vertical axis and the container number or concentration (as your teacher instructs) on the horizontal axis.

For Part III, plot the numbers of the viable organisms on the vertical axis and days on the horizontal axis for each container. Make another graph for each day with the number of viable organisms on the vertical axis and pH on the horizontal axis.

You should have a total of 18 graphs when you have finished. Ask your teacher about the possibility of superimposing some separate graphs onto one graph or about using the computer to construct your graphs.

CONCLUSIONS: Carefully examine the graphs and your notes on the viability of the wild cultures. Accept or reject your hypothesis on the basis of this data. Be sure to explain the acceptance or the rejection of the hypothesis on the basis of the observed lists of organisms.

QUESTIONS: 1. Compare your data from Part II with Part I. What evidence is there of the cell homogenate possessing a natural buffering ability?

2. Compare your team's homogenate pH's to those obtained by other teams. Did any of the homogenates appear to have a superior buffering ability? Elaborate.

3. Explain your answer to this question: Does the buffer work to reduce pH change better in acids or bases?

4. What do you think the effect of acid rain will be on a lake ecosystem? If a lake has a bed of calcium carbonate which can act as a buffer, would this make a difference in the effects of acid rain?

Teacher's Guide to What are the Effects of Acids and Bases on Plankton?

Developed by: Ranae Ikerd and Bob Brill 1993 NSF-KBS

Tested by:	Jill M. Evers	Kent City HS, Kent City, Michigan
	Ranae Ikerd	Grosse Pointe South HS, GP, Michigan
	Susie MacArthur	Van Buren Voc-Tech Center, Lawrence, Michigan
	Lynda M. Smith	Lakeshore HS, Stephensville, Michigan

OBJECTIVES: The student will determine the effects:

A. of changes in concentrations of acids and bases on buffered and unbuffered solutions.
B. of a natural internal buffering in homogenates on pH when the concentrations of acids and bases are changed.
C. on the viability of organisms and on the pH when the concentrations of acids and bases are changed in buffered and unbuffered solutions.

SUGGESTED HYPOTHESES:

Part I:

1. The pH of the buffered solutions will remain stable when the concentrations of the acid and the base are increased.
2. The pH of the unbuffered solutions will decrease when the concentration of acid is increased and increase when the concentration of base is increased.

Part II:

1. The pH of the homogenated solution will remain stable when the concentrations of the acid and the base are increased.
2. The pH of the homogenated solutions will decrease when the concentration of acid is increased and increase when the concentration of base is increased.

Part III:

1. The pH of the buffered solutions will remain stable when the concentrations of the acid and the base are increased and the organisms will remain viable.
2. The pH of the unbuffered solutions will decrease when the concentration of acid is increased and increase when the concentration of base is increased and the organisms will appear distressed.

BACKGROUND INFORMATION: This activity could be used in the chemistry, taxonomy or ecology unit.

Students may experience difficulty in generating the different hypotheses for the different parts in the lab since there are so many experimental conditions.

Be sure to keep the conditions controlled for the cultures in the four sets of tubes in the third part of the procedure. Keep them out of direct light but the photosynthetic organisms will need some light so putting them in a Northern window would be best. They should **not** be capped so that oxygen may diffuse into the containers. Baby food jars or scintillation vials would probably work better than test tubes if you don't have enough beakers for this part.

Students should examine the cultures in Part III periodically for several days. They can take a sample from the containers and examine it under the microscope. Help them identify the organisms by providing them with keys for reference. In conditions of extreme pH, the organisms may be in distress and die right away. The students need not examine those cultures repeatedly.

You can either purchase plankton cultures or collect them from your local aquatic environment. Students will enjoy collecting their own plankton samples. Since the cultures will be diluted 1:10 in Part III of the student procedure, it is important that the cultures from which the students obtain their samples from are highly concentrated. You can do this yourself by allowing the water to evaporate for a couple of days before dispensing or by straining the culture through a plankton net.

You may purchase calcium carbonate buffer or mix it yourself if you have a recipe for making buffers. To prepare 1 liter of 0.1M NaOH, add 4g NaOH pellets to 1 L distilled water. To prepare 1 liter of 0.1M HCl, dilute 100 mL of 1M HCl to 1 L with distilled water. If calcium carbonate buffer is not available, you may use any buffer with a pH of 7.0. The purpose of using calcium carbonate is to simulate the conditions of an oligotrophic lake system with a calcium carbonate bed. When preparing homogenates, blend enough of each material to give each group about 50 mL which would be the equivalent of about 3 egg whites per group.

QUESTIONS: If your students are not accustomed to writing conclusions as the lab directs, you may want to lead them to the proper method for this by using the following questions. It is recommended, however, that students learn to write their own conclusions without this type of help.

1. Does the buffered or unbuffered pH change more rapidly with the addition of acids and bases?
2. Which pH changed more rapidly:
   The pH of the homogenates when acids and bases were added or
   The pH of the water solutions when acids and bases were added?
3. Which organisms survived longer, the organisms in higher, lower or more neutral pH's? Were there any patterns? Explain.
4. Could the buffer be a toxin for organisms? Explain.

FURTHER INVESTIGATIONS: You might want to try this experiment by varying the kinds of organism. You could try using different buffers or different acids. Acid rain would be simulated more realistically by using nitric or sulfuric acids.

Another variation might be sampling different ecosystems to see which aquatic organisms can tolerate more extreme changes in pH. Bog organisms can obviously tolerate a lower pH, for example.

In advanced courses, you may want the students to do more sophisticated cell counts and statistically analyze the viability of the organisms. You may also want to have them compute the concentrations of the acids and bases in the various conditions and compute the theoretical pH.

You may want the students to use this as an introduction to graphing using computers. The students can combine the single graphs in Part III if they use different colors or symbols for the different beakers.

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Kransi, Sandy; Master's Thesis, Michigan State University, 1992

Appendix M.

Research Project Assessment Criteria

Research Project Assessment Criteria

Your Name__________________ **Team Name**____________________

Area	Description	Possible Points	Points Given	Comments
Originality of Idea	Does the idea reflect the creativity of the student(s) in the application of the scientific method?	**20**		
Experimental Design	Is the design of the experiment such that a clear hypothesis is tested with the described procedure? Are external factors controlled for in the design?	**20**		
Paper	Does the paper give a clear and organized written presentation in an acceptable format?	**20**		
Presentation	Is the presentation well-organized and smooth flowing? Is all of the necessary information present?	**10**		
Audiovisual Aid	Does the aid clarify information presented in the paper? Is it neat, attractive and relevant?	**10**		
Self-grade/peer-grade	What grade would you give yourself on the project based on the amount of time you spent and your understanding of the topic? What are the grades that your peers gave you?	**20**		

List the names of your team members and a score of 0-5 (with 5 the highest) of the grade you give each.

Appendix N.

Experimental Group Data Chart

Table 13. Experimental Group Data

Student Number	Sex	Project Grade	Pretest Score	Post-test Score	Gain Score	Number of Attitudes Unchanged	Number of Attitudes Improved	Number of Attitudes Decreased
1	F	84	15	25	10	50	21	14
2	M	78	20	23	3	49	27	9
3	M	86	18	25	7	58	13	14
4	F	78	21	33	12	61	12	11
5	M	78	8	28	20	51	15	19
6	F	84	18	28	10	40	27	18
7	M	75	15	26	11	47	17	21
8	M	85	14	29	15	32	24	29
9	M	76	27	32	5	52	15	18
10	F	68	17	27	10	39	21	25
11	M	78	14	29	15	44	12	29
12	M	73	15	25	10	45	23	17
13	F	86	15	37	22	53	12	20
14	F	81	14	29	15	44	12	29
15	F	85	21	38	17	57	18	10
16	M	68	15	23	8	55	20	10
17	M	72	12	12	0	65	9	11
18	F	82	18	24	6	56	16	13
21	M	86	15	18	3	26	33	26
22	M	66	20	31	11	51	19	15
23	F	68	17	36	19	48	18	19

Appendix O.

Control Group Data Chart

Stud Num
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Table 14. Control Group Data

Student Number	Gender	Pretest Score	Post-test Score	Gain Score	Number of Attitudes Unchanged	Number of Attitudes Improved	Number of Attitudes Decreased
25	M	13	20	7	37	41	7
26	F	6	23	17	34	14	37
27	F	21	28	7	37	27	21
28	F	11	22	11	60	12	13
29	M	19	30	11	55	13	17
30	F	22	29	7	53	13	19
31	F	13	21	8	41	25	19
32	F	19	33	14	52	27	6
33	M	18	32	14	51	16	18
34	M	9	32	23	66	9	10
35	M	23	31	8	47	17	21
36	M	18	27	9	62	8	15
37	F	15	25	10	56	12	17
38	M	13	34	21	69	11	5
39	F	12	26	14	57	11	17
40	F	19	20	1	54	19	12
41	F	12	24	12	48	21	16
42	M	17	26	9	34	13	38
43	F	20	32	12	52	15	18
44	F	11	31	20	47	19	19
45	F	19	30	11	62	16	7
46	F	14	32	18	51	23	11
47	M	26	32	6	42	18	25

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