This is to certify that the
thesis entitled

REPLACING LECTURE WITH ACTIVE LEARNING IN AN
ADVANCED PLACEMENT BIOLOGY COURSE

presented by

KELLY LYNN JOOS

has been accepted towards fulfillment
of the requirements for the

Master of Science degree in Department of Science and Mathematics Education

Major Professor's Signature

11 July 07

Date

REPLACING LECTURE WITH ACTIVE LEARNING IN AN ADVANCED PLACEMENT BIOLOGY COURSE

By

Kelly Lynn Joos

A THESIS

Submitted to
Michigan State University
in partial fulfillment of the requirements
for the degree of

MASTER OF SCIENCE

Department of Science and Mathematics Education

2007

ABSTRACT

REPLACING LECTURE WITH ACTIVE LEARNING IN AN ADVANCED PLACEMENT BIOLOGY COURSE

By

Kelly Lynn Joos

The purpose of this research project was to design and implement active learning opportunities such as lab experiments and activities into the first semester of an Advanced Placement Biology course as replacement to lecture and note-taking experiences. The lab experiences and pre and post lab questions were designed to teach biological concepts without the need of corresponding lecture material. Topics covered by implemented activities include general experimental design, capture/recapture methods of population estimation, transpiration, allelopathy, negative feedback loops and Chi Square tests. The effectiveness of the labs and activities was evaluated using pre and post test comparisons, surveys and anecdotal evidence.

The results of these assessments support the use of such activities as a method of teaching various biological concepts. Strengths and weaknesses of each of the activities are discussed and proposed adaptations for increased effectiveness of each are described.

ACKNOWLEDGEMENTS

I would like to thank the following people for their significant contributions to the completion of this thesis project.

~ Dr. Merle Heidemann, Dr. Ken Nadler, Dr. Chuck Elzinga, Dr. Jerry Urquhart, Mr. Sheldon Knoespel and Dr. Paul Hunter for their generosity with both their wealth of knowledge and their time.

~ My 2006-2007 Advanced Placement Biology students for all of their hard work and willingness to participate in this project. I wish you all the best as you step into the world beyond high school. Know that you will all be in my prayers!

~ The other students in the DSME program, especially Tracie Krawczyk, Jon VanOverloop, Marie Jasper, Melyssa Lenon and Anne Jeannette LaSovage. I was truly blessed to work alongside each of you over the past few summers. Thank you.

~ My family and friends who encouraged and supported me through all of the hard work that went into completing this thesis and who provided me with places to stay each summer as I completed my coursework!

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INTRODUCTION

Advanced Placement (AP) Biology is equivalent to a college-level Introductory Biology course taken by high school students. At the completion of the course, students are given the option to take the AP Exam. In general, if students receive a score of a four or five (out of five) on the exam, they will receive college credit for the Introductory Biology course at the undergraduate school they attend (Check with individual colleges and universities to verify the scores required for credit). These incoming credits provide students more flexibility in their college schedules which allows them to take more and varied science courses as they will already have completed the prerequisite requirements.

Advanced Placement Biology covers a variety of topics as set forth by the College Board which broadly includes Molecules and Cells, Heredity and Evolution and Organisms and Populations. In addition to these core content topics, students must also be introduced to science as a process, evolution as the basis of modern biological understanding, an integration of concepts as they pertain to biological systems and the impact of human activity on ecosystems as well as other social concerns related to biology. Laboratory experience is also a crucial component of the AP Biology Course. There are twelve experiments published in the College Board's *Laboratory Manual for Students in AP Biology* that are a required part of the course. The College Board does not issue a strict curriculum which must be followed by all AP teachers. This allows teachers the flexibility to cover topics in a method that is conducive to their teaching styles, as well as freedom to incorporate other labs and activities that they may find especially helpful or interesting. One challenge that this lack of strict guidelines has brought about is that the AP courses offered at various schools may be very different from one another in rigor and experiences offered to students. Therefore, when students apply to college, the college has no way to assess the specific experience that each individual student has had in Biology. For this reason, the College Board announced in 2006 their initiative to audit all Advanced Placement courses. The intent of this audit is to confirm to colleges that when a student enters with AP Biology on their transcript, they have completed the College Board requirements for that course.

One of the requirements instituted by the College Board regarding AP Biology is that 25% of the instructional time in the course must be spent performing hands-on laboratory activities. This new lab requirement was the motivation behind this Masters Thesis. Although the AP Biology course offered at Kalamazoo Christian High School did integrate the official laboratory experiments in the College Board's Lab Manual, there was very little additional time spent on lab activities. The existing AP Biology curriculum did not meet the new instructional guidelines as set forth by the College Board's audit.

In addition to the College Board requirements, there is a body of pedagogical research that supports the inclusion of more active learning opportunities in the classroom. Typically, college-level courses are taught using traditional lecture-based learning and associated laboratory exercises. The primary reason for this method of teaching is that it allows for a large amount of information to be conveyed to students in a relatively short amount of time (Bonwell, 1996b). There is an overwhelming amount of information that must be introduced to students in AP Biology in order to adequately prepare them for the AP Exam at the end of the school year. In addition, as scientific discoveries are made and a greater understanding of concepts is reached in the scientific community, the amount of information to be covered in the course is constantly increasing (Drayton, 2001).

Like most college courses, the AP Biology class offered at Kalamazoo Christian High School was largely lecture-based. When considering changes to the course curriculum, it was important to make sure that coverage of content was not sacrificed. This is a universal concern among educators who value both active learning opportunities and content coverage in their curriculum (Wood, 2005, Bonwell, 1996a). "Teaching students to integrate information without sacrificing content is critical" (Jones-Wilson, 2005).

One of the shortcomings of lecture-based learning is that, although content can be covered at a much faster rate, often content retention and understanding of the material on the part of the student is sacrificed. Bonwell and Sutherland describe this difference in learning experiences for students in active versus lecture-based learning environments:

> The research evidence supporting active approaches as the more effective way to facilitate student learning cannot be ignored. Students are simply more likely to internalize, understand, and remember material learned through active

> engagement in the learning process. Thus, the evidence clearly suggests the need for a change from the lecture that is so common in college classrooms. (1996a)

Wingfield and Black noted similar relationships between teaching style and student learning (2005). One of the primary reasons for a lack of retention and learning is that students involved in passive learning environments are much less likely to remain engaged in the apprehension and comprehension of new information for the entirety of the class period. Professors talk almost 80% of the time in traditional lecture-style classrooms (Weaver, 2005). According to Scott D. Wurdinger, "Lecture…has been proven to be ineffective because students often lose focus and do not remember much of what was said during the class. Forty percent of the time during a lecture, students are thinking about something other than what the professor is saying" (2005). It is a reality that adolescents enter the classroom preoccupied with matters other than biology which can make lecture less effective than would be desired. Bonwell and Sutherland note that "although most of us would like for our students to take away from our classes as much knowledge as possible…studies show that there is a practical limit to how much students can learn in any given class period" (1996a). Therefore, much of the content comprehension that occurs happens not during the class period, but outside of the classroom as students review for assessments that require their knowledge of the material (Jones-Wilson, 2005).

This method of teaching instills within students the belief that memorization of facts presented by the teacher rather than understanding of the material is most important (Hobson, 1996). Weaver refers to this as the "banking model" which "prevails in education wherein faculty use lectures to communicate knowledge and information to mostly passive students who, in turn, regurgitate on exams some portion of the knowledge and information they absorb" (2005). In courses consisting solely of lecture, students are not given opportunities to think for themselves or to think critically about the material presented.

Active learning activities in the classroom, specifically laboratory-based experiments and activities are also more engaging because they are often performed in groups. According to Smith, "Informal cooperative learning groups help counter what is proclaimed as the main problem of lectures: that the information passes from the notes of the professor to the notes of the student without passing through the mind of either one" (1996). When students must work together to complete a task or solve a problem that additionally may require higher-order thinking skills, they are required to become active participants in their learning. In a good problem-solving situation, ideas must be shared and thought through by all group members in order to reach a successful solution (Brooks, 1999). Typically, this type of learning is also better at motivating students to learn.

Most professors teach content material that they themselves find interesting. Therefore they are passionate about it and desire for the students to share their appreciation for the subject. This enthusiasm can help to make lecture more effective. According to Bonwell, "Effective lecturers can communicate the intrinsic interest of a subject through their enthusiasm" (1996b). However, many times, this enthusiasm is not enough to instill within the students the same passion for the material. Typically, the passion that the professor demonstrates is due to an experience involving interaction with the material taught rather than memorization of the facts pertaining to the subject. Thus, lecture prohibits the students from experiencing the very aspect of the subject material that originally inspired the professors.

> Even if we do not see an immediate professional need, most of us would like students to appreciate our disciplines, to understand that they can be exciting, enjoyable, perhaps even fun. Too often in our drive to cover 'the material', however, we forget to allow students opportunities to experience the joy of using our disciplinary techniques to gain an understanding of themselves and their environment (Bonwell, 1996b).

This enjoyment of the course material is an important factor in enhancing student motivation and attitudes toward the class. Students generally prefer hands-on learning to lecture (Wurdinger, 2005). According to McComas, students who participated in "laboratory experiences demonstrated increased achievement and a more positive attitude toward science than those lacking such experiences" (2005). Most of the students who register for AP Biology do so because they are interested in the subject and are planning to pursue careers in the scientific community after graduation. Therefore, it is important that the course foster their interest in the subject material. In order to prepare students for the scientific community in which they will be working, the course must also provide them with opportunities to participate in the scientific process. Not only does collaborative group work prepare students for working constructively with others as will occur in the workplace, it also provides students with the opportunity to "learn in the many and often ambiguous situations in which they will find themselves as members of a professional community" (Hobson, 1996).

Active learning also benefits a wider variety of students. Howard Gardner identified seven intelligences that students may demonstrate; these include verbal/linguistic, logical/mathematical, musical, visual/spatial, bodily/kinesthetic, interpersonal and intrapersonal (Shirley, 1996). Individual students learn material best when it is presented in a way that complements their learning style. Verbal/linguistic and visual learners are accommodated by lecture with the accompanying textbook (Bonwell, 1996b). However, about 73% of learners are successful if there is a blend of visual, verbal and kinesthetic learning (Jones-Wilson 2005). Lecture does not accommodate students who demonstrate aptitude in the other intelligences. By incorporating laboratory experiments and activities that require group work and hands-on manipulation of variables, students who learn through a broader range of learning styles are accommodated. This can lead to increased student success which, in turn, can lead to greater satisfaction and enjoyment in learning (Shirley, 1996).

The introduction of new laboratory experiments and activities to the AP Biology course at Kalamazoo Christian High School would not only help to fulfill the College Board requirements, but would also facilitate student comprehension and retention as well as increased satisfaction and enjoyment of the material. These experiences would also allow the students the opportunity to improve their abilities to think critically and to work collaboratively, both important skills for the professional workplace.

Demographics:

Kalamazoo Christian High School is a private school located in Kalamazoo, Michigan. The city has a population of approximately 250,000. The high school is located near central Kalamazoo, across the street from Western Michigan University. It has an enrollment of approximately 440 students. Students who register to take AP Biology are typically college-bound seniors. They are required to have taken General Biology and General Chemistry prior to acceptance in the course. Physics is not a prerequisite to AP Biology, although some students have completed the course and a few others take it concurrently. In order to be accepted into the course, students must have demonstrated academic rigor in their other high school courses. AP Biology is one of five AP courses offered at the high school. It is considered one of the most difficult courses offered on campus and maintains that reputation among the students. Therefore, students who register for the class are typically highly motivated and high achieving students. The 2006-2007 class consisted of twenty-seven seniors (9 males, 18 females). All of the students participated in this study.

The laboratory investigations and activities designed and implemented (Appendix B) in the AP Biology curriculum were imbedded throughout the first semester of the course. The topics introduced or reinforced by the investigations included design and analysis of controlled scientific experiments, capture-recapture methods of population estimation, transpiration, allelopathy, negative feedback loops and Chi-square statistical analysis. Lab activities pertaining to fermentation and cellular respiration were also developed (Appendix E) but were not implemented during the semester due to a lack of instructional time. Pre and post-tests, surveys of students and students' reactions to each activity (Appendix C) were used to determine the effectiveness of the activities.

IMPLEMENTATION

Introduction

During the first semester of Advanced Placement Biology, the topics of ecology, macromolecules, enzymes, cell structure and function, homeostasis, photosynthesis, cellular respiration, mitosis, meiosis and genetics are taught. For this research project, laboratory experiments and other activities were designed and implemented to replace some of the lectures on various topics. Specific lab topics included experimental design, capture-recapture methods of population estimation, transpiration, allelopathy, negative feedback loops, genetics, fermentation and cellular respiration. These lab activities were incorporated into the curriculum throughout the semester (Table 1) during and between units that covered material that would be reinforced or introduced in the lab experience itself.

Table 1: General Semester Outline with New Experiments and Activities

Semester One Unit	New Activity/Experiment (*activity not implemented)	Activity/Experiment Objective
Introduction to Biology	General Experimental Design Worksheets (Roly Poly Behavior Lab)	Students design, perform and analyze the results of a controlled experiment involving animal behavior.
Ecology	Capture/Recapture Activity	Students calculate the estimated size of a simulated population.
	Transpiration Lab	Students determine the effects of sun and wind exposure on the rate of transpiration.
	Allelopathy Lab	Students determine the effect of chemicals produced by one plant species on another.
Macromolecules/ Enzymes	N/A	N/A
Cell Structure/ Function	N/A	N/A
Homeostasis/ Osmoregulation	Negative Feedback Loops Activity	Students identify the role of each of the functioning units of a negative feedback loop and the importance of such regulation.
Photosynthesis/ Cellular Respiration	General Experimental Design Worksheets (Rate of Photosynthesis)	Students design, perform and analyze the results of a controlled experiment involving photosynthetic rate.
	*Seed Respiration Lab	Students determine the effect of temperature and germination on the rate of respiration in seeds.
	*General Experimental Design Worksheets (Rate of Yeast Fermentation)	Students design, perform and analyze the results of a controlled experiment involving rate of fermentation in yeast.
Mitosis/Meiosis	N/A	N/A
Mendalian Genetics	Chi Square Activity	Students identify the mode of inheritance of a mutation in fruit flies and use a Chi Square test to analyze data.

Activity 1: General Experimental Design (Appendix BI)

In order for scientists to gather information about the natural world and to determine cause and effect relationships they must perform experiments. A scientist develops a question to be answered and then states a hypothesis as to the answer based on previous experience and prior knowledge in addition to credible research. An experiment must then be conducted to test the hypothesis. In order for the experimental results to be taken seriously by the scientific community, the experiment must be designed in such as way as to gain credibility. First of all, the scientist must have only one independent variable and they must also have a control group to be used as a comparison to their test group. This should be the only difference between the test and control groups. All other parameters of the experiment must remain the same (controlled variables). The experiment should be performed many times so as to show whether or not the results are consistent. Data that are obtained should be quantitative as well as qualitative. Generally, there should be some sort of statistical analysis of the data to verify its significance. Graphs may be produced to demonstrate trends in the data collected and conclusions should be drawn. These conclusions should refer to any discrepancies in the data or sources of error. They should include a discussion of ways in which the experiment could be improved as well as a discussion of the next steps to be taken. This also requires some research and the use of other credible sources (peer reviewed scientific journal articles and other published materials) referring to studies pertaining to the same or similar phenomena.

In order to help students learn how to conduct meaningful experiments, the lab worksheets were developed to guide them through the process. Using labs already in the curriculum wherein students design their own experimental set up and data collection process (animal behavior and photosynthetic rate), these worksheets were incorporated to better assess their understanding of appropriate lab techniques and experimental design. Prior to performing the experiment students were required to fill out their Lab Design Worksheet wherein they developed a hypothesis based on credible background information which they had to cite. They also had to identify their independent, dependent and controlled variables and explain how they would collect and analyze their data. After the experiment, students received another worksheet which required them to assemble their results and conclusions. A graph of their quantitative data generated using Microsoft Excel was required along with an explanation of sources of error and experimental results. This section required them to search for credible sources to support their ideas as well.

Activity 2: Capture-Recapture Activity (Appendix BII)

When ecologists are working in the field and attempting to survey the size of a wild population, very rarely is it feasible for them to simply count all of the organisms in that population. In some cases, however, it is important that they have an estimate of the number of organisms in the population. For example, they may want to assess the size of an endangered population to determine if conservation efforts have had an effect on the success of that species. In these cases, an estimate can be determined using capture-recapture methods.

Scientists perform these assessments of population size by capturing a random sample of organisms from the wild population. Ecologists tag and collect any other necessary data pertaining to these organisms before releasing them back into the wild. They then return to the area shortly thereafter to capture another random sample of organisms from the same population. By using a simple proportion of the number of tagged organisms caught with respect to the total number of organisms caught during the second capture, the ecologists can estimate the actual size of the population (number tagged/total population = number tagged and recaptured/number in second capture).

Students in AP biology have knowledge of how to manipulate simple proportions to solve for an unknown. For this reason, students should have the capability of understanding and constructing the process and equation themselves without the need for a lecture to cover new material. The lab that was developed for students was a discovery activity performed during the ecology unit. Students worked in groups to think critically about the process and develop for themselves the equation that could be used to estimate the total population size from given capture-recapture data.

After the students had developed a method for determining the population size from such data, they were given the opportunity to try the process using Goldfish® crackers. Students were then given "ponds" of "fish" which consisted of cheddar flavored Goldfish® crackers in a large re-sealable bag. Their goal was to use the capture-recapture method of population estimation to determine the number of "fish" in the "pond". Each group received a small fish net for use in capturing the "fish" in their "pond". They then counted and tagged those "fish" by returning them to the pond as pretzel flavored Goldfish®. They mixed the "fish" in their bag and then caught another sample of "fish" from their population to determine the total population size. They repeated this process up to five times (as many times as class time would allow) to calculate an average population size. Unlike the circumstances faced by ecologists who study natural populations, this experiment allowed the students the opportunity to count the actual number of "fish" in the population. They then used this data to calculate the percent error in their experiment and to assess the effectiveness of capture-recapture methods of population estimation.

Activity 3: Transpiration Lab (Appendix BIII)

Transpiration is the evaporation of water from the leaves of plants. This plays a significant role in the water cycle in areas with dense plant populations. Typically, transpiration occurs very rapidly on sunny days. This is due to the fact that C3 plants open their stomata in the presence of sunlight so that they can obtain carbon dioxide for assimilation into sugar through the process of photosynthesis. When the stomata are open, water moves from the intercellular spaces between the spongy mesophyll cells of the leaf out into the surrounding air. The movement of water is due to a difference between the water potential (ψ) of the leaf and that of the air. Water moves from areas of high water potential to areas of low water potential. Typically, the leaf has a higher water concentration and thus a higher water potential than the surrounding air so water will leave the leaf.

Different environmental conditions can have an effect on the rate of transpiration. Increasing the temperature of the leaf increases the kinetic energy of water molecules inside of the leaf which will cause them to evaporate from the surface of the stomata. As water molecules evaporate into the air surrounding the leaf, the localized humidity around the leaf will increase which will increase the water potential of the surrounding air and decrease the rate of transpiration. However, if there is wind in the environment, it can move this localized humid air away from the leaf surface and bring dry air to replace it. This will cause the difference in water potential between the leaf and the air to remain high and cause the rate of transpiration to remain constant as well. Some plants have adaptations that prevent water loss. These adaptations include a thick, waxy cuticle which acts as a waterproofing layer, leaf hairs which allow for better maintenance of localized humid air around the leaf surface and a small surface area with fewer stomata to limit the places through which water can exit the leaf.

In this experiment, groups of students were given three small florist vials filled with water. Each group chose one species of plant to use for their experiment. They cut healthy leaves from that plant and placed them directly into the florist vials. (The number of leaves used was dependent on the plant species used. Students who chose to use maple (*Acer*) leaves could fit many more leaves in than students who chose to use leaves from a sumac tree for which one leaf has many leaflets and a wide petiole.) Groups were not allowed to choose the same species as any other group. Students were encouraged to look for species whose leaves were different in some way from those of other groups.

Students were asked to list general characteristics of their chosen leaves, paying attention to factors such as color, texture, shape and surface area. They then used a gram balance to measure the mass of their floral tubes containing both water and leaves. The mass of each vial was recorded and then vials were placed either under a grow light, in front of a fan or in a sheltered storage room overnight. Students returned the following day and recorded the final masses of each of their vials to determine the amount of water lost by each setup.

Assessment for this lab activity included calculations and post-lab questions pertaining to the data calculated. Students were responsible for calculating the average mass of water lost per gram of leaf tissue per hour for each of their trials. They then had to account for differences between the various test groups. This activity was done between the ecology unit (which included information about the water cycle) and the basic chemistry and cells unit (which included information about the properties of water and water potential). For this reason, there were some additional questions in the lab which were revisited after students had gained a better understanding of the characteristics of water and water potential so that they had a big picture understanding of the concepts involved in transpiration.

Activity 4: Allelopathy Lab (Appendix BIV)

Species do not live independently of one another. The behavior and activities of one species can have a direct impact on the success of another population. In some instances, populations have a positive influence on one another. When both organisms in such a relationship benefit, this is called a mutualistic relationship. In commensalistic relationships, one species benefits from another species that is unaffected. Other interactions between organisms can be beneficial to one species and harmful or even fatal to another. These are parasitic relationships (Campbell, 2002). Competition for resources such as food, water and space within a community can also occur if the populations are at or near the carrying capacity of the particular environment. Over time, species may evolve adaptations that allow them to more effectively compete for these resources.

When this topic is introduced in class, students typically think of ways in which animals compete for resources and the various adaptations that allow them to do so. However, students rarely think of plants in this context. Some plants have developed a means, termed allelopathy, for minimizing competition from other plant species. Allelopathic plants have the ability to synthesize chemicals that can positively or negatively affect other local plants. Garlic (*Allium sativum*) is one species that produces such chemicals. It produces a volatile chemical called allicin, the presence of which inhibits the germination and growth of a variety of plant species including lettuce (*Lactuca*) (Shimabukuro, 2006). Black walnut trees (*Juglans nigra*) are also allelopathic plants. They create a chemical called juglone (5-hydroxy-1,4-naphthoquinone) that inhibits ATPase activity and water uptake in neighboring plants (Heijl, 2004).

In order to better understand these interactions, students performed an experiment in which they placed twenty lettuce seeds in each of two Petri dishes containing a damp piece of filter paper. A piece of aluminum foil was placed in the center of each Petri dish. In one dish, students placed one clove of finely minced garlic on the foil. Lids were placed on each dish and the dishes were sealed with Parafilm. Students recorded observations of both dishes over the following six days.

This experiment was performed during the ecology unit. Students completed pre and post-lab questions as part of their laboratory assessment for this experiment. This lab was performed at the beginning of the year when students are still learning about the components of a good controlled experiment and how to find credible scientific sources. For this reason, they were required to do outside research to gather credible background information on the experiment as well as answer questions pertaining to independent and dependent variables and the like. Students were also asked to think critically about the implications of such interactions between plants and how the isolation of such chemicals for agricultural purposes could be harmful or beneficial to the environment.

Activity 5: Negative Feedback Loops Activity (Appendix BV)

In order for organisms to survive, they must have a means of regulating processes within themselves. For each reaction or process occurring within a cell, there is a specific rate and/or level at which that process must be maintained in order for life to continue. For example, humans must regulate internal conditions such as body temperature, blood glucose level, pH and osmolarity of the body tissues. For each of these variables, there is an acceptable level at which the body functions best. This is called the set point. The set point for the body temperature of a human, for example, is 98.6°F (37°C). If the body's temperature were to vary too far from this point, the enzymes within the body could become disabled and fail to catalyze all of the reactions necessary for life. Therefore, the body must have a mechanism in place to maintain this set point despite disturbances that may occur. This is called maintaining homeostasis and it is usually done within organisms by means of negative feedback loops.

A negative feedback loop functions to counteract a disturbance and return the regulated variable to its original set point. There are multiple parts that function together to make this occur. First, there is a sensor which detects the level of the variable being regulated. If the sensor detects a significant change in the variable, it relays an error signal to the integrator of the system which causes the effector to work to counteract the original disturbance. If, for example, an error signal was sent that the body temperature was too high, the brain would cause the sweat glands in the body to produce sweat so that evaporative cooling could bring the body back to its original temperature.

The activity designed to teach this topic was a dialogue that the students read in partners. It was written from the perspectives of Bert and Ernie from the PBS show Sesame Street. Students read through the dialogue together as Bert and Ernie learned about negative feedback loops and how they work using regulation of room temperature by a thermostat as an example. Once students finished reading through the dialogue, they filled out a chart identifying the various parts of a negative feedback loop from the example found in the dialogue. Then each group was given a biological factor that is maintained within living organisms along with a disturbance to that system. They had to use their book and notes from the dialogue to identify how the body would deal with such a disturbance to bring itself back to the original set point. Students drew a flow chart to show the order of events for their system. This provided a segue into the unit on osmoregulation in animals, specifically the use of antidiuretic hormone and aldosterone in the excretory system to regulate the concentration of water in the bloodstream.

Activity 6: Chi Square Activity (Appendix BVI)

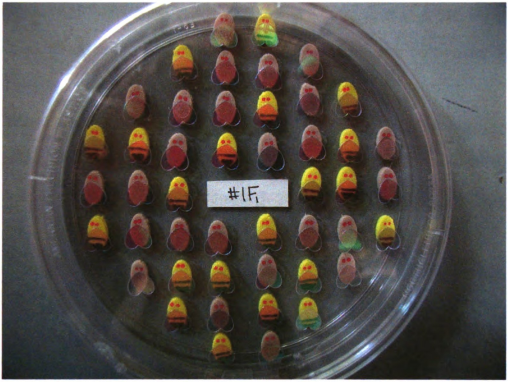
Punnett squares are used in genetics to determine the probability of the occurrence of various genotypes and phenotypes of offspring from a given cross. These can be used to follow the inheritance of autosomal or sex-linked traits as they move from generation to generation. Autosomal traits are characteristics that are coded for by a gene on any of the chromosome pairs except for the sex chromosomes (X and Y). These traits have the same chance of showing up in males and females as they pass from generation to generation. Sex-linked traits are so named because they are traits that are found on the sex chromosomes. Most of the sex-linked traits that are studied are found on the X chromosome and thus could be found in both males and females. However, for some traits, namely those that are sex-linked recessive, there will be a significant difference in the number of males versus females that show the trait. This is because males are hemizygous, having only one X chromosome whereas females have two. For this reason, females must have two copies of the recessive allele in order to demonstrate the trait. Males, on the other hand, have only one X chromosome and thus one copy of each of the alleles on that chromosome. Therefore, if they receive the recessive allele, they will automatically demonstrate the trait.

Geneticists can use Punnett squares as a tool to predict the mode of inheritance of a trait by comparing their predicted probabilities to the actual results of such crosses. Rarely do the actual data match the theoretical outcome when performing such experiments. There are variations due to chance that can cause the data to vary from what is expected. In order for scientists to determine whether or not the experimental data vary significantly from the expected data, which would cause them to reject their hypothesis as to the mode of inheritance, a statistical test must be done. For experiments where numbers of organisms with different phenotypes actually produced are compared with numbers of organisms theoretically expected, a Chi Square (X^2) test is performed.

The formula for calculating the Chi Square value is $\sum (o-e)^2/e$ where o is the number of observed organisms of the specific trait and e is the expected number of organisms with the same trait. Once the Chi Square value is calculated, it must be compared with the critical value to determine whether or not the differences between the observed and expected values are significant. Scientists typically accept the null hypothesis if the p-value is less than 0.05 (that is, the values are the same 95% of the time and only 5% of the time would you expect similar values by chance alone). Therefore, the calculated Chi Square value would be compared to a table of critical values with p=0.05 at the correct number of degrees of freedom (the number of categories minus one). If the Chi Square value is less than the critical value on the table, then the null hypothesis is accepted and there is no significant difference between the theoretical data and the actual data.

In this activity, each lab group was given a fruit fly family (P, F_1 and F_2 generations) with a specific mutation. The fruit flies were handmade using foam and other supplies from a craft store (Figure 1). Each generation was contained in its own Petri dish. The various mutations included yellow body, ebony body, bar eye, apterous, wrinkled wings and miniature. Some of these mutations are known to be sex-linked and others are autosomal. The number of "flies" of each sex and phenotype was made to closely follow but not exactly match the theoretical values, much like would happen if flies were actually bred to produce the various generations. Students had to count "flies" of each sex and phenotype in each generation and then develop a hypothesis as to the mode of inheritance of that specific trait. They then had to perform a Chi Square test to determine whether or not their data were significantly different from the expected data according to their hypothesis. In most cases, if the students correctly predicted the mode of inheritance their hypothesis was supported by the data. There were a couple of instances, however, when the numbers did vary significantly from the expected values. The purpose of this was to demonstrate to the students the importance of sample size and repeated trials when performing such experiments.

Figure 1: Sample Fruit Fly Petri Dish (Yellow Body, F_1)



The assessment for this lab included an activity worksheet that required the students to predict the mode of inheritance and provide explanations as to why they chose that specific method. They also had to calculate Chi Square values and explain what the results suggested along with how other factors such as sample size may affect the overall data.

Activity 7: Seed Respiration Lab (Appendix EI)

Aerobic respiration is the metabolic process by which organisms use oxygen in the process of breaking down sugar to release stored energy. The end products of this process are carbon dioxide and water. All organisms perform respiration as a means of releasing chemical energy to make adenosine triphosphate (ATP), an energy-rich molecule that can be used as a sort of energy currency within the cell to perform reactions or other processes that require an input of energy in order to proceed.

The process of cellular respiration is a sequence of many different chemical reactions, each of which is catalyzed by a specific enzyme. The rate of reactions can be affected by temperature. If temperature is increased, kinetic energy of molecules also increases. Enzymes engage by randomly colliding with their substrate. Therefore, if there is an increased amount of kinetic energy in a system, this will allow for more collisions to occur and cause the reaction to proceed at a faster rate. (This is only true, however, up to a certain point. At some temperature, the increased kinetic energy will actually cause the enzyme to move so much that its tertiary structure is changed at which point it will be unable to bind to the substrate to catalyze the reaction.) The opposite is true when the system is cooled down.

An experiment was designed in which students could study the effects of temperature on the rate of respiration. Students commonly carry the misconception that only plants perform photosynthesis and only animals perform respiration. However, plants perform both processes. For this reason, and to help students remember this fact, this experiment was designed to use radish seedlings as the respiring organism. When designed, twenty-five germinating and twenty-five non-germinating radish seeds were placed on a piece of wet filter paper. A Petri dish containing 30 mL of 0.025M barium hydroxide ($Ba(OH)_2$) was placed on each piece of filter paper and the seeds and dish were covered with a plastic storage container. Another container and Petri dish was constructed without seeds which served as the control group of the experiment. Two sets of these containers were made. One set was placed in a refrigerator and the other was left at room temperature for twenty-four hours. Carbon dioxide produced by the respiration occurring in the seedlings reacted with the barium hydroxide in the Petri dish to produce barium carbonate and water. Thus, after twenty four hours, the students were to titrate the $Ba(OH)_2$ solution in the Petri dish with 0.01M hydrochloric acid (HCl). The more acid used, the more barium hydroxide left in the dish and the less carbon dioxide produced by respiration in the seeds. Due to time constraints, this experiment was not performed in class; however the intended assessment included calculations of the amount of carbon dioxide produced by the seeds in each set up, along with explanations of the data comparing the respiration rates of germinating versus non-germinating seeds and cold versus room temperature seeds.

Activity 8: Yeast Fermentation Lab (Appendix EII)

Yeast perform the metabolic process of cellular respiration under aerobic conditions but, as facultative organisms, can be made to perform the anaerobic process of fermentation instead under certain conditions. These organisms break down glucose into carbon dioxide and ethanol. Just like in aerobic respiration, enzymes are required in order for each of the reactions in the process of fermentation to occur. The different variables that can affect the rate of reaction for an enzyme, then, could also affect the rate of fermentation as performed by yeast. Variables such as type of substrate, concentration of substrate, temperature, and concentration of yeast could all influence the rate of fermentation.

The monosaccharide glucose is a simple substrate that can be metabolized by yeast through fermentation. However, an experiment could be done in which one changes the substrate of the reaction to determine if yeast have the enzymatic capability of utilizing other sugars or sugar substitutes like sucrose, sucralose or aspartame, for this purpose. Enzymes tend to be very specific in their binding to substrates. Therefore, if these other substrates are used, they are either close enough in structure to the natural substrate broken down by the enzymes that they will still fit in the active site or there are other enzymes present within the yeast that can break down these other substrates.

Concentration of substrate in the presence of a set concentration of enzymes is another variable that can affect the rate of fermentation. Because enzymes catalyze reactions by randomly colliding with their specific substrate in solution, the rate of the reaction will increase if there are more collisions occurring. Eventually, the reaction rate should decrease as most of the substrate has reacted to form product. Likewise, if one were to increase the enzyme concentration in the presence of a set concentration of substrate, the reaction rate should also increase due to the higher likelihood of collision between the enzyme and the substrate. However, as the reaction proceeds, the rate should decrease because most of the substrate will have been converted into product.

The effect of temperature on rate of an enzyme catalyzed reaction has already been discussed. Increased temperature should cause an increased rate of reaction up to a point. At some temperature, the heat energy will cause the enzymes to denature and the reaction will stop.

Due to time constraints, this lab was not performed. For this activity, students were to design their own experiment to test the effect of an independent variable of their choice on the rate of fermentation by yeast cells. Students were not to be given the list of variables to choose from, but rather told to think about how fermentation occurs (through enzyme catalysis) and factors that could influence the rate of such a process. Students would have been shown a basic apparatus that could be used to perform such an experiment (Figure 2). In the process of designing this demonstration, a small (20 oz.) water bottle was filled with water at room temperature. A plastic pipet was filled with 2mL of a 3% yeast solution and 2mL of a 10% sucrose solution. The solutions were mixed within the pipet and then the pipet was inverted. Two metal hardware nuts were placed over the tip to keep the pipet from floating and the pipet was placed in the water bottle. As fermentation began to occur in the bulb of the pipet, carbon dioxide gas was produced. These gas bubbles would form at the tip of the inverted pipet within the water bottle and eventually break free and rise to the top. By simply counting the number of bubbles released over time, students could calculate the rate of fermentation within the pipet.

Figure 2: Fermentation Lab Demonstration Setup

This experiment would have been performed later in the year (second semester) as a review of enzymes and energetics as well as basic characteristics of a good controlled experiment. Assessment of the lab would have included a thorough experimental design along with results and conclusions.

An additional lab protocol was developed for this topic involving the same setup but with a structured, step-by-step procedure. This can also be found in Appendix EII.

Assessment:

In order to evaluate the effectiveness of each of the implemented lab activities and experiments, students were given a test (Appendix CI) before and after participation in the activities. The pre and post test questions were all short answer questions and were graded using a consistent rubric (Appendix CII). Students did not answer the questions that referred to the lab activities designed but not implemented during the school year (fermentation and seed respiration). In addition to these content questions, student opinions were also gathered using a subjective test (Appendix CIII) and an exit survey (Appendix CIV) to determine both their familiarity with design and implementation of controlled scientific experiments as well as their level of satisfaction with each of the activities performed. Student comments were encouraged and thus both objective and subjective data were used to determine the overall effectiveness of the active learning experiences.

RESULTS

Data collected through objective pre and post-tests (Appendix CI) were graphically analyzed and statistically analyzed using a paired t-test. Other data, collected through a subjective test (Appendix CIII) and exit survey (Appendix CIV) were also analyzed. Together, both the objective and subjective data were used to determine the overall effectiveness of the implemented lab activities.

Objective Analysis

At the beginning of each unit that had a new lab experience, students were given a short pre-test consisting of short answer questions based on the content to be covered in the active learning experiences. At the end of the semester, students were given a lab practical which covered all of the lab activities performed throughout the semester, including both the newly implemented labs as well as the preexisting experiments. The pre-test questions from each of the pre-assessments were imbedded in this lab practical.

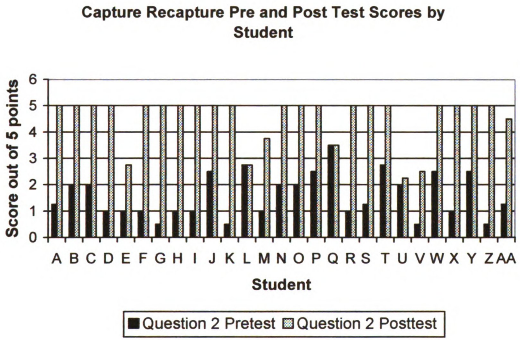
Table 2: Pre and Post Test Question Topics

Question Number	**Experiment Covered**
2	Capture-Recapture Experiments
4	Transpiration Experiment
5	Allelopathy
6	Negative Feedback Loops
7	Chi Square Tests

The experiment topics covered by each of the five questions are listed in Table 2. Both the pre and post-test questions were graded using a common rubric (Appendix CII). Table 6 (Appendix DI) shows students' pre and post-test scores for each of the questions along with total points possible for each which ranged from 2 to 11 depending on the topic.

The following graphs (Figures 3-7) show students' pre and post-test scores for each of the test questions. For the *Capture-Recapture Activity* (Figure 3), all but two of the students (students L and Q) tested improved their performance on the post-test compared to the pre-test.

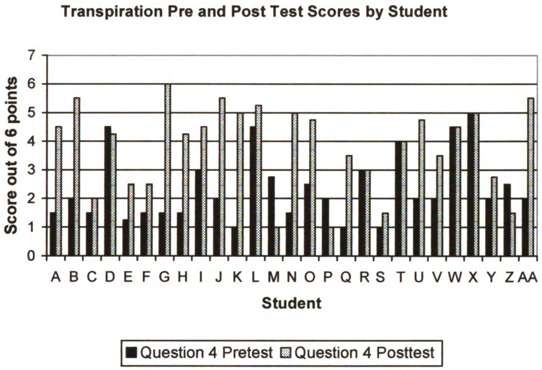
Figure 3: Pre and Post Test Scores for the Capture/Recapture Activity



The pre and post-test means were 1.58 and 4.52, respectively. Students were not introduced to this topic at all in the sophomore level biology class in the curriculum at Kalamazoo Christian High School; however, all of them scored higher than zero on the pre-test question. Twenty of the twenty-seven students earned a perfect score on the question on the post-test.

The graphical representation of the results of the *Transpiration Lab* pre and post-test questions is shown in Figure 4.

Figure 4: Pre and Post Test Scores for the Transpiration Lab



This data set shows more variation in student achievement than the previous one. Nineteen of the twenty-seven students improved on the post-test; however, only one scored one hundred percent (G). Four of the students (R, T, W, X) had no change between their pre and post-test scores and four of the students (D, M, P, Z) showed a decrease in their scores between their pre and post-tests. The class pre-test mean was 2.35 and the post-test mean was 3.81.

Results from the *Allelopathy Lab* (Figure 5) showed the greatest increase in student achievement as none of the students earned any points on the pre-test and fourteen of them scored one hundred percent on the post-test. The pre-test mean was 0.00 and the post-test mean was 1.47. Only two students showed no improvement on the post-test (C, Z).

Figure 5: Pre and Post Test Scores for the Allelopathy Lab

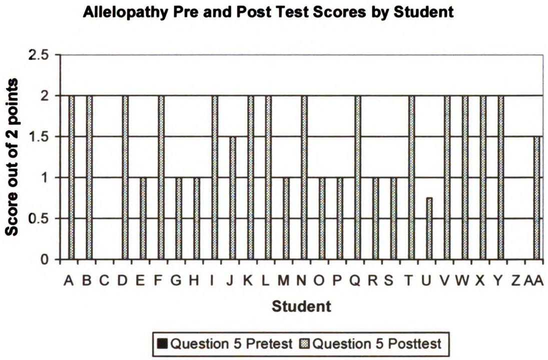
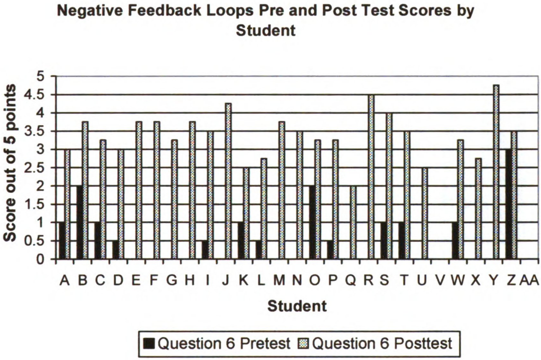


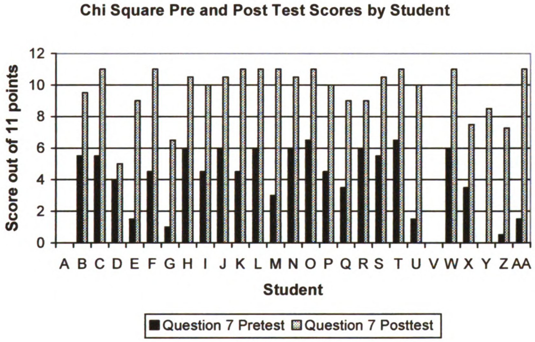
Figure 6 shows the pre and post-test scores for the *Negative Feedback Loops Activity*. Two of the students did not participate in the data collection for this lab activity (V and AA). All of the students who participated showed an increase in their score from the pre to post-test. The average pretest score was 0.60 and that of the posttest was 3.40. However, none of the students earned all five points.

Figure 6: Pre and Post Test Scores for Negative Feedback Loops Activity



The last lab performed and analyzed was the *Chi Square Activity* using artificial fruit fly families (P, F_1 and F_2 generations). Students A and V did not participate in the data collection for this activity. All students improved from pre to post-test with the pre-test mean at 4.14 and the post-test mean at 9.69. Many of the students earned all of the possible points on the questions as shown in Figure 7.

Figure 7: Pre and Post Test Scores for the Chi Square Lab



Statistical Analysis:

The null hypothesis was that the implemented experiments and activities would have no effect on student learning as indicated by pre and post-test comparisons. A paired t-test was performed to analyze the data collected for each of the five pre and post-test sections. The results of these t-tests are shown in Table 3.

Table 3: Paired t-Test Results for Pre and Post Test Data

Question	# 2	# 4	# 5	# 6	# 7
t-value	-11.8	-4.43	-12.0	-13.4	-14.8
Degree of freedom (df)	26	26	26	24	24
p-value	0.000	0.000	0.000	0.000	0.000
Mean difference	-2.94	-1.46	-1.47	-2.80	-5.55

The p-value for each of the pre and post-test comparisons was equal to 0.000. Therefore, the null hypothesis is rejected. This analysis suggests that all of the implemented experiments and activities had a significant effect on student learning.

Analysis of Survey Results

Prior to and after participating in the designed lab activities, students were given a baseline survey (Appendix CIII) to determine their confidence in their own scientific abilities and learning. Their answers ranged from strongly disagree (1) to strongly agree (5). Average rankings for each of the survey questions are shown in Table 4 along with the difference between the pre and post-survey means. The entire data set can be found in Appendix DII.

Table 4: Average Pre and Post Survey Answers

I feel confident in my ability to.... (1= strongly disagree, 5 = strongly agree)	Pre-Survey Mean	Post-Survey Mean	Difference Between Pre and Post Means
...identify the independent and dependent variables in an experiment.	4.1	4.5	0.4
...design and conduct a controlled scientific experiment.	3.9	4.4	0.5
...prepare a graph of experimental data using Microsoft Excel.	3.6	4.0	0.4
...analyze a graph of experimental data to draw conclusions.	4.0	4.3	0.3
...use a Chi-square test to determine whether or not data vary significantly from what is expected.	2.4	4.1	1.7
...work constructively in a group to perform a task.	4.5	4.6	0.1
...think critically about a problem and pose several possible solutions.	4.2	4.1	-0.1
I can better explain an important biological concept after participating in a hands-on lab activity involving that concept.	4.3	4.5	0.2

As can be seen in Table 4, there was the greatest positive difference for the question regarding students' confidence in their ability to perform a Chi-square test to statistically analyze data. The average student answer for that statement increased from 2.4 (disagree) to 4.1 (agree). There was a negative difference in the statement concerning students' ability to think critically about a problem to determine multiple solutions. The difference between the mean answers for this question was only 0.1, so there was relatively little change in the answers and the average student answer in the post test was a 4.1 (agree). For this reason, it seems that although students did not show an increase in their confidence level for this area of scientific literacy, they were fairly confident initially. For the other statements, there was only a slight increase in student confidence (between 0.1 and 0.5). For all of the questions involved, student post-survey data showed an overall confidence in their abilities. Average student answers for all eight of the questions on the post-test were between 4.0 and 4.6 (agree to strongly agree).

In addition to the confidence survey, students were also given an exit survey to assess their satisfaction with each of the implemented labs (Appendix CIV). Please note that the exit survey did not contain a question regarding the transpiration lab, therefore there are no data pertaining to student assessment of that experiment. The students were asked to assess each lab based on its helpfulness in furthering their ability to explain the biological concepts involved in each. Students ranked each lab on a scale of not helpful to extremely helpful. Average student rankings for each lab are shown in Table 5. The entire set of class data can be found in Appendix DIII.

Table 5: Average Student Ranking of Lab Effectiveness

Lab Activity	Average Ranking (5=extremely helpful, 1=not helpful)
Capture/Recapture Activity	4.25
Transpiration Lab	----
Allelopathy Lab	3.96
Negative Feedback Loops Activity	3.46
Chi Square Activity	4.27

Student perception of the effectiveness of the various lab activities was positive. The average answer for all of the labs assessed was greater than 3 (helpful). The highest average ranking was for the Chi square activity, followed closely by the Capture/Recapture Activity. Students seemed to appreciate the lab activities that involved their manipulation of materials. In the Chi Square activity, they worked directly with Petri dishes containing fruit fly families and in the Capture/Recapture Activity they worked with Goldfish® crackers. The Negative Feedback Loops activity was perceived as the least helpful of the labs in question. This was less of a lab experiment and more of a conceptual activity where students read through a dialogue and then applied their knowledge to another situation using their textbook.

In addition to ranking the labs, students were encouraged to provide feedback in the form of comments, as well as to indicate which of the labs was their favorite and least favorite with some explanation. A complete list of student responses to these questions can be found in Appendix DIV. Student responses were varied for all of the lab activities. Many of the students found the Capture-Recapture activity enjoyable. One student stated, "I didn't understand capture-recapture until after this activity". Another stated that this was their favorite of the lab activities because, "I understood the concept completely afterwards, and I'm not likely to forget it because it was done in a fun way". Multiple students commented on the real-life applicability of the lab and how the quick results and mathematical manipulation of the data to produce a population estimate were helpful in their understanding of the concept. A few of the students, however, did not find this lab especially helpful. Their primary concern was that the concept itself was not overly difficult for them and they found the time spent doing the activity could be better spent on more difficult concepts.

Student responses to the allelopathy experiment were mixed. Many students stated that what they disliked most about this lab was the fact that after a week, the garlic had really caused the room to smell. In terms of the actual experiment, some students really enjoyed the fact that this lab involved manipulation and observation of real organisms. One student stated, "I most enjoyed the garlic/allelopathy experiment. I enjoyed seeing a real-life example of allelopathy. I found the subject very interesting and to see how it actually happened was really cool". Another stated that, "The allelopathy study was interesting. We used live, real-world examples (as opposed to Pepperidge Farm Goldfish® or foam fruit flies) to discover allelopathy". One other student made a comment that supported the overall purpose of this thesis project; students appreciate learning through hands-on activities as opposed to lecture. This student stated, "I think it was really cool to see the lettuce leaves grow and see the effects of garlic on it. It's one thing to talk about/take notes on something but it was cool to actually see it happen". Many of the students disliked this lab, however. They found it boring and tedious because of the fact that most of the lab time was spent making observations and little else. Other students disliked this lab because the pre and post lab questions required that they find credible sources (published journal articles) to support their answers. Some of the students had a difficult time finding such sources.

The negative feedback loops activity had the most mixed results. Some students listed this activity as their favorite. They enjoyed the different way of learning. One student responded by stating, "I like using actions or skits to learn an idea". Another said, "I most enjoyed the Bert and Ernie Discover Negative Feedback Loops skit because not only was it a trip back to my childhood, but it related negative feedback loops to something I already know and I can therefore understand it more clearly". Many other students found this activity to be their least favorite. They disliked the fact that it was a dialogue involving Sesame Street characters as that was too juvenile for them. Student responses to the use of elementary characters in the dialogue were mixed. During the activity one student stated that he enjoyed learning through the use of Sesame Street characters because in general, topics in AP Biology are difficult to understand, but psychologically he found that if Bert and Ernie could understand it then he could too. A few others disliked the dialogue because they are visual learners and aside from the flow chart the students produced, there was very little in the way of visual aids involved.

The Chi Square lab using foam fruit flies also got mixed comments. Again, some students commented on their appreciation of having manipulatives to work with as they are more visual learners. One student commented, "I enjoyed the foamy fruit fly experiment because it helped you see the phenotypes of the whole population". Some of the negative comments about the flies were that they were hard to count and that the process was repetitive.

Overall, the subjective feedback from the students suggests that students appreciate the opportunity to do activities and experiments in addition to taking notes as part of the AP Biology class. Students' opinions of the effectiveness of each of the lab activities in the building of their understanding of various concepts varied depending on the activity and the individual learning styles of the students.

DISCUSSION

The data presented suggest that the lab activities and experiments implemented in AP Biology were successful in helping the students to understand and remember the various biological concepts that they were intended to teach (Table 3). Student satisfaction with the various activities was mixed but overall students ranked them as helpful to their ability to explain the concepts involved (Table 5).

One of the goals of this project was to replace lecture with various activities in order to meet the needs of students with various learning styles. Lecture tends to be an effective method of learning for students who are verbal/linguistic learners. These students tend to be highly motivated. The labs and activities implemented through this project were all very different from one another in terms of student involvement and content presentation. This may explain the varied responses by students to each of the lab activities.

The Capture/Recapture Activity was rated very helpful overall by students, in terms of helping them in their ability to explain the biological concepts involved. A few students considered the activity unnecessary in their development of understanding. These students are probably those who are more verbal/linguistic and logical/mathematical learners. For them, the concepts involved and actual procedure used to estimate population size would come naturally and make the process fairly elementary to understand. However, there were students who valued the experience as it truly helped them to gain a better understanding of the process. These were probably those who excel at activities that involve visual/spatial, bodily/kinesthetic and interpersonal skills. Through this activity, students with strengths in all of these various intelligences were accommodated. Thus, many students felt that the activity was worthwhile and their scores on the pre-test versus post-test showed a significant improvement.

After having performed the activity in class, there are a few changes that should be made to the procedure itself. First of all, the activity took longer than expected so students felt somewhat rushed in completing their trials and calculations. Part of the procedure called for the students to do one capture/recapture trial and then replace all of the fish and start over again from scratch. This meant that for each trial, students captured, tagged and recaptured. However, as one student pointed out, ecologists would not perform all of these steps when they performed multiple trials in the field. It is much more likely that the ecologist would capture and tag organisms once and then recapture multiple times to determine an accurate population estimation. Thus, in the future, this lab could be changed so that the students capture and tag the fish once, then recapture multiple times and use that data to calculate their population size. By making this change, the activity itself would have taken less time, as sorting back through the entire population of fish between trials to remove and replace the tagged organisms each time was very tedious and time consuming.

The activity was also beneficial in that it allowed students to see the necessity for multiple trials and how chance can play a role in the collection of data that is not true to the actual data. One group in the class had a large amount of error because of an outlier data point produced by one of their trials. This led to a class discussion about the importance of sample size and repetition in all scientific experiments.

The transpiration lab went fairly well. Although there are no data on student perceived effectiveness of this lab, the pre and post-test scores (Table 6) show student understanding of the topics presented. A few students stated that this was one of the labs that they felt helped them most out of all of the labs performed throughout the year (including labs performed that were not part of this project). It is hypothesized that student satisfaction with this lab would also be fairly high as it implemented many of the multiple intelligences as well, including bodily/kinesthetic, logical/mathematical, interpersonal and visual/spatial.

Students enjoyed the opportunity to go outside to collect their leaves. They also appreciated the use of live organisms in the lab because of its applicability to real-world situations. Due to space constraints, the lab was altered so that each lab group did one trial for each of the three groups (light, wind and control) for their plant species. Each lab group was required to choose a plant species to study that was different from that of all of the other groups. However, some of the species chosen were hard to identify. Thus, it would be helpful in future years to have a thorough field guide to Michigan plants available for use by the students. A couple of groups chose plants with compound leaves (like sumac) and for some reason these leaves had a much harder time staying hydrated in the florist tubes. Thus, they died and did not perform much, if any, transpiration. Students should be advised in the future to choose simple leaves or, if they choose compound leaves, to make sure there are only a few leaflets on each leaf. They could also cut the petioles again underwater to maintain the integrity of the water column. Overall class data were as expected. Aside from the groups whose leaves dried up, the other lab groups all had higher rates of transpiration occurring in the leaves exposed to light and wind than those in the control group.

The allelopathy lab was disliked by students primarily by the pungent odor of the classroom as the garlic was fairly potent and observations had to occur over about a one week time period. However, students found the lab to be helpful in their understanding of the material and they showed a significant improvement in their pre and post-test scores as a result of having performed this lab activity. This lab, like the transpiration lab, provided students with the opportunity to work with organisms to determine their interactions with one another. However, unlike some of the other activities, this lab required observations over a long period of time. This is much like what research scientists do in the real-world. It was interesting to note that some students found this repetition tedious and monotonous. In school, students are usually exposed to lab activities that have a "shock and awe" feeling about them. Typically, teachers choose to perform lab activities that can be completed in one class period and can entertain the students. Students are used to those kinds of lab activities by the time they are seniors in high school, so this long-term, less exciting type of lab does not seem as enjoyable to the students. However, the students who take AP Biology are those that are more likely to pursue careers in the sciences and it is important that they learn that much of what research scientists do is rather long-term and monotonous.

The lab went very well in terms of producing the desired results. Each lab group used a clove of crushed garlic instead of 1.0 grams so as to save on time in weighing out samples. In all lab groups the control group lettuce seeds had sprouted rather long white roots (about two centimeters in length) and some had small green leaves produced after about one week. The lettuce seeds in the Petri dish containing the garlic were severely limited in their growth. Many of them failed to germinate. If roots were present they only protruded from the seed by about 0.2 centimeters and had a black tip. This discrepancy between the two groups of plants was extremely obvious and really helped the students in visualizing and understanding the effects of allelopathic chemicals.

Some students really enjoyed the Negative Feedback Loops dialogue and felt that it was very effective in helping them to picture how such regulation occurs within the body. A few of these students wrote their own dialogues to explain other biological concepts as part of a final project at the end of the class. Other students did not feel that this activity helped them very much. This may be because of the fact that such an activity would appeal to those students who are interpersonal and verbal/linguistic learners but would not benefit visual/spatial or bodily/kinesthetic learners as much. This lab was rated as helpful by the students overall but scored the lowest of all of the labs surveyed. Despite the lower ranking by the students, their pre and post-test scores regarding the subject material showed significant improvement in learning.

Changes could be implemented the next time this activity is used in order to increase its effectiveness for all students. First of all, in order to reach more of the intelligences, visual/spatial and bodily/kinesthetic experiences could be integrated into it. For example, after the students draw a flow chart of their biological negative feedback loop, they could be asked to write and perform their own dialogue demonstrating how their biological loop works. Each student could take on a role (i.e. sensor, integrator, effector). They could introduce themselves to the class and explain what they do. This would also give the other lab groups the opportunity to hear about other feedback loops and not just about the one they are assigned.

The Chi Square activity with the foam fruit flies scored the highest of all of the labs according to the student survey (Table 5). This lab targeted students who prefer using logical/mathematical, bodily/kinesthetic, interpersonal, and visual/spatial skills. The high perception of the effectiveness of this activity by the students may be due to the fact that so many of the multiple intelligences were covered. For this reason, the activity would appeal to more students. Prior to doing this activity, students had already completed a unit on genetics. Therefore, their pre- test scores on the questions that required them to determine a method of inheritance and genotypes of organisms in the various generations were fairly high due to their knowledge of these topics. However, they showed a drastic increase in both their knowledge of and confidence in their ability to perform Chi Square tests. The pre and post-test showed a significant difference (Table 3) and the pre and post-survey questions pertaining to this lab showed the greatest difference (Table 4).

The most frequent complaint among the students was their frustration with the difficulty they had in counting the organisms of different phenotypes in each generation. However, this is a demonstration of laziness on the students' part. Had the students had to raise and count phenotypes of actual fruit flies, it would have been much more difficult than counting those of foam fruit flies that were glued in place in their Petri dish.

Each lab group was successful in determining and explaining the method of inheritance for their specific mutation. Many also enjoyed the fact that the lab gave them a visual representation of the organisms from the different generations as it helped them to better understand the genetics unit that they had just completed.

The other topics that were part of the pre and post-test survey included questions about students' confidence in their scientific abilities. As stated in the results, there was little change in most of these areas (Table 4). However, it is important to note that students' perceived confidence in their abilities in the pre-test was already fairly high. Therefore, that left little room for improvement through these activities. As the students observed in this study were all fairly high achieving seniors with an interest in science, this should not be surprising. The increase shown in the confidence in their ability to identify independent and dependent variables, design and perform controlled experiments and analyze collected data to draw conclusions could be attributed to their having had the opportunity to do using the general experimental design worksheets. Also, students were given the opportunity to design labs through activities not developed as a part of this thesis throughout the year. It was intended that they also design a lab testing the effect of some variable on the rate of yeast fermentation through this project. However, due to time constraints, that lab was not implemented. The integration of that lab activity as well as the seed respiration lab into the curriculum in future years would most likely be beneficial to the further development of these skills among the students.

The activities and experiments developed and implemented as a part of this thesis project were successful in accomplishing the goals set out initially. The activities engaged the students and were an effective method for teaching the content material in place of lecture and notes. Despite the inclusion of these activities this year, students still complained about the amount of note-taking they did throughout the year. It is intended that in the future, more lab activities could be designed and implemented in much the same way with similar success.

APPENDICES

APPENDIX A: CONSENT FORM

APPENDIX B: EXPERIMENTS AND ACTIVITIES

APPENDIX C: ASSESSMENTS AND RUBRICS

APPENDIX D: STUDENT RESULTS

APPENDIX E: LABS AND ACTIVITIES NOT IMPLEMENTED

APPENDIX A

CONSENT FORM

I. PARENTAL CONSENT AND STUDENT ASSENT FORM

Replacing Lecture with Active Learning in an Advanced Placement Biology Course:
Consent Form

Dear Parents/Guardians and Students:

I am currently working on my Master's degree through the Division of Science and Mathematics Education (DSME) at Michigan State University. I spent this past summer developing my thesis project which I will implement this year in my Advanced Placement Biology class. This course is equivalent to a college-level Introduction to Biology course and as such tends to be a largely lecture-based course. My research has focused on developing lab activities for the course that will both help students gain a better understanding of the course content and allow the students to be more actively engaged in the learning process. I will be implementing these lab activities throughout the first semester this year.

In order to evaluate the effectiveness of these lab activities, I will be collecting student-generated data in the form of several pre and post-tests, surveys and lab questions. With your permission, I would like to include data generated by your child in my thesis paper and presentation. The data collected will be kept strictly confidential. Your child's identity will not be connected to the data they provide nor will they be identified in any of the pictures used in my thesis presentation. There are no known risks or benefits associated with your participation in the study.

Participation in this study is completely voluntary. Your child's grade will not be affected in anyway if you choose to withhold their data. All students will be required to do the same amount of work regardless of their participation in the study. If at any time during the semester you choose to remove your child's data from my thesis, your request will be honored.

Please fill out the back of this form to let me know of your consent or lack thereof in the use of your child's data in my thesis. Seal this form in the accompanying envelope and return it by September 15th, 2006. I will not open the envelope until all semester grades have been recorded so that inclusion or exclusion of data from my study will in no way affect your child's grade in class.

If you have any questions or concerns regarding my project, you can contact me by phone (381-2250 ext. 309) or by email (kjoos@kcsa.org). Questions regarding my thesis project can also be directed to Dr. Merle Heidemann at DSME, 118 N. Kedzie, Michigan State University, East Lansing, MI, 48824, by phone at (517)432-2152 ext. 107, or by email at heidema2@msu.edu.

If you have any questions or concerns regarding your rights as a study participant, or are dissatisfied at any time with any aspect of this study, you may contact – anonymously, if you wish - Peter Vasilenko, Ph.D., Director of the Human Subject Protection Programs at Michigan State University, by phone: (517)355-2180, fax: (517)432-4503, email: irb@msu.edu, or regular mail: 202 Olds Hall, East Lansing, MI, 48824.

Thank you,

Kelly Joos
Kalamazoo Christian High School

The following pertains to my son/daughter ________________________________'s participation in Ms. Joos' thesis project. (Print student name here)

Please check all that apply:

_____ I approve of Ms. Joos' use of data generated by my child in her thesis project. I am aware that all data she collects will remain confidential.

_____ I DO NOT approve of Ms. Joos' use of data generated by my child in her thesis project.

_____ I approve Ms. Joos' use of pictures of my child in her thesis presentation. I am aware that my child will not be identified in such pictures.

_____ I DO NOT approve Ms. Joos' use of pictures of my child in her thesis presentation.

_______________________________________ _______________

(Parent/Guardian Signature) Date

I voluntarily agree to participate in Ms. Joos' thesis project. I am aware that my grade will be unaffected by my decision.

_______________________________________ _______________

(Student Signature) Date

APPENDIX B

EXPERIMENTS AND ACTIVITIES

I. EXPERIMENTAL DESIGN WORKSHEET

II. CAPTURE/RECAPTURE ACTIVITY

III. TRANSPIRATION LAB

IV. ALLELOPATHY LAB

V. NEGATIVE FEEDBACK LOOPS ACTIVITY

VI. CHI SQUARE ACTIVITY

Our Names: ______________________
____
____
____

OUR BRILLIANT LAB PROPOSAL

We will test the effect of ______________________________________ on
____

Our hypothesis (It is hypothesized that..... OR If....,then....): ______________
____
____

Information that supports our hypothesis:

Write your factual information below with the author of the source in which you found the information in parenthesis after each statement. You should use <u>at least three</u> different sources.

____
____
____
____
____
____
____
____
____
____
____
____
____

Attach all sources (except information from your textbook) to this page before you hand it in.

Our Independent Variable (include units if applicable): ____________________

Our Dependent Variable (include units if applicable): ____________________

Our Experimental Set-Up (include Materials Needed):

Our Control Group will be... ______________________________________

____

Our Test Group(s) will be... ______________________________________

____

Our Controlled Variables: ______________________________________

____

____

____

____

We will collect our Quantitative Data by recording...____________________

____

We will satistically analyze our results by.... ____________________________

____

Our Names: ________________
____
____
____

Our Brilliant Results and Conclusions

RESULTS:

A graph(s) of the data from our lab is attached. The graph(s) shows that

____
____
____
____

Our statistical test showed that... ______________________
____
____

CONCLUSIONS:

Do your results support your hypothesis? How do you know? __________
____
____
____

Where would you go from here? **(Explain any discrepancies between your results and your hypothesis, further questions to ask, future experiments to perform?) If you use any information from credible sources here, include the author in parenthesis.**

____
____
____
____

Attach all sources (except information from your textbook) to this page before you hand it in.

Name: ____________________

ESTIMATING POPULATION SIZE

The size of various populations will change over time. At any given time, ecologists may want to determine the size of a particular population. This could be because they fear the population is dwindling or perhaps because they believe the population to have grown too large.

When ecologists want to estimate the size of a population, they frequently use the Capture-Recapture Method to do so. This involves catching members of a population and tagging them in some way. When the ecologists return to the area, they catch more members of the population and determine the population size based on the number of tagged organisms caught.

For example:

Dr. Zucchini, a renowned ornithologist, goes out to a Jack Pine forest in Northern Michigan to determine the size of the Kirtland's Warbler (soon to be Michigan's new state bird??) population. Because of the shrinking forest, Dr. Zucchini and many other ecologists fear that the warbler population may soon disappear.

She sets up mist nets in the area and catches birds from 5 am until 11 am. She tags each bird by putting a metal band around its right leg before releasing it. She returns to the area a week later and sets up her mist nets again. Her data for both visits is below:

Number of warblers originally caught and tagged: 20
Total number of warblers caught on return visit: 18
Number of tagged warblers caught on return visit: 11

From her data, how can she estimate the size of the Kirtland's Warbler population? (Do not write calculations here, explain in complete sentences.)

Write an equation that could be used in any Capture-Recapture Procedure to calculate the total estimated population size.

Calculate the estimated Warbler population size from Dr. Zucchini's data.

Today your job as a new ecologist will be to use the Capture-Recapture method of population estimation to determine the size of a goldfish population feared to be endangered in this part of the world.

Your group will be given a "pond" of fish and a fish net. The goldfish species that you are collecting is called *Cheddarus peppridgus*. When you catch them, you can tag them by "pretzeling" them and releasing them back into the pond. After you have released them all, make sure you mix the pond up well before returning to recapture. Record your data in the table below. Then, remove all of the "pretzeled" goldfish and put the original fish back in the pond. Because we all know how important it is to verify your results in any experiment, repeat the process four more times.

Trial	# Captured and Tagged	Total # Recaptured	# of Tagged Recaptured	Calculations	Estimated Population Size
1					
2					
3					
4					
5					
				Average Population Size	

Class Average Population Size: ____________________

When ecologists do these sorts of surveys of a population, they do not have access to the actual population size. (If they did, they wouldn't need to do the survey!) However, you do have access to this information!

Actual Population Size: ____________________________

You can determine the percent error in the class data.

% Error = |Observed – Expected| / Expected * 100

What was the class' percent error? _______________________

Name: ___________________

Transpiration and the Water Cycle

Plants play an important role in the water cycle. Rain water that is absorbed by the soil can travel into the roots of plants. When it does so, it travels through cells in the plants roots, stem/trunk and possibly branches to the leaves. Transpiration is the evaporation of water from the leaves of a plant into the surrounding air.

What is the name of the plant tissue which transports water throughout the plant? (You may have to refresh your memory from biology – look in your textbook if you can't remember!) ___________________

Today you are going to test the effect of various factors on the rate of transpiration from leaves. Your lab group will be given a set of six florist tubes.

Fill these with tap water and cap them before you continue.

Place the florist tubes in a test tube rack and obtain a pair of scissors and you are ready to go outside!!! ☺

Once outside, your group needs to decide on the plant species which you wish to test. You will be comparing your species with each of the other groups' species. For this reason, you should make sure that the species you choose has significant structural differences (surface area, texture and color) when compared to the species of other groups. You'll want leaves that have long petioles so that they don't dry up as they use the water in the tube! For some species, the leaves have fairly nonexistent petioles, in this case it may be appropriate to use a branch. Check with your instructor.

Cut nine leaves and place them **IMMEDIATELY** into the filled florist tubes (three leaves per tube).

When your leaf collecting is finished, you're ready to get the mass of each of your tubes. Dry the outside of the tube off before you weigh it. Record the masses in the appropriate column of the attached table.

We will be testing the effect of wind and sun on the rate of transpiration. Place tubes A and B in the back room (control treatment), C and D under the plant lights and E and F in front of the fan. (Make sure you keep a record of which tubes are under each treatment!)

Leave the tubes under each treatment for 24 hours.

Results:

Species Used: ______________________________

General Charactistics of Our Leaves (shape, color, texture, surface area)

	Trial	Initial Mass (g) (w/tube)	Final Mass (g) (w/tube)	Mass of H_2O Lost (g)	Mass of Leaves (g)	Mass of H_2O Lost (g) per Gram of Leaf Tissue	Average H_2O Lost (g) per Gram of Leaf Tissue	Average H_2O Lost (g) per Gram of Leaf Tissue per Hour
A	Control							
B	Control							
C	Light							
D	Light							
E	Wind							
F	Wind							

1. Which treatment caused the HIGHEST transpiration rate? Why do you think that is?

2. Which treatment caused the LOWEST transpiration rate? Why do you think that is?

3. Some of the water that was absorbed by the leaves was used in a chemical reaction. What was it used for? ____________________

4. Unlike humans, plants are not very efficient in their water usage and much of the water absorbed is released through the leaves. As an adult, a human is supposed to drink eight 8 oz. glasses of water a day.

   If you were a plant (whatever species your group is studying) of YOUR body mass on a windy day, how much water would you need to drink in a day? (Hint: 1 ounce = 29.57mL, 1 mL H_2O = 1 g H_2O, 1 kg = 2.2 lbs)

5. Compare your control data with that of other groups (different plant species).

    a. Which leaves seem to do the best job at reducing their water loss throughout the day?

    b. What adaptations do these leaves have? Explain how these adaptations could decrease water loss.

The following questions will be revisited in weeks to come.... ☺

6. List and describe how <u>three</u> of the characteristics of water make it possible for a plant to transport water as it does.

7. Now that you know about water potential...

    a. ...explain why each of the test conditions (control, light, wind) provided the results that they did.

    b. ...explain why the adaptations listed in 5b. could help decrease the movement of water from the leaf to the environment.

COMPETITION BETWEEN PLANTS
AKA CHEMICAL WARFARE

As you know, organisms in an ecosystem are affected by one another. All of these organisms must have adaptations that allow them to survive in their habitat. If competition is fierce, plants that have genetic information that will allow them to out-compete other species will survive and reproduce to pass on that genetic information. This experiment will demonstrate plants' ability to compete and distinguish between the fit and the not so fit.

Pre-lab Questions:

1. What types of resources would plants compete with each other to obtain in their natural habitats? (List at least three and state the importance of each to the survival of the plant.)

2. The phenomenon that we are going to explore in this lab is called **allelopathy**. Using a credible journal source, explain what allelopathy is. (Attach a copy of your source to this page.)

Read through the following lab procedure and then answer the following questions:

3. What question are you trying to answer in this experiment?

4. What is your hypothesis for this experiment?

5. Describe the control group of this experiment.

6. Describe the test group of this experiment.

7. What is the independent variable of this experiment? ________________

8. What is the dependent variable of this experiment? _________________

9. List the controlled variables of this experiment (at least 5).

10. What type of data will you record under the observations column of the data table?

Procedure:

Your lab group will be given the following:

- Two Petri dishes
- Four pieces of filter paper
- 40 lettuce seeds
- Two strips of Parafilm
- One clove of garlic (*Allium sativum*)
- A small beaker and plastic pipet
- Two small pieces of aluminum foil

1. Place two pieces of filter paper in each of the Petri dishes and add 2.5 mL of water to each of the dishes using the pipet.

2. Chop the garlic into SMALL pieces (almost like liquid!) and measure out a 1.0 gram sample of the garlic on one of the pieces of aluminum foil.

3. Place the empty aluminum foil in the center of one Petri dish and the aluminum foil with the garlic in the center of the other.

4. Place 20 lettuce seeds on the wet filter paper of each Petri dish. Make sure that the lettuce seeds are not touching the aluminum foil in either dish!

5. Wrap each dish with a piece of Parafilm and set them on the side of the counter to allow time for the lettuce seeds to germinate.

6. Check on your dishes every day for a week and record your observations in the table below.

Results:

Day # / Date:	Observations:
0 /	

Post-lab Questions:

1. You will be learning statistical tests that could be used to analyze data like these later in the semester. Statistical tests allow you to determine whether there is a difference between the data of your test group and your control group. For now, just use your own intuition to determine whether or not your hypothesis was supported.

2. Do some research to find the name of the chemical compound that is being released by the garlic to cause its allelopathic affects. Cite your source below.

3. Black walnut trees (*Juglans nigra*) are also well-known allelopathic organisms. What chemical do they release and by what mechanism does it affect surrounding plants? Cite your source below.

4. How could the isolation of these chemicals from garlic and/or black walnut be used commercially in agriculture?

5. Through biotechnology, scientists have incorporated the genes of one species into the genome of another species.
   a. How could this process be used commercially in agriculture?

   b. What are some possible harmful effects of this process?

Bert and Ernie Discover Negative Feedback Loops

It is a VERY warm day. Bert has just returned from lunch with Big Bird to find Ernie splashing around in a kiddie pool in their living room with his rubber ducky. The windows are wide open and the room is sweltering.

Ernie: Hi Bert! You're just in time! It was getting really warm in here so I decided to blow up the kiddie pool and go for a swim. This sure hits the spot on a day like today!

Bert: (perturbed, annoyed and exasperated) ERNIE!!! You can't swim in a kiddie pool in the living room! You're splashing all over the carpet! Luis and Maria are going to have water dripping from their ceiling and we're going to lose our security deposit!

Ernie: But Bert, you can't possibly expect me stay in this apartment in these temperatures without going for a swim; it's just too hot!

Bert: Ernie, we have air conditioning! You just have to set the thermostat!

Ernie: You told me not to touch the thermostat – because you thought I'd break it Bert. Can you show me how it works?

Bert closes the window and walks over to the thermostat, Ernie follows.

Bert: Alright Ern. Here's how it works. The temperature in the room is called the **controlled variable**. We can choose the temperature we'd like it to be by pushing these arrows on the thermometer up and down. We'll set it at 72°F, that's called the **set point.** Does that make sense?

Ernie: Sure does Bert.

Bert: Alright, now the thermostat is the **integrator** or **controller** of the system. It has a thermometer inside of it that acts as the **sensor** to detect the temperature of the room. On a hot day, the muggy air from outside comes in and the room gets too hot. That's called the **disturbance.** The thermometer senses that and lets the thermostat know that something needs to be done - this is called the **error signal**.

Ernie: I know what comes next Bert! Can I try?

Bert: Sure.

Ernie: Alright.... The thermostat sends a message to the air conditioner to turn on so that it can cool down the room to get the temperature back to the **set point.**

Bert: That's right Ernie – and the air conditioner is called the **effector.**

Ernie: But Bert, if the air conditioner stayed on all of the time, then the room would get way too cold! Instead of my swimming trunks, I'd have to put on my fuzzy parka! How does the thermostat keep the room near the same temperature all of the time?

Bert: You're right Ernie! See if you can figure out how that would work!

Ernie: Let me put my thinking cap on here….. So, the cold air would be the **disturbance**. And it would cause the temperature, the **controlled variable,** to decrease below the **setpoint.** Am I right so far?

Bert: You're doing great – what's next?

Ernie: The **sensor,** the thermometer, would detect this and send an **error signal** to the thermostat. What's the thermostat again Bert?

Bert: The **integrator** or **controller.**

Ernie: Right! So the thermostat will cause the furnace to turn on to heat the apartment right back up!

Bert: Almost, Ernie. The thermostat will just turn the air conditioner (the **effector**) off – the room will heat up again on its own because of the sweltering heat outside.

Ernie: What if it was really cold outside Bert?

Bert: Then the cold temperature would trigger the thermostat to make the furnace start up so that the room would heat up!

Ernie: How cool is that Bert! That thermostat is amazing. If you heat the room up it cools it back down and if you cool the room down it will heat it back up! Every time something happens to the room, the thermostat makes the OPPOSITE happen to get it right back to where it was!

Bert: That's right, Ernie. It's all about opposites.

Ernie: What's this whole thing called then Bert?

Bert: A **negative feedback loop**.

Ernie: Wow, Bert. I wonder if there are any other negative feedback loops around us.

Bert: They're everywhere Ernie – some are even inside of you!

Ernie: Inside of me? You've got to be kidding Bert! How can negative feedback loops happen inside of me if I don't even know about them?

Bert: There's a lot happening inside of you Ernie. You don't have to think about them because they're involuntary.

Ernie: So I can think about things like shapes and colors and the alphabet!

Bert: Exactly!

Ernie: But why do I need negative feedback loops Bert? How are they important to me?

Bert: Because you need to maintain **ho-me-o-sta-sis** Ernie.

Ernie: **Ho-me-o-sta-sis.** What's that Bert?

Bert: Your body maintains constant conditions necessary for life. Just like we want our apartment to stay near 72°F, our bodies want to stay around 98.6°F.

Ernie: So I have a thermostat and an air conditioner inside of me Bert? That's amazing!

Bert: Not quite Ernie.... But you have parts inside of you that have the same functions; **integrators, sensors and effectors.**

Ernie: What else does my body use negative feedback loops for?

Bert: Your body uses negative feedback loops to keep your blood sugar level constant and to keep the right amount of oxygen moving through your blood to your cells. There are a TON of negative feedback loops inside of you Ernie! All living things use them – even plants! They have to maintain a certain concentration of water inside of their leaves on hot and sunny days!

Ernie: Does my rubber ducky use negative feedback loops Bert?

Bert: No, Ernie because your rubber ducky doesn't have any of the parts of a negative feedback loop.

Ernie: Oh, right. But a REAL ducky would, huh, Bert?

Bert: (rolling his eyes) Yes Ernie a real ducky would.

Ernie: I get it Bert! I've got another one for ya.

Bert: Alright, what is it.

Ernie: Well, It goes like this. Ernie filled up the swimming pool. Bert detected the filled swimming pool and sent out an error signal that sounded like this: ERNIE!!!! Ernie heard the error signal and ran out of the apartment and Bert emptied the pool. This is a negative feedback loop because emptying is the opposite of filling! Have fun Bert!

Ernie bolts out the door. Bert rolls his eyes and begins to dismantle the mess that Ernie made.

Now it's your turn! You and your partner must join another group. Together, you must choose one of the variables controlled by negative feedback loops mentioned by Bert and Ernie. (They are underlined.) You need to use your textbook to determine how that variable is regulated.

You will be given a piece of poster board. You and your group need to diagram the negative feedback loop and label each of the **bold** terms from this script on your poster. When everyone is finished you will be presenting your poster to the rest of the groups! Have fun!

Fill in the table below to get yourself sorted out!

	Bert & Ernie	**Definition**	**Your Loop**
Set Point			
Disturbance			
Effector			
Integrator/ Controller			
Controlled Variable			
Sensor			
Error Signal			

regulation of blood sugar

you eat a candy bar
with lots of sugar

regulation of blood sugar

YOU HAVEN'T EATEN
ALL DAY!!!

REGULATION OF OXYGEN AND CARBON DIOXIDE IN THE BLOOD

YOU'VE JUST BEGUN EXERCISING
AND YOUR MUSCLES ARE USING
OXYGEN AND MAKING CO_2 QUICKLY!

REGULATION OF OXYGEN AND CARBON DIOXIDE IN THE BLOOD

YOU'RE HYPERVENTILATING!

REGULATION OF BODY TEMPERATURE

YOU'VE BEEN PLAYING
SOCCER OUTSIDE ON A
HOT DAY!

regulation of body temperature

you're sitting on the
bleachers watching a
football game on a
very cold day

DISTURBANCE

SET POINT

SENSOR

ERROR SIGNAL

EFFECTOR

INTEGRATOR/ CONTROLLER

CONTROLLED VARIABLE

DISTURBANCE

SET POINT

SENSOR

ERROR SIGNAL

EFFECTOR

INTEGRATOR/ CONTROLLER

CONTROLLED VARIABLE

Name: ________________

THE FOAMY FRUIT FLY FAMILY

Before beginning this lab activity, you should have read the Overview, Objectives and Introduction sections of Lab 7: Genetics of Organisms in your lab book (pages 78-80).

Instead of working with live fruit flies that you would have to monitor almost constantly for the next few weeks, you will be given a family of foamy fruit flies. These flies exhibit the same mutations as real *Drosophila* – but are MUCH easier to work with. You can distinguish between males and females by coloration of the abdomen. Use Figure 7.2 in your lab book to distinguish between the two.

You will be given two families of flies. Each family will have a single trait that varies from the wild-type. You will be responsible for identifying and naming the mutation. Once you have done this, you will have to tally the F_1 and F_2 generation data and use this information to determine the means by which this mutation is inherited. You will also draw a pedigree for each family.

Questions:

1. Our Foamy Fruit Fly Family is Family # _____.

2. P Generation: For each parent, draw a picture of the fly in the space provided and identify the phenotype. (Flies without a mutation are called wild-type flies).

Female phenotype ________________ Male phenotype ______________

3. There should be 46 flies in the F_1 Generation. Count the flies of each sex and phenotype and record your data below. It's easy to make mistakes in counting here so make sure you check your counts!

Sex and Phenotype	**Observed # of Flies**

a. How can you use this data to determine if the mutation is sex-linked or autosomal?

b. Does the mutation appear to be dominant or recessive? How do you know?

c. Based on your answers to 3a and 3b, write a hypothesis that describes the mode of inheritance of the mutation. This is your null hypothesis.

4. a. Based on your hypothesis, what are the genotypes of the two parents? _______

b. Fill in the Punnett Square below to show the expected F_1 offspring ratio from these parents.

c. How many flies were in your F_1 generation? ___________

Based on your Punnett Square, fill in the expected number of F_1 flies of each sex and phenotype in the table below.

Sex and Phenotype	Genotype	Expected # of Flies

5. Now, let's look at what the F_2 generation would be expected to look like according to your null hypothesis.

   a. Fill in the Punnett Square below to show the expected ratio of the F_2 flies from the F_1 cross.

   b. Using your Punnett Square result, fill in the table below. (There will be 46 flies in your F_2 generation as well.)

Sex and Phenotype	Genotype	Expected # of Flies

6. Now count (and recheck) the actual number of flies in the F_2 Generation. Record your data below.

Sex and Phenotype	Observed # of Flies

7. a. Your observed and expected number of flies from the F_1 and F_2 generations probably aren't exactly the same. Why is this? Explain in detail.

8. Does this mean that your hypothesis is incorrect? ________

Name: ______________________

STATISTICAL ANALYSIS OF YOUR FOAMY FRUIT FLY FAMILY DATA

Remember, the formula for calculating Chi-square is: $X^2 = \sum(o-e)^2/e$
<u>Do not include phenotypes for which e=0.</u>

1. a. Use the following table to calculate the Chi-square value for the F_1 generation.

Sex/Phenotype	**Observed (o)**	**Expected (e)**	**(o-e)**	**$(o-e)^2$**	**$(o-e)^2/e$**
				$X^2 =$	

b. How many degrees of freedom are there for this data set? __________

c. Using Table 7.5 on pg. 86 of your lab book, what is the critical value for this data at p = 0.05? ________________

d. Is your Chi-square value greater or less than the critical value at p=0.05? ____

e. Does your data vary significantly from the expected data? ____________

f. Does this data support your null hypothesis? ______________________

2. a. Use the following table to calculate the Chi-square value for the F_2 generation.

Sex/Phenotype	**Observed (o)**	**Expected (e)**	**(o-e)**	**$(o-e)^2$**	**$(o-e)^2/e$**
				$X^2 =$	

b. How many degrees of freedom are there for this data set? ___________

c. Using Table 7.5 on pg. 86 of your lab book, what is the critical value for this data at p = 0.05? ___________________

d. Is your Chi-square value greater or less than the critical value at p=0.05? ____

e. Does your data vary significantly from the expected data? _____________

f. Does this data support your null hypothesis? _________________________

3. Your answer to 1f. or 2f.could have been **NO** even though your null hypothesis was correct. What source of error (that you had no control over) could have caused the null hypothesis to be rejected?

4. Draw the pedigree for your foamy fruit fly family below. Label the P, F_1 and F_2 generations. (If multiple flies of the same phenotype are produced in a generation, write the number of identical flies next to that symbol on the pedigree.)

APPENDIX C

ASSESSMENTS AND RUBRICS

I. PRE AND POST TEST QUESTIONS

II. PRE AND POST TEST SCORING RUBRIC

III. SUBJECTIVE PRE AND POST TEST

IV. SUBJECTIVE EXIT SURVEY

Name: _______________

AP Biology Survey of Prior Knowledge

Answer each of the following questions to the **best** of your ability. Do not leave any question blank.

1. You need to measure the rate of aerobic respiration of an apple.

    a. What substances are needed for aerobic respiration to occur?

    b. What substances are produced by aerobic respiration?

    c. Explain how you could use a base like barium hydroxide ($Ba(OH)_2$) measure the respiration rate of an apple.

    d. Describe the data you would collect and how you would analyze the data collected in your experiment to determine the rate of respiration.

2. There is a population of woodchucks around Kalamazoo Christian High School. You want to use the Capture-Recapture method to determine the size of the woodchuck population.

    a. How would you do your experiment?

    b. Provide hypothetical results of your experiment and show the calculations you would use to determine the actual population size.

3. You want to test the effect of acid on the fermentation rate in yeast. Describe how you would set up a CONTROLLED experiment to do so.

4. a. Describe the water cycle. (You may draw a labeled diagram if you wish.)

b. Define transpiration and explain how it is involved in the water cycle.

c. List two variables that can affect the rate of transpiration. State the effect each has and **explain** why.

5. Explain how an allelopathic plant is better able to survive than non-allelopathic plants.

6. a. Explain what negative feedback loops are **and** why they are important to the survival of any organism.

   b. Give an example of a specific negative feedback loop in a living organism and explain how it works.

7. Complete the following sentence by providing **three** reasons. Fruit flies are model organisms for genetic experiments because....

   1.

   2.

   3.

8. Fruit flies that display the common "normal" phenotype for a trait are called wild type fruit flies. Eye color in fruit flies is controlled by a single gene on one of their chromosomes. You are a world-renowned geneticist and you perform an experiment to determine how the vermilion eye mutation is passed down from generation to generation. Your data are shown below. (For each of the following questions, use E to represent the dominant allele and e to represent the recessive allele.)

P generation: Wild-type Male Vermilion-eyed Female

F_1 generation:

Wild-type Males	Wild-type Females	Vermilion-eyed Males	Vermilion-eyed Females
0	47	53	0

F_2 generation:

Wild-type Males	Wild-type Females	Vermilion-eyed Males	Vermilion-eyed Females
21	28	20	31

a. Based on your data, what is your hypothesis as to the mode of inheritance of the vermilion eye mutation? Why?

b. Based on your answer to a., what are the genotypes of the parents?

Wild-type Male: ________ Vermilion-eyed Female: __________

c. What are the genotypes of the F_1 flies?

Wild-type Females: __________ Vermilion-eyed Males: ____________

d. What are the genotypes of the F_2 flies?

Wild-type Males: ________________ Vermilion-eyed Males: ______________
Wild-type Females: _______________ Vermilion-eyed Females: _____________

e. Perform a Chi-square test on the F_2 generation.
The formula for Chi-square is $X^2 = \sum[(o-e)^2/e]$

f. Is your hypothesis (from a.) supported by these data? Explain how you know.

The following table shows critical values at a probability of 0.05.

Degrees of Freedom:	1	2	3	4	5
p = 0.05	3.84	5.99	7.82	9.49	11.1

g. Your hypothesis may not be supported by experimental data and still actually be the correct explanation. Explain how this could occur.

Question #8 adapted from apcentral.collegeboard.com

Pre and Post Test Scoring Rubric

1. You need to measure the rate of <u>aerobic</u> respiration of an apple.

    a. What substances are needed for aerobic respiration to occur? **N/A**

    b. What substances are produced by aerobic respiration? **N/A**

    c. Explain how you could use a base like barium hydroxide ($Ba(OH)_2$) measure the respiration rate of an apple. **N/A**

    d. Describe the data you would collect and how you would analyze the data collected in your experiment to determine the rate of respiration. **N/A**

2. There is a population of woodchucks around Kalamazoo Christian High School. You want to use the Capture-Recapture method to determine the size of the woodchuck population.

    a. How would you do your experiment?
    Catch and tag some of the organisms. (1 pt)
    Return later and catch more organisms from the population (1 pt)
    Use the number of tagged organisms in the second capture to calculate total population size. (1 pt)
    (total = # tagged*# recaptured/# tagged and recaptured)

    b. Provide hypothetical results of your experiment and show the calculations you would use to determine the actual population size.
    Catch and tag __ organisms. (0.25 pts)
    Return later and catch ___ organisms, __ of which are tagged (0.5 pts)
    Correct equation and work shown (1 pt)
    Correct answer (0.25 pts)

3. You want to test the effect of acid on the fermentation rate in yeast. Describe how you would set up a CONTROLLED experiment to do so. **N/A**

4. a. Describe the water cycle. (You may draw a <u>labeled</u> diagram if you wish.)
    Evaporation (0.5 pts)
    Precipitation/Rain (0.5 pts)
    No credit if words present without associated diagram or explanation.

    b. Define transpiration and explain how it is involved in the water cycle.
    Evaporation of water (0.5 pts) from the leaves of a plant (0.5 pts).
    If transpiration rate is high, there is more water in the air/more humid (1 pt)

c. List two variables that can affect the rate of transpiration. State the effect each has and **explain** why.

Increased light (0.5 pts) – increases transpiration (0.5 pts) because heat energy causes evaporation (0.5 pts).

Increased wind (0.5 pts) – increases transpiration (0.5 pts) because water in air moves away from leaves/decreases water potential (0.5 pts)

5. Explain how an allelopathic plant is better able to survive than non-allelopathic plants.

Allelopathic plants produce chemicals that they secrete into their environment (1 pt.) These chemicals kill off surrounding plants that may compete with them for resources. (1 pt.)

6. a. Explain what negative feedback loops are **and** why they are important to the survival of any organism.

Negative feedback loops are a means by which a disturbance to a system within an organism is counteracted (1 pt) to maintain homeostasis (1 pt).
In order for an organism to survive, they must regulate their internal environment (1 pt).

b. Give an example of a specific negative feedback loop in a living organism and explain how it works.

Examples vary.
Indicate disturbance (0.5 pts)
Indicate sensor that detects disturbance (0.5 pts)
-0.25 pts if not specific sensor mentioned
Indicate integrator that responds (0.5 pts)
-0.25 pts if not specific integrator mentioned
Indicate effector that counteracts disturbance (0.5 pts)
-0.25 pts if not specific effector mentioned

7. Complete the following sentence by providing **three** reasons. Fruit flies are model organisms for genetic experiments because….

1. **N/A**
2. **N/A**
3. **N/A**

8. Fruit flies that display the common "normal" phenotype for a trait are called wild type fruit flies. Eye color in fruit flies is controlled by a single gene on one of their chromosomes. You are a world-renowned geneticist and you perform an experiment to determine how the vermilion eye mutation is passed down from generation to generation. Your data are shown below. (For each of the following questions, use E to represent the dominant allele and e to represent the recessive allele.)

P generation: Wild-type Male Vermilion-eyed Female

F_1 generation:

Wild-type Males	Wild-type Females	Vermilion-eyed Males	Vermilion-eyed Females
0	47	53	0

F_2 generation:

Wild-type Males	Wild-type Females	Vermilion-eyed Males	Vermilion-eyed Females
21	28	20	31

a. Based on your data, what is your hypothesis as to the mode of inheritance of the vermilion eye mutation? Why?

Sex-linked (0.5 pts) – because different phenotypes between males and females in F_1 generation (0.5 pts)

Recessive (0.5 pts) – because all males in the F_1 generation show the trait (0.5pts)

b. Based on your answer to a., what are the genotypes of the parents?

Wild-type Male: **X^EY (0.5 pts)** Vermilion-eyed Female: **X^eX^e (0.5 pts)**

c. What are the genotypes of the F_1 flies?

Wild-type Females: **X^EX^e (0.5 pts)** Vermilion-eyed Males: **X^eY (0.5 pts)**

d. What are the genotypes of the F_2 flies?

Wild-type Males: **X^EY (0.5 pts)** Vermilion-eyed Males: **X^eY (0.5 pts)**
Wild-type Females: **X^EX^e (0.5 pts)** Vermilion-eyed Females: **X^eX^e (0.5 pts)**

e. Perform a Chi-square test on the F_2 generation.

The formula for Chi-square is $X^2 = \sum[(o-e)^2/e]$

9/25 + 16/25 + 25/25 + 36/25 = 86/25 = 3.5

f. Is your hypothesis (from a.) supported by these data? Explain how you know.

The following table shows critical values at a probability of 0.05.

Degrees of Freedom:	1	2	3	4	5
p = 0.05	3.84	5.99	7.82	9.49	11.1

Critical Value = 7.82 (1 pt)
Yes (1 pt.) because 3.5 < 7.82 (1 pt)
(0 pts yes, alone)

g. Your hypothesis may not be supported by experimental data and still actually be the correct explanation. Explain how this could occur.
Sample size (1 pt) might not be large enough. Probability can vary by chance.

Question #8 adapted from apcentral.collegeboard.com

Name: ______________________

AP Thesis Project Baseline Data

Answer each of the following questions with what you feel is the best answer.
Please include any comments you may have pertaining to each question.

I feel confident in my ability to.......

1. ...identify the independent and dependent variables in an experiment.

Strongly Disagree	Disagree	Uncertain	Agree	Strongly Agree

Comment:

2. ...design and conduct a controlled scientific experiment.

Strongly Disagree	Disagree	Uncertain	Agree	Strongly Agree

Comment:

3. ...prepare a graph of experimental data using Microsoft Excel.

Strongly Disagree	Disagree	Uncertain	Agree	Strongly Agree

Comment:

4. ...analyze a graph of experimental data to draw conclusions.

Strongly Disagree	Disagree	Uncertain	Agree	Strongly Agree

Comment:

5. …use a Chi-square test to determine whether or not data vary significantly from what is expected.

Strongly Disagree	Disagree	Uncertain	Agree	Strongly Agree

Comment:

6. …work constructively in a group to perform a task.

Strongly Disagree	Disagree	Uncertain	Agree	Strongly Agree

Comment:

7. …think critically about a problem and pose several possible solutions.

Strongly Disagree	Disagree	Uncertain	Agree	Strongly Agree

Comment:

8. I can better explain an important biological concept after participating in a hands-on lab activity involving that concept.

Strongly Disagree	Disagree	Uncertain	Agree	Strongly Agree

Comment:

Name: ______________________

AP Lab Activities Exit Survey

Circle the answer that best describes how helpful the following activities and experiments were in furthering your ability to explain the biological concepts involved in each.

1 The Goldfish Capture-Recapture Activity

Not Helpful	Somewhat Helpful	Helpful	Very Helpful	Extremely Helpful

Comments:

2. The Seed Respiration Experiment

Not Helpful	Somewhat Helpful	Helpful	Very Helpful	Extremely Helpful

Comments:

3. The Foamy Fruit Fly Experiment

Not Helpful	Somewhat Helpful	Helpful	Very Helpful	Extremely Helpful

Comments:

4. The Garlic/Lettuce Allelopathy Study

Not Helpful	Somewhat Helpful	Helpful	Very Helpful	Extremely Helpful

Comments:

5. The Yeast Fermentation Experiment

Not Helpful	Somewhat Helpful	Helpful	Very Helpful	Extremely Helpful

Comments:

6. The Bert and Ernie Discover Negative Feedback Loops skit and posters

Not Helpful	Somewhat Helpful	Helpful	Very Helpful	Extremely Helpful

Comments:

7. Of the activities and experiments listed above, which did you MOST enjoy? Why?

8. Of the activities and experiments listed above, which did you LEAST enjoy? Why?

APPENDIX D

STUDENT RESULTS

I. STUDENT PRE AND POST TEST SCORES

II. STUDENT PRE AND POST SURVEY SCORES

III. SUBJECTIVE STUDENT ACTIVITY RATINGS

IV. SUBJECTIVE STUDENT ACTIVITY RESPONSES

Student Pre and Post Test Scores

Table 6: Pre and Post Test Scores by Topic Question

	Question 2 (5)		Question 4 (6)		Question 5 (2)		Question 6 (5)		Question 7 (11)	
Student	PRE	POST	PRE	POST	PRE	POST	PRE	POST	PRE	POST
A	1.25	5	1.5	4.5	0	2	1	3	—	—
B	2	5	2	5.5	0	2	2	3.75	5.5	9.5
C	2	5	1.5	2	0	0	1	3.25	5.5	11
D	1	5	4.5	4.25	0	2	0.5	3	4	5
E	1	2.75	1.25	2.5	0	1	0	3.75	1.5	9
F	1	5	1.5	2.5	0	2	0	3.75	4.5	11
G	0.5	5	1.5	6	0	1	0	3.25	1	6.5
H	1	5	1.5	4.25	0	1	0	3.75	6	10.5
I	1	5	3	4.5	0	2	0.5	3.5	4.5	10
J	2.5	5	2	5.5	0	1.5	0	4.25	6	10.5
K	0.5	5	1	5	0	2	1	2.5	4.5	11
L	2.75	2.75	4.5	5.25	0	2	0.5	2.75	6	11
M	1	3.75	2.75	1	0	1	0	3.75	3	11
N	2	5	1.5	5	0	2	0	3.5	6	10.5
O	2	5	2.5	4.75	0	1	2	3.25	6.5	11
P	2.5	5	2	1	0	1	0.5	3.25	4.5	10
Q	3.5	3.5	1	3.5	0	2	0	2	3.5	9
R	1	5	3	3	0	1	0	4.5	6	9
S	1.25	5	1	1.5	0	1	1	4	5.5	10.5
T	2.75	5	4	4	0	2	1	3.5	6.5	11
U	2	2.25	2	4.75	0	0.75	0	2.5	1.5	10
V	0.5	2.5	2	3.5	0	2	—	—	—	—
W	2.5	5	4.5	4.5	0	2	1	3.25	6	11
X	1	5	5	5	0	2	0	2.75	3.5	7.5
Y	2.5	5	2	2.75	0	2	0	4.75	0	8.5
Z	0.5	5	2.5	1.5	0	0	3	3.5	0.5	7.25
AA	1.25	4.5	2	5.5	0	1.5	—	—	1.5	11

Student Pre and Post Survey Scores

Table 7: Student Pre and Post Survey Scores by Question

	Question 1		Question 2		Question 3		Question 4		Question 5	
Student	PRE	POST	PRE	POST	PRE	POST	PRE	POST	PRE	POST
A	---	---	---	---	---	---	---	---	---	---
B	4	5	5	5	4	5	5	5	3	4
C	4	4	4	4	4	5	4	5	2	3
D	4	4	4	3	4	3	5	4	3	4
E	3	5	4	5	3	4	4	4	3	4
F	4	5	3	4	4	5	4	4	2	4
G	5	5	4	5	4	4	4	5	3	5
H	5	5	4	5	4	5	4	5	2	3
I	4	5	5	5	3	5	5	5	2	4
J	5	5	4	5	5	5	4	5	4	5
K	4	5	3	4	2	3	5	4	2	4
L	5	5	4	5	4	4	3	5	1	5
M	4	5	4	4	3	3	4	4	2	3
N	4	4	3	4	3	4	4	4	3	4
O	5	4	4	5	4	4	4	4	2.5	4
P	3	4	3	4	2	3	3	4	2	4
Q	5	5	5	5	4	5	5	5	3	5
R	5	5	5	5	5	5	4	4	3	4
S	3	5	2	4	4	5	4	5	3	5
T	5	5	4	5	4	4	4	4	1	5
U	4	5	5	5	5	5	4	5	3	5
V	4	5	5	4	5	5	4	4	3	5
W	5	5	4	5	4	5	4	4	1	4
X	5	5	4	4	4	4	5	5	3	3
Y	4	5	4	5	3	1	5	5	1	5
Z	4	3	4	4	3	4	4	4	4	5
AA	4	4	4	5	3	4	4	4	2	4
Average	4.27	4.69	4.00	4.54	3.73	4.19	4.19	4.46	2.44	4.23

Table 7 (cont'd)

Student	Question 6		Question 7		Question 8	
	PRE	POST	PRE	POST	PRE	POST
A	---	---	---	---	---	---
B	5	5	5	5	5	4
C	5	5	4	4	5	4
D	5	5	4	4	5	5
E	5	5	5	4	5	5
F	4	5	4	5	4	5
G	5	5	4	5	4	5
H	4	2	5	5	4	4
I	5	5	4	4	4	5
J	5	5	4	4	5	5
K	5	5	5	4	5	5
L	5	5	4	5	4	5
M	5	5	4	4	5	5
N	4	4	4	4	4	4
O	5	5	4	4	5	5
P	---	---	---	---	---	---
Q	5	5	5	4	4	5
R	5	5	5	4	4	5
S	2.5	5	3	5	2.5	4
T	5	5	5	4	4	5
U	5	4	4	4	4	3
V	5	5	5	4	5	5
W	4	5	4	5	4	5
X	5	5	5	5	5	4
Y	5	5	4	4	5	5
Z	5	4	5	3	4	4
AA	5	5	4	4	5	5
Average	4.74	4.76	4.36	4.28	4.42	4.64

Subjective Student Activity Ratings

Table 8: Student Activity Effectiveness Ratings

Student	Capture/ Recapture	Allelopathy	Negative Feedback	Chi Square
A	----	----	----	----
B	5	4	2	4
C	4	4	4	3
D	5	4	4	5
E	5	4	3	4
F	5	4	3	4
G	5	5	3	3
H	3	3	2	4
I	----	4	4	4
J	5	5	5	5
K	5	4	3	4
L	5	4	5	5
M	4	4	1	5
N	3	3	4	4
O	3	4	3	4
P	5	5	3	5
Q	3	3	3	4
R	4	3	3	5
S	4	4	4	5
T	4	4	4	5
U	----	3	5	5
V	4	5	3	3
W	3	4	4	4
X	5	4	3	4
Y	5	5	5	5
Z	4	3	4	5
AA	4	4	3	3
Average Rating	4.25	3.96	3.46	4.27

Subjective Student Activity Responses

Capture Recapture Activity

- So fun!
- Fun.
- I didn't understand capture-recapture until after this activity.
- Favorite: Goldfish® capture-recapture. I understood the concept completely afterwards, and I'm not likely to forget it because it was done in a fun way.
- My favorite part was eating the Goldfish® afterward.
- I enjoyed the capture recapture because it was enjoyable yet educational.
- The Goldfish® capture/recapture was my favorite because we got to see how they do it in real-life and the data was right in front of us.
- Helped give example of real-life.
- Favorite: The Goldfish® lab, it was fun to do and made the concept easy to understand.
- Favorite: Catching Goldfish® because it was easy and it stuck in my head as an example of capture/recapture.
- Least favorite: Capture/recapture with Goldfish®. I didn't need to do the experiment to understand how it works.
- I enjoyed the Goldfish® capture-recapture experiment the most because it was helpful to put the equation into a visual representation.
- I liked the Goldfish® one the best because it was really fun and cemented the capture-recapture method in our brains.
- I most enjoyed the Goldfish® experiment because it clearly demonstrated how this process occurs. It didn't require a lot of waiting around.
- Goldfish® capture-recapture lab was the most enjoyable because my group got very weird data and the idea of 'capture-recapture' of 'Goldfish®' was fun.
- It helped me to practice the method so that it stuck in my head.

- I liked the Goldfish® one because we got to eat Goldfish® and do some really easy math.

- Favorite: I liked the Goldfish® capture recapture lab. It was fun.

- It was helpful and fun, it also tasted good.

- Favorite: Goldfish® because it explained the capture recapture method and made it very easy to understand. It was fun going fishing in a ziplock bag.

- Least favorite: Tedious

- It was nice to try it out rather than just read about it, but we probably spent more time than necessary on a not-so-difficult thing.

- I didn't do this lab…I just copied data so it didn't really help.

Allelopathy Experiment

- Smelled bad, but helpful.

- I enjoyed the garlic/lettuce allelopathy lab because it really helped me see what allelopathy is and how it affects plants.

- I won't forget what allelopathy is now.

- Least favorite: It was alright, the others were just more fun. I didn't like having to look up information from journals online as the process can be frustrating when you can't find the information you need.

- I most enjoyed the allelopathy lab with the garlic and lettuce seeds. It was very interactive.

- Least favorite: Probably the garlic and lettuce leaf experiment was my least favorite. I don't remember a whole lot about it, but I think I felt like I didn't know what to expect from the garlic.

- The garlic/lettuce lab was my least favorite because it smelled bad!

- I disliked the garlic/allelopathy study because the garlic smelled really bad after a couple of days.

- The garlic lab didn't help me as much because we didn't really do things actively with our hands.

- Garlic and lettuce lab was kind of boring because we didn't really do much except for observing.

- Least favorite: Allelopathy study because it is hard to find relevant scholarly articles.

- Easy and to the point.

- Least favorite: Garlic, it was gross! It smelled bad and it was boring.

- I least enjoyed garlic/lettuce allelopathy study. It was really smelly. The smell distracted me.

- The allelopathy study was interesting. We used live, real world examples (as opposed to Pepperidge farm goldfish or foam fruit flies) to discover allelopathy.

- I think it was really cool to see the lettuce leaves grow and see the effects of garlic on it. It's one thing to talk about/ take notes on something but it was cool to actually see it happen.

- The garlic one because it was very scientific and not very fun so it didn't stick in my head as well.

- I most enjoyed the garlic/allelopathy experiment. I enjoyed seeing a real life example of allelopathy. I found the subject very interesting and to see how it actually happened was really cool.

- Least favorite: The garlic/lettuce allelopathy experiment because it involved checking our seeds daily for about a week and the garlic made the room smell.

- It did smell pretty gross though.

- It helped me remember but it was gross.

Negative Feedback Loops Activity

- I most enjoyed the Bert and Ernie Discover Negative Feedback Loops because not only was it a trip back to my childhood, but it related negative feedback loops to something I already know and I can therefore understand it more clearly.

- This was one of my favorites. [My partner] and I had a blast acting this out. It was a great way to wake up. Before we knew it, we had an audience and were teaching them by our acting. I loved it. The activity at the end helped me understand it a lot better.

- I least enjoyed the negative feedback loop one because I still have trouble remembering what is what and never fully understood.

- A bit elementary for 12th graders.

- The Bert and Ernie skit was my least favorite. I fully understood negative feedback loops and doing this skit was a waste of my time.

- Fun and helped me remember!!

- Least favorite: The feedback loops because I'm a visual learner.

- I liked that it was in skit form.

- The Bert and Ernie negative feedback loop skit didn't help me much because I don't understand well from merely reading how something works – I need to see it happen.

- I learn better visually.

- It had thorough explanations of all the components of negative feedback loops.

- I enjoyed the Bert and Ernie Negative Feedback Loops skits and posters because it was fun to do the skit. The posters were easy to fill out and helped to get a better picture of how negative feedback loops function.

- Another real-life example.

- Out of all of the experiments I found the Bert and Ernie discover negative feedback loops the least helpful. I was not sure it was necessary for me to read a very long skit when I already understood the concept clearly.

- [My partner] and I had a great time with this one so it stuck in my head.

- It illustrated the concept well.

- Least favorite: Bert and Ernie, it was kinda boring and a little downplayed on the level of learning that we should be at as seniors.

- Favorite: Negative feedback loops because [my partner] had never seen Sesame Street before.

- Least favorite: The Bert and Ernie Negative Feedback Loop because it was just reading a story and cutting out paper.

- Least favorite : Bert and Ernie only because I wasn't there that day.

- I enjoyed the Bert and Ernie Lab the most. This was a different way of learning and it really helped.

- I like using actions or skits to learn an idea.

- Favorite: The Bert and Ernie Negative Feedback Loops skit and posters because it involved reading and doing a skit with a partner and then we made the posters where we cut and glued parts.

Chi Square Activity

- Very fun! It helped a lot and I loved the way they were out of stickers. It'd be fun to make.

- I least enjoyed the foamy fruit flies because it was hard to tell the specific traits of the flies and it was not as interesting as other labs.

- Nice to get a visual of how different generations occur.

- This somewhat long experiment explained a simple concept.

- The flies were hard to count (but they were cute). It was a good way to work through an equation.

- I enjoyed the foamy fruit fly experiment because it helped you see the phenotypes of the whole population.

- This experiment gave me a good picture to keep in my head.

- Foamy fruit fly was hard to follow. However, it was probably more realistic. But to learn the concept...perhaps it would be beneficial to have more clearly defined phenotypic differences than only O/O.

- I enjoyed the foamy fruit fly experiment the least. This is because the concept was repetitive. We had done so many of those kind of problems before.

- I love labs like these! It is so much fun to have to do genetic mutations with cute little fruit flies!

- It helped to see a visual representation for genetics.

- Favorite: Fruit fly. They were cute, it was fun and it was on my favorite subject genetics!

APPENDIX E

LABS AND ACTIVITIES NOT IMPLEMENTED

I. SEED RESPIRATION LAB

II. YEAST FERMENTATION LAB

Name: ____________________

lab five (revised): Plants Respire Too

When a seed is placed in a suitable environment, it will begin to germinate and grow into a full-fledged plant. Some seeds have more stringent requirements than others in order for this to occur. For example, the seed of the *Calvaria major* tree requires passage through the digestive system of *Raphus cucullatus* (a dodo bird). These birds went extinct 300 years ago – and thus, there are no *Calvaria major* trees younger than 300 in age.

Most seeds require less specific conditions. In general, seeds require an environment that contains water in order to grow. *Answer pre-lab question #1.*

In order to grow, seeds require energy which is necessary in order to build new cells and perform all functions necessary for life. Seeds use the process of respiration to produce the necessary ATP. *Answer pre-lab questions #2 and 3.*

In this lab, you will be comparing the respiration rates of germinating and non-germinating seeds. You will also be testing the effect of temperature on the rate or respiration. *Answer pre-lab questions #4-5.*

Prelab Questions:

1. Why would the presence of water in an environment cause a seed to begin growing? What does water have to do with anything?

2. Why don't seeds obtain their energy using the process of photosynthesis?

3. What are the reactants in the process of respiration and where does a seed get these things?

4. What is your hypothesis as to the comparison of the respiration rates of germinating and non-germinating seeds? Why?

5. What is your hypothesis as to the effect of temperature (room vs. cold) on the respiration rates of seeds? Why?

6. a. When you add the phenolphthalein to the $Ba(OH)_2$, the solution turns pink. Why?

   b. If respiration is occurring and is left to occur indefinitely, the solution will turn clear. Why? (There is a chemical reaction occurring, write its equation below.)

   c. How is this going to help us determine the respiration rate for each of the trials?

Procedure:

1. Obtain three Petri dishes, three pieces of filter paper and three plastic containers from your instructor.

2. Wet two of the filter papers with tap water until saturated.

3. If your group is doing the ROOM temperature trial:
   Place the pieces of filter paper on the counter next to your lab bench. (Make sure this is out of the way as you will be leaving these overnight and you don't want anyone messing with it!)

   If your group is doing the COLD temperature trial:
   Place one piece of filter paper in each of the shallow containers given to you by your instructor.

4. Place 25 germinating radish seeds on one wet piece of filter paper and 25 non-germinating radish seeds on the **dry** piece of filter paper.

5. Fill the Petri dishes with 30mL of 0.025M $Ba(OH)_2$.

6. Add two drops of phenolphthalein to each dish.

7. Place a plastic container over the whole setup (Petri dish and filter paper with seeds). If you are doing the COLD trial, give your setups to your instructor to place in the refrigerator overnight.

8. Wait 24 hours before continuing the lab.

9. Pour the liquid contents of one Petri dish into a beaker. (If it is not pink, let your instructor know!)

10. Fill a 60mL syringe with 0.01M HCl. It doesn't matter if you fill the syringe completely, just make sure that you record the amount of HCl in the syringe on the attached table before you start!

11. Now you get to titrate! Add HCl to the beaker JUST UNTIL the pink color disappears COMPLETELY. Gently swirl the beaker as you add the acid to make sure that it mixes thoroughly. You should hold the beaker over a piece of white paper so that you can detect the color change.

12. When you have finished titrating, record the amount of HCl left in the syringe. And calculate the amount of HCl used.

13. Rinse the contents of the beaker down the drain with generous amounts of water.

14. Repeat steps 9-13 for each of the other two Petri dishes.

15. When you have finished, pour any extra HCl back in the stock bottle. Rinse out your Petri dishes.

After reading through the procedure before lab, answer pre-lab question #6.

Results and Questions:

1. If each setup starts with 30.0 mL of 0.025M $Ba(OH)_2$, how many moles of $Ba(OH)_2$ are there? ____________________

GROUP DATA:

Temp. (°C) ________	Initial Vol. of HCl in the Syringe (mL)	Final Vol. of HCl in the Syringe (mL)	Vol. of HCl Needed to Neutralize Base (mL)	Avg. Volume of HCl for Room Temp.	Avg. Volume of HCl for Cold Temp.
Control					
Germinating Seeds					
Non-Germinating Seeds					

CLASS DATA:

2. Write the equation for the neutralization reaction that occurs when you add HCl below. You will need this before you can completely fill in the table below.

Trial	Average Volume HCl Used (mL)	Moles $Ba(OH)_2$ Left after 24 hrs.	Moles $Ba(OH)_2$ Reacted over 24 hrs.	Total Moles CO_2 Reacted over 24 hrs.	Moles CO_2 Produced by Respiration
Room Control					
Room Germinating					
Room Non-germinating					
Cold Control					
Cold Germinating					
Cold Non-germinating					

* To calculate the moles of $Ba(OH)_2$ left after 24 hours you will need to use dimensional analysis!

3. Was your hypothesis as to the respiration rate of germinating vs. non germinating seeds supported? Explain.

4. Was your hypothesis as to the respiration rate of room temperature vs. cold seeds supported? Explain.

5. Draw and label the graph below to show your prediction of carbon dioxide production by germinating seeds from 0°C to 50°C. Temperature should be on the X-axis and moles of carbon dioxide should be on the Y-axis.

Explain why your graph looks the way it does.

6. How would you expect a mammal's respiration rate to respond to a change of temperature from room temperature to refrigerator temperature? Why?

7. In this lab you measured the rate of carbon dioxide production over 24 hours. In what other ways could you have measured the respiration rate?

Our Names: ____________________

____

____

____

OUR BRILLIANT LAB PROPOSAL

We will test the effect of ________________________________ on

____

Our hypothesis (It is hypothesized that..... OR If....,then....): ____________

____

____

Information that supports our hypothesis:

Write your factual information below with the author of the source in which you found the information in parenthesis after each statement. You should use at least three different sources.

____

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Attach all sources (except information from your textbook) to this page before you hand it in.

Our Independent Variable (include units if applicable): ____________________

Our Dependent Variable (include units if applicable): ____________________

Our Experimental Set-Up (include Materials Needed):

Our Control Group will be... ____________________________________

____

Our Test Group(s) will be... ____________________________________

____

Our Controlled Variables: ____

____

____

____

____

We will collect our Quantitative Data by recording...____________________

____

We will satistically analyze our results by.... ___________________________

____

Our Names: ________________

____

____

____

Our Brilliant Results and Conclusions

RESULTS:

A graph(s) of the data from our lab is attached. The graph(s) shows that

____

____

____

____

Our statistical test showed that...________________________

____

____

CONCLUSIONS:

Do your results support your hypothesis? How do you know? ____________

____

____

____

Where would you go from here? (Explain any discrepancies between your results and your hypothesis, further questions to ask, future experiments to perform?) If you use any information from credible sources here, include the author in parenthesis.

____

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Attach all sources (except information from your textbook) to this page before you hand it in.

Name: ________________

A YEAST FERMENTATION INVESTIGATION

As you know, fermentation occurs in certain organisms under anaerobic conditions. Yeast is an example of an organism that can perform fermentation.

You are going to conduct an experiment to determine the effect of temperature on the rate of fermentation in yeast cells.

Answer question #1 on the attached answer sheet.

You will be using a 3% yeast solution and a 10% sucrose (table sugar) solution.

1. Your group must obtain four 20oz pop bottles (make sure the bottles are all the same shape). Fill one bottle with hot water, one with warm water, one with room temperature water and one with cold water.

2. Record the temperature of the water in each of the bottles.

3. Obtain eight pipets, label half of them "CONTROL" and half of them "SUGAR".

4. Mix together 2 mL of the yeast solution and 2 mL of distilled water in each of four small beakers. (Make sure you use different syringes for these two solutions – you don't want to cross contaminate!!!)

5. Use one of the "CONTROL" pipets to draw the solution from each of the beakers. Make sure all of the solution is in the BULB of the pipet – if it is stuck in the stem of the pipet you'll have to squeeze it back into the beaker and try again until you get it all in the bulb. Set these pipets aside.

6. Rinse out each of your small beakers.

7. Place 2 mL of the yeast solution in each of the beakers. Using the other syringe (the one you used for the distilled water in step 5), place 2 mL of the sucrose solution in each beaker.

8. Use one of the "SUGAR" pipets to draw the solution from each of the beakers. Make sure all of the solution is in the BULB of the pipet – if it is stuck in the stem of the pipet you'll have to squeeze it back into the beaker and try again until you get it all in the bulb.

9. Obtain sixteen hardware nuts and place two on each of the inverted pipets. These will make your pipets sink when placed in the water.

10. Obtain a stopwatch. Place a "CONTROL" and a "SUGAR" pipet (open end up) into each of the bottles. Wait two minutes so that the temperature of the pipets can equilibrate to that of the water in each of the bottles.

11. Record the number of bubbles that are released by each of the pipets each minute for thirty minutes. Happy Counting!

Answer Sheet

1. What is your hypothesis for this experiment?

2. What is the independent variable for this experiment?

3. What is the dependent variable for this experiment?

4. List at least five controlled variables for this experiment.

5. Why is it necessary to have a control pipet in each of the bottles?

6. Why is it necessary to make sure all of the solution is in the bulb of the pipet and not the stem?

7. a. What gas is being produced by the yeast?

   b. Describe a test that could be used to determine if this was actually the gas being produced.

Data Table:

Time (min)	Cold Control	Cold Sugar	Room Temp Control	Room Temp Sugar	Warm Control	Warm Sugar	Hot Control	Hot Sugar
1								
2								
3								
4								
5								
6								
7								
8								
9								
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11								
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30								

Make a line graph using Excel.

Data Analysis: Feel free to continue your answers on the back of this sheet.

8. According to your data and graphs, what is the relationship between temperature and fermentation rate?

9. What conclusions can you draw from this data? Apply concepts learned in other units to explain why these relationships occur.

BIBLIOGRAPHY

Bonwell, C.C. & Sutherland, T.E. 1996. The Active Learning Continuum: Choosing Activities to Engage Students in the Classroom. In Sutherland, T.E. & Bonwell, C.C. (Editors), *Using Active Learning in College Classes: A Range of Options for Faculty. New Directions for Teaching and Learning*, 67 (pp. 3-16). San Francisco: Jossey-Bass Publishers.

Bonwell, C.C. 1996. Enhancing the Lecture: Revitalizing a Traditional Format. In Sutherland, T.E. & Bonwell, C.C. (Editors), *Using Active Learning in College Classes: A Range of Options for Faculty. New Directions for Teaching and Learning*, 67 (pp. 31-44). San Francisco: Jossey-Bass Publishers.

Brooks, J.G. & Brooks, M.G. 1999. In Search of Understanding: The Case for Constructivist Classrooms. Alexandria, VA: Association for Supervision and Curriculum Development.

Campbell, N.A. & Reece, J.B. 2002. Biology. San Francisco, CA: Benjamin Cummings.

Drayton, Brian & Falk, Joni. 2001. Tell-Tale Signs of the Inquiry-Oriented Classroom. 2001. *National Association of Secondary Schools Principals, NASSP Bulletin*, 85(623), 24-34.

Heijl, A.M. & Koster, K.L. 2004. Juglone Disrupts Root Plasma Membrane H^+-ATPase Activity and Impairs Water Uptake, Root Respiration, and Growth in Soybean (*Glycine max*) and Corn (*Zea mays*). *Journal of Chemical Ecology*, 30(2), 453-471.

Hobson, E.H. 1996. Encouraging Self-Assessment: Writing as Active Learning. In Sutherland, T.E. & Bonwell, C.C. (Editors), Using Active Learning in College Classes: A Range of Options for Faculty. New Directions for Teaching and Learning, 67 (pp. 45-58). San Francisco: Jossey-Bass Publishers.

Jones-Wilson, T. Michelle. 2005. Teaching Problem-Solving Skills without Sacrificing Course Content: Marrying Traditional Lecture and Active Learning in an Organic Chemistry Class. *Journal of College Science Teaching*, 35(1): 42-46.

McComas, William. 2005. Laboratory Instruction in the Service of Science Teaching and Learning. *The Science Teacher*, 72(7), 24-29.

Shimabukuro, Mary A & Haberman, Vickie. 2006. An Aromatic Adventure with Allelopathy: Using Garlic To Study Allelopathy in the Classroom. *The American Biology Teacher*, 68(4), 242-247.

Shirley, Linda J. 1996. Pocket Guide to Multiple Intelligences. Clemson, South Carolina: National Dropout Prevention Center.

Smith, K.A. 1996. Cooperative Learning: Making "Groupwork" Work. In Sutherland, T.E. & Bonwell, C.C. (Editors), *Using Active Learning in College Classes: A Range of Options for Faculty. New Directions for Teaching and Learning*, 67 (pp. 71-82). San Francisco: Jossey-Bass Publishers.

Weaver, Robert R. & Qi, Jiang. 2005. Classroom Organization and Participation: College Students Perceptions. *The Journal of Higher Education,* 76(5), 570-601.

Wingfield, Sue S. & Black, Gregory S. 2005. Active Versus Passive Course Designs: The Impact on Student Outcomes. *Journal of Education for Business*, 81(2), 119-125.

Wood, Bonnie S. 2005. Lecture-Free Teaching in Seven Steps. *The American Biology Teacher,* 67(6), 334-342.

Wurdinger, Scott D. 2005. Using Experiential Learning in the Classroom: Practical Ideas for All Educators. Lanham, Maryland: ScarecrowEducation.